SKYLAB

A CHRONOLOGY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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A CHRONOLOGY

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with
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FOREWORD

Skylab exceeded all early expectations by being manned for 28, 59, and 84 days respectively, a full 31 days longer than planned. Even today, more than three years since its launch, people around the world are only a small part of the way through evaluating all the data that were returned from this sophisticated space endeavor. Scientists will continue gleaning knowledge for years to come, even as Skylab goes on orbiting the Earth, spent but having more than fulfilled its purpose.

Over the years, Skylab evolved in the wake of the lunar landing program. In early 1970 the configuration had solidified, based on conversion of the S–IVB stage of the Apollo launch vehicle. Now came the operational fine tuning to turn concept into reality. How do you compress the most out of the vehicle into each working day? What kind of give and take between ground and crew will optimize performance and value of the flights?

All was ready by May of 1973. *Skylab 1* was launched on 14 May and within seconds the meteoroid shield was lost; NASA faced its biggest and most expensive problem thus far in the manned flight program. But Mercury, Gemini, and Apollo had conditioned the team for the rigors of a quick solution. The ten days between the *Skylab 1* and *2* launches were perhaps NASA's "finest hours." Plans were formulated, priorities for solutions were established, and repair equipment was designed, while the ground controllers kept *Skylab 1* alive. The newly designed equipment was mocked-up, tested, and turned into flight hardware almost overnight. These efforts were successful because of the dedication and teamwork of thousands of NASA and contractor personnel. By the end of the Skylab program in February 1974, all scheduled flight objectives of the Skylab program had been accomplished, plus other objectives added as the program progressed.

This chronology relates only the beginning; the best is yet to come from Skylab.

Charles Conrad, Jr.

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THE KEY EVENTS

1959

20 February: NASA officials outlined the long-range objectives of the agency's space program to a Senate committee. The objectives included a multimanned orbital space station.

8 June: In a Project Horizon report, Wernher von Braun advanced a theory for using a spent booster stage as a space station's basic structure.

1961

5–6 January: McDonnell Aircraft Corporation proposed a one-man space station consisting of a Mercury spacecraft and a cylindrical space laboratory capable of a 14-day mission in a shirt-sleeve environment.

1962

April: MSC designers and planners prepared a preliminary document that outlined areas of investigation for a space station.

17 October: Joseph F. Shea, OMSF, solicited suggestions from each of the NASA Hq Program Offices and the NASA Centers on potential uses and requirements for a manned space station. Such ideas, he said, would help determine whether adequate justification existed for such a space laboratory.

1963

1 June: MSC announced two space station study contracts for a 24-man orbital laboratory to be designed for a useful orbital lifetime of five years.

1965

6–10 August: NASA's Associate Administrator for Manned Space Flight advised Center Directors of establishment of a Saturn/Apollo Applications Office within OMSF.

20 August: MSFC designers began serious investigation of an S–IVB Orbital Workshop involving in-orbit conversion of a spent S–IVB stage to a habitable shelter for extended manned utilization.

10 September: The Apollo Extension System was redesignated the Apollo Applications Program.

13 September: MSC, MSFC, and KSC were officially informed of the changed guidelines for Center management roles.

1966

28 January: Potential benefits of the Apollo Applications Program were summarized by George E. Mueller.

January: Douglas Aircraft Company submitted a summary report to LaRC covering the activities of three phases of the Manned Orbital Research Laboratory conducted from June 1963 to February 1966.

21 March: The Manned Space Flight Experiments Board was created by agreement between NASA and the Department of Defense.

1 April: MSC presented a request for proposals to Douglas, Grumman, and McDonnell for definition studies on the Saturn S–IVB spent-stage experiment support module (SSESM).

6 May: Astronauts voiced concern over the purposes and proposed work statement for the SSESM, noting a number of operational and safety concerns connected with purging the stage's hydrogen tank to create a habitable structure in space.

11 July: NASA Hq officials made several significant AAP decisions concerning the roles of MSFC and MSC.

25 July: The Orbital Workshop was approved as an experiment for flight on AS–209.

26 July: Full responsibility for AAP missions was assigned to the Office of Manned Space Flight, NASA Hq.

13–15 August: Agreement was reached on the respective roles of MSC and MSFC in development and operations of future manned space flight hardware.

19 August: NASA announced selection of McDonnell to manufacture the airlock module for AAP.

30 December: Mission objectives for AAP–1 and AAP–2 flights were outlined by NASA Hq.

1967

26 January: NASA announced plans to use a cluster configuration for AAP flights.

26 July: NASA selected Martin Marietta Corporation as contractor for payload integration of experiments and experiments support equipment.

2 August: NASA terminated all activity associated with the lunar mapping and survey system.

1968

2 February: Key check points were established for AAP to ensure sufficient management visibility of the program status.

20 July: The Post Apollo Advisory Committee issued its report which confirmed the basic objectives of AAP and played a deciding role in its later evolution.

1969

4 March: An AAP baseline configuration review was held at NASA Hq.

2 May: An AAP Software Board was established.

21 May: Choice of a Saturn IB "wet" Workshop vs. a Saturn V "dry" Workshop was the major subject discussed at a Manned Space Flight Management Council meeting.

23 May: MSFC Director Wernher von Braun responded to George E. Mueller's request for recommendations from the field Centers on the "wet" vs. "dry" Workshop issue, saying he preferred the "dry" Workshop and giving his reasons.

18 July: NASA Administrator Thomas O. Paine approved the shift from a "wet" to a "dry" Workshop.

22 July: AAP Director William C. Schneider directed the three manned space flight Centers to implement the necessary changes to effect the "dry" Workshop program.

8 August: MSFC definitized the contract with McDonnell Douglas for two Orbital Workshops for AAP.

16 September: NASA announced the AAP change from "wet" to "dry" Workshop substantially improved the probability of mission success and crew safety.

22 October: The AAP Director approved changes in the Orbital Workshop at a meeting at MSFC.

1970

2 January: MSFC shipped a test version of the Saturn S–IVB stage to McDonnell Douglas to be converted into an Orbital Workshop test article.

17 February: NASA announced that AAP had been redesignated the Skylab Program.
18 March: An interface panel organization was established within the NASA Skylab Program for defining, controlling, and resolving inter-Center problems.
4 May: A system flexibility study was conducted of systems and subsystems in the Skylab cluster to achieve maximum flexibility in case of a malfunction.
15 May: NASA announced that both the Skylab Saturn V and Saturn IB launches would be from Launch Complex 39 at KSC.
26 May: The Apollo telescope mount critical design review was completed at MSFC and final approval given the ATM design.
10–14 August: A critical design review for the airlock module was held at McDonnell Douglas.
24–27 August: A critical design review of Skylab's multiple docking adapter was completed at Martin Marietta, Denver.
14–18 September: An Orbital Workshop critical design review was conducted at McDonnell Douglas, Huntington Beach, California.
21 September: A Saturn Workshop crew station review began at MSFC with Government and industry engineers monitoring the progress of nine astronauts as they "walked through" many of the Workshop tasks.
16–20 November: An EVA critical design review was held at the MSFC mockup area and neutral buoyancy simulator with 10 astronauts participating.

1971

12 February: Acoustic testing of the Orbital Workshop dynamic test article was completed at MSC.
15 December: An MSFC–MSC agreement was approved detailing responsibilities for Skylab flight crew training in the neutral buoyancy simulator at MSFC.
December: The Skylab Program was reviewed by a Skylab midterm task team.

1972

11–12 January: The Manned Space Flight Management Council agreed to retain the 30 April 1973 launch-readiness date.
19 January: Prime crewmen were named for the three Skylab missions.
7 March: The Skylab rescue mission was a definite NASA commitment.
21 June: A CSM design certification review board met at MSC and concurred in accepting the CSM design for Skylab.
17 July: A Skylab vibration and acoustic test program which began at MSC in January 1971 was completed.
29 August: After completion of 28 days of the Skylab medical experiments altitude tests at MSC, it was decided to continue the planned 56-day test to completion.
6–7 September: A special ceremony marked completion of the Orbital Workshop prior to its readiness for shipment from Huntington Beach to KSC.
19 October: A Skylab cluster systems design certification review was conducted at MSFC.
21 November: NASA Hq defined the review procedure and readiness requirements for the flight readiness review which would be conducted prior to each Skylab mission.
30 November: Skylab cost savings were achieved by increasing payload weights in some instances.

1973

29–30 January: The airlock, multiple docking adapter, and Apollo telescope mount flight units were mated to the lunar vehicle.
27 February: Skylab 2 was moved from the Vehicle Assembly Building to Launch Pad 39.
5 April: Planning dates for the four Skylab launches were officially confirmed by NASA.
17–20 April: A flight readiness review was held at KSC, followed by an announcement of "ready to go" for Skylab 1 on 14 May and Skylab 2 on 15 May.

14 May: Skylab 1 was launched from KSC. Deployment of the Workshop solar array and the meteoroid shield was not successful, requiring a postponement of the Skylab 2 launch.

23–24 May: The design certification review board determined that a "Skylab Parasol," deployed through the scientific airlock, would be the prime method of improvising a thermal shield for the Workshop.

25 May: Skylab 2 was launched from KSC and rendezvoused with *Skylab 1* during the fifth revolution. Damage to *Skylab 1* was reported to the ground.

26 May: The crew completed the task of deploying the Skylab parasol, and the Workshop temperature started to drop.

7 June: Two astronauts performed an EVA and successfully freed the undeployed solar array, after which it was fully deployed.

22 June: The *Skylab 2* command module splashed down in the Pacific Ocean following a successful 28-day mission.

28 July: Skylab 3 was launched from KSC and began its mission, ending with a landing in the Pacific Ocean on 25 September.

13 August: A decision was made to delete the Skylab Saturn V Orbital Workshop capability effective 15 August.

30 August: Guidelines were issued by NASA for release, disposition, and storage of all unneeded Skylab Program equipment.

16 November: Skylab 4 was launched from KSC for a planned duration mission of 56 days with an option of extending it to 84 days. The command module and crew splashed down in the Pacific Ocean 8 February 1974, 84 days 1 hour 15 minutes 31 seconds after liftoff.

PREFACE

The Skylab Program was specifically designed to conduct a series of experiments from beyond the Earth's atmosphere. Since the number and types of experiments to be conducted during the operational phase of Skylab were constantly changing, rather than encumber the body of the chronology with these changes, a lengthy appendix on experiments (number 3) has been included. This appendix identifies the Principal Investigators and Coinvestigators; gives the types, numbers, and descriptions of the experiments; explains the purposes of the various experiments; and, where available, gives the results or findings of the experiments. Because of the time required to reduce the voluminous amount of data acquired during the Skylab missions, definitive results on some of the experiments may not be available for some years.

This document was intended to capture the key events that contributed to the success of Skylab and to provide the sources and documentation essential to a narrative history of the program. It was not the intent of the authors, nor should it have been their intent, to interpret the decisionmaking processes, the policies, the budgetary constraints, the politics, and the inter-Center rivalries that interwove themselves into the pattern of the Skylab Program from its inception on the drawing board to its culmination as America's most successful manned space program to date. For these interpretations, the interested reader must await the narrative history of Skylab—a history which is now being written. Meanwhile, it is hoped that the chronology will serve as a ready reference for those who might be seeking a comprehensive source of information on the Skylab Program.

The body of the Skylab chronology has been divided into three parts: early space station activities, Apollo Applications, and Skylab development and operations.

The first part traces the concept of space stations beginning with Hermann Oberth's study on a manned space station, which he presented to the scientific community in 1923, through July 1965 when Grumman completed a study for NASA on Earth orbital missions. During the years between those dates, the scientific community had begun to show considerable interest in a space station that would enable them to study the physical and psychological effects on man of extended periods in a space environment; evaluate techniques for scientific experiments from space; and develop and evaluate techniques for the construction and successful launch of a space station. A key step in this direction was the manned space station symposium held in Los Angeles in 1960. During the symposium, leading aeronautical and aerospace scientists and engineers presented 40 papers on these subjects.

The second part of the chronology covers the period from July 1965 to February 1970 and encompasses those periods of the program designated the

Apollo Extension System and the Apollo Applications Program. It was during this period that concepts (based in part on experience gained in the Mercury, Gemini, and Apollo Programs) were refined, contracts were issued, and the gradual evolution of the Orbital Workshop to its final "dry" concept occurred.

In February 1970, what had previously been called the Apollo Applications Program was redesignated the Skylab Program. Part three of the chronology covers the period from this redesignation through the final mission of the program and the postoperational phase. This, essentially, was the construction and operational phase of the program. It was the period of final equipment and experiment checkout, launch and flight, recovery and evaluation.

In writing this chronology, certain NASA Centers which appear frequently are referred to by their acronyms. These are: MSFC (the George C. Marshall Space Flight Center), KSC (the John F. Kennedy Space Center), MSC (the Manned Spacecraft Center) which later became JSC (the Lyndon B. Johnson Space Center), and LaRC (Langley Research Center). The National Aeronautics and Space Administration is generally referred to as NASA, or when the context of the entry requires, NASA Hq. The Centers which appear with less frequency in this chronology, such as the Goddard Space Flight Center, the Ames Research Center, the Lewis Research Center, and the Jet Propulsion Laboratory, are spelled out.

Similarly, a short form is used for a number of the aerospace contractors. The Martin Marietta Corporation is referred to as simply Martin Marietta, the Grumman Aerospace Corporation as Grumman, the McDonnell Douglas Corporation as either McDonnell Douglas, Huntington Beach, California, or McDonnell Douglas, St. Louis (to distinguish between the eastern and western facilities), and North American Aviation, Incorporated (later North American Rockwell and still later Rockwell International), is referred to as North American. Other aerospace contractors, appearing less frequently in the chronology, are given their full titles. Examples are The Boeing Company, the Lockheed Aircraft Corporation, and the Bendix Corporation.

Material used in preparing this chronology has basically been primary source materials—official correspondence, memoranda, NASA and contractor reports, minutes of meetings, and minutes of reviews, etc. Secondary source materials—NASA and contractor news releases and references to newspaper and magazine articles—were used minimally.

This chronology could not have been written without the assistance of a great number of individuals within the aerospace community. To list them all would be impossible. However, the authors wish to acknowledge by name the assistance received from Monte D. Wright, John H. Disher, Frank W. Anderson, Jr., J. Pemble Field, Thomas Hanes, Edward Christianson, and Lee D. Saegesser of NASA Headquarters; Leland F. Belew, Hilmar Haenisch, Charles L. Wood, Ralph Murphy, James Bishop, Lois Robertson, and Robert G. Sheppard of MSFC; James Perris, Konstanty Kebalka, James W. Craig, Jr., and Jimmy D. Broadwell of KSC; Robert F. Thompson, Kenneth S. Kleinknecht, Walter D. Wolhart, Edward A. Armstrong, Reginald M. Machell, Joe W. Dodson, Robert Gordon, Roy L. Magin, Jr., Harold J. Davis, James M.

Grimwood, and Sally D. Gates of JSC; Edward Regan, Walter Cleveland, Dan Green, and Frank Morgan of McDonnell Douglas; and Richard Barton and Ralph Oakley of Rockwell International.

Special kudos go to Melba Henderson and Virginia A. Trotter of JSC for their outstanding assistance and cooperation in making available the files and records from which a large portion of this chronology has been derived; to Willard M. Taub, whose assistance was invaluable in location and identification of some of the illustrations; and to Hilda J. Grimwood, who performed such an outstanding job in the typing and proofing of this manuscript in addition to carrying out the other innumerable duties essential to good office operations.

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R. W. N.
I. D. E.
C. G. B.

PART I

Early Space Station Activities

1923 through July 1965

PART I

Early Space Station Activities

1923 through July 1965

1923

Hermann Oberth published *Die Rakete zu den Planetenraumen* (*The Rocket into Planetary Space*), which contained the first serious proposal for a manned space station to appear in scientific literature rather than fiction. Oberth's study presented to the scientific community a broad treatise on the practicability and scientific value not only of manned permanent stations in orbit above the Earth, but also space flight in general. Oberth suggested a permanent station supplied by smaller rockets on a periodic basis and suggested rotation of the vehicle to produce an artificial gravity for the crew. Such a station, he said, could serve as a base for Earth observations, as a weather forecasting satellite, as a communications satellite, and as a refueling station for extraterrestrial vehicles launched from orbit.

Translation of Hermann Oberth's *Die Rakete zu den Planetenraumen*, Verlag von R. Oldenbourg, Munich and Berlin, 1923.

1928

Writing in the monthly journal *Die Rakete*, Baron Guido von Pirquet presented broad arguments in favor of the scientific possibility of manned space travel and the velocities required for orbital and interplanetary flight, of which orbital speed was by far the more difficult to attain. Von Pirquet suggested several different space stations for diverse functions: one in a near-Earth orbit as primarily an observation site and another station in a much higher orbit that would be more suitable as an orbital refueling station for escape vehicles.

Translation of Guido von Pirquet's article "Fahrtrouten" in *Die Rakete*, 2. Jahrgang, Breslau, Deutschland, 1928.

1928

Hermann Noordung (the pseudonym for Captain Potocnik of the Austrian Imperial Army) published *Das Problem der Befahrung des Weltraums* (*The Problem of Space Flight*), which included one of the first serious attempts to put on paper the design of a manned space station. Noordung's proposed design consisted of a doughnut-shaped structure for living quarters, a power generating station attached to one end of the central hub, and an astronomical observation

1928 station. He was among the first to suggest a wheel-shaped design for a space station to produce artificial gravity, and also argued the scientific value of such a station in a synchronous orbit above the Earth.

Hermann Noordung, *Das Problem der Befahrung des Weltraums,* 1928.

1929 Hermann Oberth published *Wege zur Raumschiffahrt,* in which he greatly elaborated on ideas presented in his 1923 book. Oberth here presented several specific designs for orbital space stations, ranging from spherical living quarters for the crew to large reflective mirrors fabricated in orbit. Among several innovations were methods for fabrication in orbit, propulsion by particle emission, and small ferry vehicles to permit travel in the vicinity of the station. Such stations could be used for a variety of purposes, ranging from scientific observation sites to military installations.

Translation of Hermann Oberth's *Wege zur Raumschiffahrt,* Verlag von R. Oldenbourg, Munich and Berlin, 1929.

1945 In a summary of his work on rockets during World War II, Wernher von Braun speculated on the potential and future uses of rocket power and space vehicles. Von Braun prophesied large scientific observatories in space, the construction of space stations in orbit, and interplanetary travel, beginning with manned flights to the Moon.

Wernher von Braun, "Survey of the Development of Liquid Rockets in Germany and their Future Prospects," in F. Zwicky, *Report on Certain Phases of War Research in Germany,* Headquarters Air Materiel Command Report No. F–SU–3–RE, January 1947, pp. 38–42.

1946

March The Army Air Forces established Project RAND at the Santa Monica, California, plant of Douglas Aircraft Company, Inc. On 12 May, Project RAND, which had studied supersonic aircraft, guided missiles, and satellite applications, released a report on "Preliminary Design of an Experimental World-Circling Space Ship" that argued the technical feasibility of building and operating an artificial Earth satellite.

Eugene M. Emme, *Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Space, 1915–1960,* Washington, D.C., 1961, p. 53; U.S. Congress, House, *Military Astronautics (Preliminary Report): Report of the Committee on Science and Astronautics,* House Report 360, 87th Cong., 1st sess., 4 May 1961, p. 2.

May

2 Douglas Aircraft Company, Inc., completed an engineering study on the feasibility of designing a man-carrying satellite. The study showed that if a vehicle could be accelerated to a speed of 27 360 km per hr and aimed properly it would revolve on a circular orbit above the Earth's atmosphere as a new satellite. Such a vehicle would make a complete circuit of the Earth approximately every hour and a half. However, it would not pass over the same ground

1946

May

stations on successive circuits because the Earth would make about a one-sixteenth turn for each circuit of the satellite. Two fuels were considered in the study: hydrogen-oxygen and alcohol-oxygen. The liquid alcohol-hydrogen had been used to propel the German V–2 rockets. The use of either fuel to orbit a man-made satellite, the study showed, would require the use of a multistage vehicle. The study also indicated that maximum acceleration and temperatures could be kept within limits safe for man. The vehicle envisioned would be used in obtaining scientific information on cosmic rays, gravitation, geophysics, terrestrial magnetism, astronomy, and meteorology.

Douglas Aircraft Co., Report No. SM–11827, *Preliminary Design of an Experimental World-Circling Spaceship,* 2 May 1946.

1948

November

13

In a paper presented to the British Interplanetary Society, H. E. Ross described a manned satellite station in Earth orbit that would serve as an astronomical and zero-gravity and vacuum research laboratory. (Ross' bold suggestions also included schemes for a manned landing on the Moon and return to Earth through use of the rendezvous technique in Earth orbit and about the Moon.) Ross' suggested design comprised a circular structure that housed the crew of the space laboratory (numbering 24 specialists and support personnel) as well as telescopes and research equipment. The station, he suggested, could be resupplied with oxygen and other life-support essentials by supply ships launched every three months.

H. E. Ross, "Orbital Bases," *Journal of the British Interplanetary Society,* 8, 1949, pp. 1–7.

1949–1952

Awakening public interest in the United States and in Europe was manifested by publication in September 1949 of *The Conquest of Space* by Willy Ley. Ley featured detailed descriptions of orbital space stations and manned flights to the Moon and back as part of man's quest to conquer the frontier of space. The First Symposium on Space Flight was held 12 October 1951 at the Hayden Planetarium in New York City. Papers read at the Symposium were published in March 1952 by *Collier*'s magazine under the title "Man Will Conquer Space Soon." Contributors were Wernher von Braun, Joseph Kaplan, Heinz Haber, Willy Ley, Oscar Schachter, and Fred L. Whipple. Topics ranged from manned orbiting space stations and orbiting astronomical observatories to problems of human survival in space, lunar space ventures, and questions of international law and sovereignty in space. Finally, Arthur C. Clarke's *The Exploration of Space,* first published in England in 1951 and a Book of the Month Club selection in America the following year, persuasively argued the case for orbital space stations and manned lunar and planetary space expeditions, popularizing the notion of space flight in general.

Willy Ley, *The Conquest of Space,* 1959; "Man Will Conquer Space Soon," *Collier*'s, 22 March 1952, pp. 22–36, 65–67, 70–72, 74; Arthur C. Clarke, *The Exploration of Space,* 1952.

1951

September

At the second annual congress of the International Astronautical Federation in London, H. H. Koelle described "Die Aussenstation" as part of a paper on "Der Einfluss der Konstruktiven Gestaltung der Aussenstation auf die Gesamtkosten des Projektes (The Influence of the Layout of the Satellite on the Overall Cost of the Project)." Koelle's paper represented the most realistic appraisal so far of the problems of design and construction of a space station. He dealt with problems of payload limitation, orbital assembly, limitations on the crew in the space environment, and national and economic factors behind space station growth. In Koelle's view, such a station might be used for scientific investigations of Earth's upper atmosphere, weather observation, astrophysical research, and human and chemical research in a zero-gravity environment. Also, such a station might serve as a communications and navigation link with the ground and as a station for launching more distant space missions. He suggested a large circular structure consisting of 36 separate 5-m spheres arranged around a central hub, the whole structure rotating to provide an artificial gravity environment to offset physiological effects of prolonged weightlessness on the crew. One of the unique elements in Koelle's scheme was assembly of various parts of the station launched via separate rockets, with each segment being a complete structure. In this way the station could be made operational before fabrication was completed, and subsequent expansion of the structure could take place whenever desired. Total personnel complement of the station would range from 50 to 65 people. Koelle even estimated the cost of such a project: $518 million for construction and $620 million over an operational lifetime of six months.

John W. Massey, *Historical Resume of Manned Space Stations,* Army Ballistic Missile Agency Report No. DSP–TM–9–60, 15 June 1960, pp. 19–26.

1954

In "Analysis of Orbital Systems," a paper read at the fifth congress of the International Astronautical Federation in Innsbruck, Austria, Krafft Ehricke described a four-man orbital station. Arguing that a very large space station was neither necessary nor desirable, Ehricke postulated a four-man design that might serve a number of different purposes, depending upon altitude and orbital inclination. He suggested that such a station might be used for a multitude of scientific research, for orbital reconnaissance, for an observation platform, and as a launch site for more distant space ventures. The station would be launched initially by a large multistaged booster and subsequently visited by crews and resupplied by means of smaller ferry rockets.

Ibid., pp. 28–31.

1958

May

20

The National Advisory Committee for Aeronautics (NACA) and the Air Force signed a Memorandum of Understanding concerning the principles in the development and testing of the Air Force's Hypersonic Boost Glide Vehicle (Dyna Soar I).

1958

May

The following principles would apply to the project: (1) The project would be conducted as a joint Air Force-NACA project. (2) Overall technical control of the project would rest with the Air Force, acting with the advice and assistance of NACA. (3) Financing of the design, construction, and Air Force test of the vehicles would be borne by the Air Force. (4) Management of the project would be conducted by an Air Force project office within the Directorate of Systems Management, Headquarters, Air Research and Development Command. NACA would provide liaison representation in the project office and provide the chairman of the technical team responsible for data transmission and research instrumentation. (5) Design and construction of the system would be conducted through a negotiated prime contractor. (6) Flight tests of the vehicle and related equipment would be accomplished by NACA, the USAF, and the prime contractor in a combined test program, under the overall control of a joint NACA–USAF committee chaired by the Air Force.

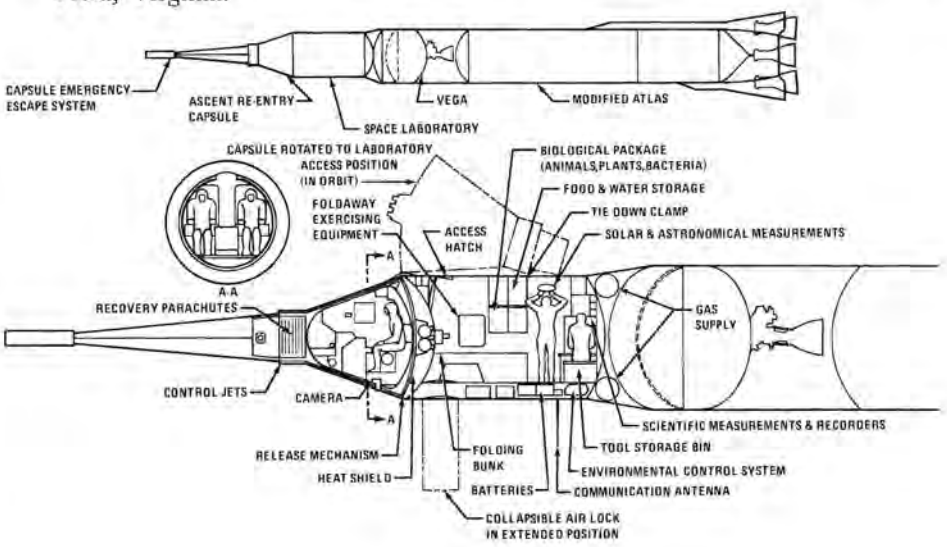
Memorandum of understanding, "Principles for Participation of NACA in Development and Testing of the 'Air Force System 464L Hypersonic Boost Glide Vehicle (Dyna Soar I),'" signed by Gen. Thomas D. White, Chief of Staff, USAF, 13 May 1958, and Hugh L. Dryden, Director NACA, 20 May 1958.

During the Year

In 1958, the year after *Sputnik 1,* Krafft Ehricke, then with General Dynamics' Convair Division, designed a four-man space station known as Outpost. Ehricke proposed that the Atlas ICBM being developed by Convair could be adapted as the station's basic structure. The Atlas, 3 m in diameter and 22.8 m long, was America's largest rocket at the time.

Dave Dooling, "The Evolution of Skylab," *Spaceflight,* January 1974, p. 20.

A 1958 spacecraft design concept for a two-man orbiting laboratory prepared by H. Kurt Strass and Caldwell C. Johnson of NASA's Space Task Group at Langley Field, Virginia.



1959

February

20

In testimony before the Senate Committee on Aeronautical and Space Sciences, NASA Deputy Administrator Hugh L. Dryden and DeMarquis D. Wyatt, Assistant to the Director of Space Flight Development, described the long-range objectives of the agency's space program: a multimanned orbiting space station; a permanent manned orbiting laboratory; unmanned lunar probes; and manned lunar orbital, lunar-landing, and—ultimately—interplanetary flight.

U.S. Congress, Senate, NASA Authorization Subcommittee of the Committee on Aeronautical and Space Sciences, *NASA Supplemental Authorization for Fiscal Year 1959: Hearings on S.1096,* 86th Cong., 1st sess., 1959, pp. 46, 81.

April

1

John W. Crowley, Director of Aeronautical and Space Research, appointed Harry J. Goett of the Ames Research Center to head a Research Steering Committee on Manned Space Flight to assist Headquarters in long-range planning and basic research on manned space flight. Composed of representatives from the field centers as well as Headquarters, members of the Goett Committee (as it was called) met for the first time on 25–26 May. From the outset, they agreed to concentrate on the long-range objectives of NASA's man-in-space program, including supporting research required, coordinating the research efforts of the various field centers, and recommending specific research projects and vehicle development programs.

The most important task facing the Goett Committee was the issue of a flight program to follow Mercury. H. Kurt Strass of the Space Task Group (STG) at Langley Field, Virginia (the field element that subsequently evolved into the Manned Spacecraft Center), described some preliminary ideas of STG planners regarding a follow-on to Mercury: (1) an enlarged Mercury capsule to place two men in orbit for three days; (2) a two-man Mercury capsule and a large cylindrical structure to support a two-week mission. (In its 1960 budget, NASA had requested $2 million to study methods of constructing a manned orbiting laboratory or converting the Mercury spacecraft into a two-man laboratory for extended space missions.)

Memorandum, John W. Crowley to Dist., "Research Steering Committee on Manned Space Flight," 1 April 1959; "Minutes, Research Steering Committee on Manned Space Flight," 25–26 May 1959, pp. 1–2, 6–9; U.S. Congress, House, Subcommittee of the Committee on Appropriations, *National Aeronautics and Space Administration Appropriations: Hearings,* 86th Cong., 1st sess., 1959, pp. 42–45.

24

DeMarquis D. Wyatt, Assistant to the Director of Space Flight Development, testified before Congress in support of NASA's request for $3 million in Fiscal Year 1960 for research on techniques and problems of space rendezvous. Wyatt explained that logistic support for a manned space laboratory, a possible post-Mercury flight program, depended upon resolving several key problems and making rendezvous in orbit practical. Among key problems he cited were establishment of methods for fixing the relative positions of two objects in space; development of accurate target acquisition devices to enable supply craft to locate the space station; development of guidance systems to permit precise determina-

1959

April

tion of flight paths; and development of reliable propulsion systems for maneuvering in orbit.

U.S. Congress, House, Committee on Science and Astronautics and Subcommittees Nos. 1, 2, 3, and 4, *1960 NASA Authorization: Hearings on H.R. 6512,* 86th Cong., 1st sess., 1959, pp. 97, 170, 267–68.

June

8

In a Project Horizon report, Wernher von Braun, then with the Army Ballistic Missile Agency, advanced a theory that he had conceived years earlier for using a booster's spent stage as a space station's basic structure. This later evolved into the "wet stage" concept for the Skylab Program.

Project Horizon, Phase I Report: A U.S. Army Study for the Establishment of a Lunar Military Outpost, Vol. II, pp. 127–130.

25–26

Laurence K. Loftin, Jr., of Langley Research Center, presented to the Research Steering Committee on Manned Space Flight a report on a projected manned space station. During subsequent discussion, Committee Chairman Harry J. Goett stated that considerations of space stations and orbiting laboratories should be an integral part of coordinated planning for a lunar landing mission. George M. Low of NASA Hq warned that care must be exercised that each successive step in space be taken with an eye toward the principal objective (i.e., lunar landing) because the number of steps that realistically could be funded and attempted was extremely limited. (Subsequently, Low's thinking and the recommendations of the Research Steering Committee were influential in shifting the planning focus of NASA's manned space program away from ideas of large space stations and laboratories and toward lunar flight and the Apollo program.

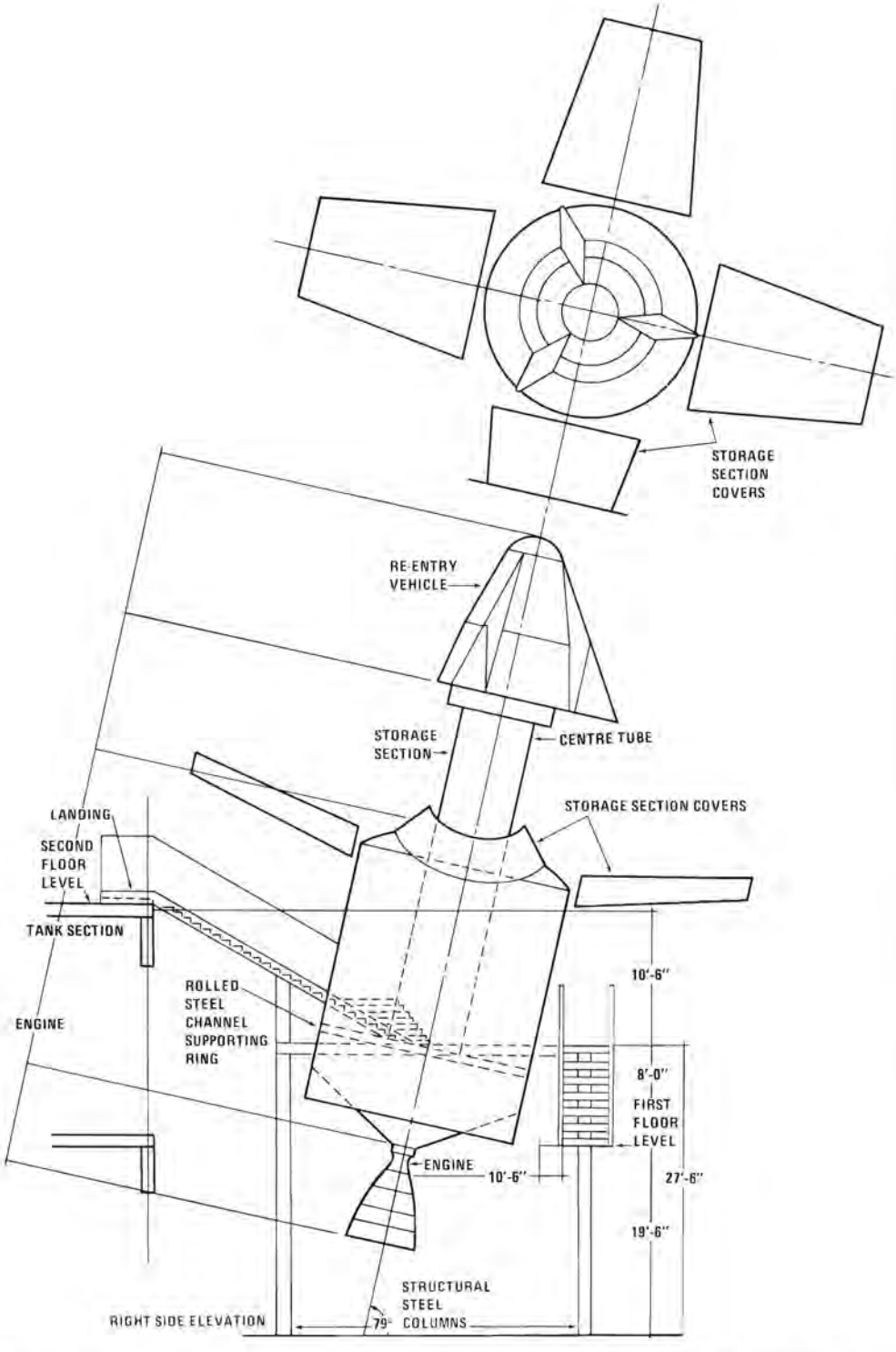
"Minutes, Research Steering Committee on Manned Space Flight, 25–26 June 1959," p. 6.

July

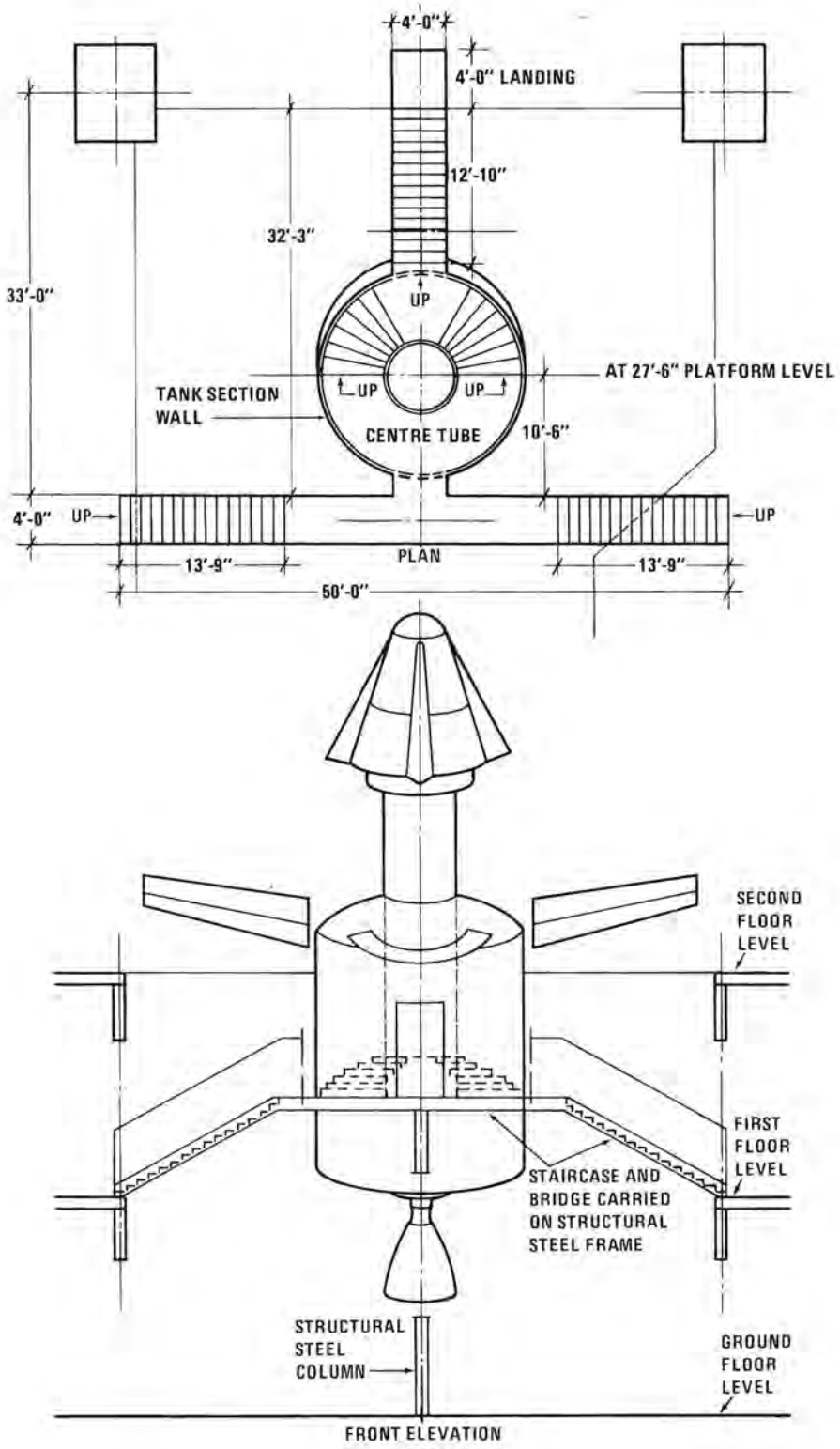
10

E. C. Braley and L. K. Loftin, Jr., sponsored a conference at LaRC to focus study at the Center on placing a manned space station in Earth orbit. Participants at the conference aimed at concentrating research efforts on developing the technology to build, launch, and operate such a station. Braley, Loftin, and others envisioned several purposes of such a space station: (1) to study the physical and psychological reactions of man in the space environment for extended periods of time, as well as his capabilities and usefulness during such missions; (2) to study materials, structures, and control systems for extended-duration space vehicles, and means for communication, orbit control, and rendezvous in space; and (3) to evaluate various techniques for terrestrial and astronomical observation and how man's unique abilities could enhance those techniques in space. Participants envisioned this Langley study project as an initial step toward landing men on the Moon some 10 to 15 years later.

Memorandum, Beverly Z. Henry, Jr., to Associate Director, "Langley Manned Space Laboratory Effort," 5 October 1959.



The architectural plans drawn for the 1960 Ideal Home Exhibition in Empire Hall, London, showing three views of the mockup space station.—Drawings courtesy of the London *Daily Mail*.


4'-0"
4'-0" LANDING
12'-10"
32'-3"
33'-0"
UP
AT 27'-6" PLATFORM LEVEL
TANK SECTION WALL
UP
UP
CENTRE TUBE
10'-6"
4'-0"
UP
UP
PLAN
13'-9"
13'-9"
50'-0"
SECOND FLOOR LEVEL
FIRST FLOOR LEVEL
STAIRCASE AND BRIDGE CARRIED ON STRUCTURAL STEEL FRAME
STRUCTURAL STEEL COLUMN
GROUND FLOOR LEVEL
FRONT ELEVATION

Two photographs of the 1960 Ideal Home Exhibition in London: At left, a "crewman" is at the control panel that operates the battery of space telescopes. Note his "shirt-sleeve" clothing. At right, a space-suited "crewman" is outside the space station working on one of the telescopes.—Photos courtesy of the London *Daily Mail*.

1960

May

16–17

Representatives from the various NASA Field Centers and Headquarters attended a conference on space rendezvous held at LaRC under the chairmanship of Bernard Maggin. The participants reviewed current Center research programs on space rendezvous and exchanged ideas on future projects. Many of the studies already in progress involved the idea of a space ferry and rendezvous with a station in cislunar space. Although as yet NASA had no funding for a rendezvous flight test program, consensus of those at this conference held that rendezvous would be essential in future manned space programs and that the Centers should undertake experiments to establish its feasibility and to develop various rendezvous techniques.

Inter-NASA Research and Development Centers Discussion on Space Rendezvous, LaRC, 16–17 May 1960.

1961

January

5–6

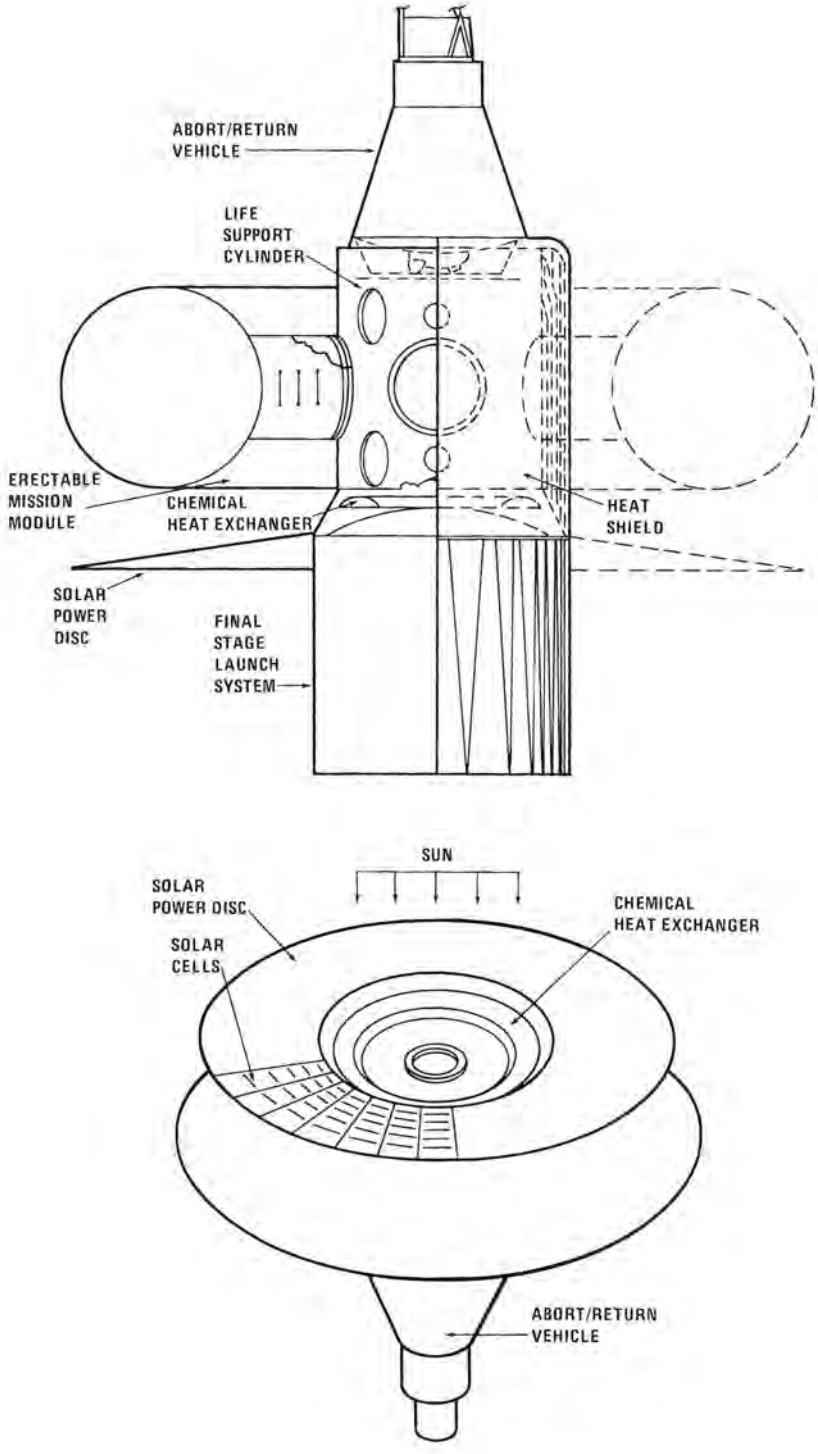
McDonnell Aircraft Corporation officials proposed to NASA a one-man space station consisting of a Mercury capsule and a cylindrical space laboratory capable of supporting one astronaut in a shirt-sleeve environment for 14 days in orbit. The complete vehicle, McDonnell said, could be placed in a 240-km orbit by an Atlas-Agena booster, thus affording NASA what the company termed a "minimum cost manned space station."

McDonnell Aircraft Corp., *One Man Space Station*, 24 August 1960 (rev. 28 October 1960).

May

5

A NASA Hq working group headed by Bernard Maggin completed a staff study recommending an integrated research, development, and applied orbital operations program through 1970 at an approximate cost of $1 billion. In its report, the group identified three broad categories of orbital operations: inspection, ferry, and orbital launch. Maggin and company reasoned that future space programs



In October 1960 Rene A. Berglund of Langley Research Center's Space Station Office prepared the spacecraft design concept of an inflatable space laboratory based on the Mercury spacecraft.

1961

May

required the capability for such orbital operations and recommended that a development program, coordinated with the Department of Defense, be undertaken immediately. Also, because of the size and scope of such a program, they recommended that it be independent of other space projects and that NASA create a separate administrative office to initiate and manage the program.

Memorandum, Bernard Maggin to Associate Administrator, "Staff Paper—'Guidelines for a Program for Manned and Unmanned Orbital Operations,'" 22 May 1961.

18–31

Space Task Group Director Robert R. Gilruth informed Ames Research Center that current planning for Apollo "A" called for an adapter between the Saturn second stage and the Apollo spacecraft to include, as an integral part, a section to be used as an orbiting laboratory. Preliminary in-house configuration designs indicated this laboratory would be a cylindrical section about 3.9 m in diameter and 2.4 m in height. The laboratory would provide the environment and facilities to conduct scientific experiments related to manned operation of spacecraft. Gilruth requested that Ames forward to STG descriptions of scientific experiments believed to be important to the development of manned space flights, together with a list of necessary support equipment requirements.

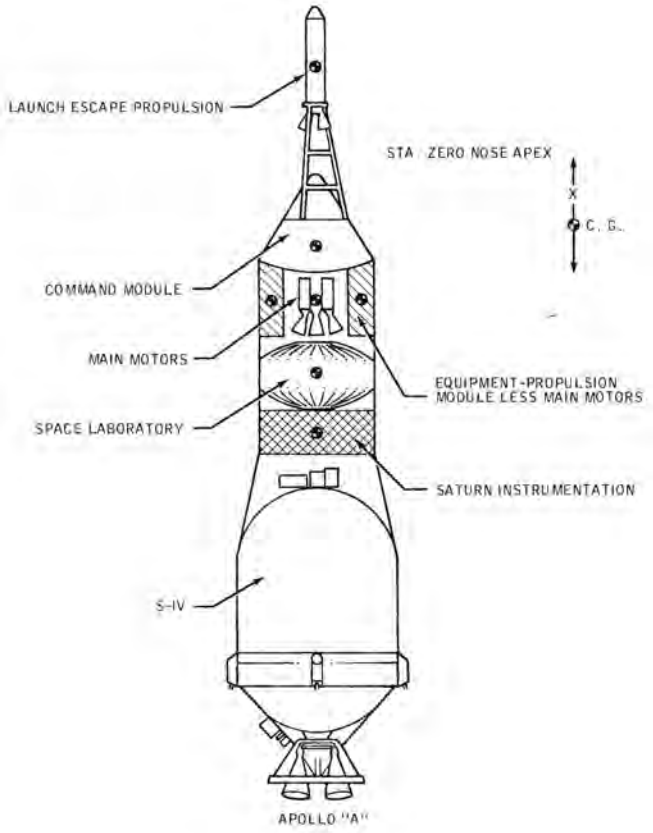
In response to the request from the STG, ARC Director Smith J. DeFrance suggested a series of experiments that might be conducted from an Earth-orbiting laboratory: astronomical observations; monitoring the Sun's activity; testing man's ability to work outside the vehicle; zero-g testing; and micrometeoroid impact study. DeFrance noted that all of these experiments could be performed in the lunar mission module part of the Apollo space vehicle with little or no design modification.

Letters, Robert R. Gilruth to ARC, "Scientific experiments to be conducted in an orbiting laboratory," 18 May 1961; Smith J. DeFrance to STG, Attn: Apollo Project Office, "Suggestions for experiments to be conducted in an earth-orbiting scientific laboratory," 31 May 1961.

October

Emanuel Schnitzer of LaRC suggested a possible adaptation for existing Apollo hardware to create a space laboratory, which he termed an "Apollo X" vehicle. Schnitzer's concept involved using a standard Apollo command and service module in conjunction with an inflatable spheroid structure and transfer tunnel to create a space laboratory with artificial gravity potential. He argued the technical feasibility of such a scheme with minimal weight penalties on the basic Apollo system. (Although little apparently was done with his idea, Schnitzer's thinking, along with similar thoughts by many of his colleagues, created a fertile environment within NASA for the idea of adapting Apollo-developed space hardware to laboratories and space stations in Earth orbit.) In April 1962 Paul Hill, Chief of the Applied Materials and Physics Division, stated that structures were under study which could hold from 4 to 30 people.

Emanuel Schnitzer, *Possible APOLLO "X" Inflatable Space Laboratory,* October 1961; *Astronautical and Aeronautical Events of 1962,* 12 June 1963, p. 64.



POSSIBLE APOLLO ORBITING LABORATORY

This spacecraft design of the possible use of Apollo as a space station was prepared by H. Kurt Strass of Space Task Group in the fall of 1961.

1962

April

MSC designers and planners prepared a preliminary document that outlined areas of investigation for a space station study program (handled largely under the aegis of Edward H. Olling of the Spacecraft Research Division). Flight Operations Division Chief Christopher C. Kraft, Jr., urged that the study format be expanded to include such areas as the operational requirements for a ground support and control network, logistics vehicles, and space station occupied versus unoccupied intervals.

Memorandum, Christopher C. Kraft, Jr., to Edward H. Olling, "Rough Draft of Space Station Study Document," 1 May 1962, with enclosure, "Proposed Revision."

May

10

John C. Fischer, Jr., an aerospace technologist at Lewis Research Center, put forward a plan for a two-phased approach for a space station program. The more immediate step, involving launching a manned and fully equipped station into orbit, would span some four to six years. Such a station would allow investigation of stationkeeping, rotation of personnel in orbit through supply and ferry craft, and replacement of modules in orbit through modular construction. The second and more sophisticated phase of a space station program, evolving from the earlier

1962

September

and $300 000 to MSFC for contractor-related studies, compared to OART's funding to LaRC of $800 000.

Maxime A. Faget stated that MSC was revising some of its earlier plans for space station studies to include a thorough operational analysis so that rational cost-based decisions could be made in 1964. He observed that cost would be a very important—if not the most important—factor in any early space station program decision, thus dictating a simple design for the vehicle.

Clint Brown, representing Langley, agreed with Faget's views and announced that LaRC had reorganized its original space station steering group and had re-oriented and broadened their conceptual design studies, with greater emphasis upon simplicity of configuration and system design. Although Brown and Faget disagreed on the principal justification for a space station program (Faget viewed it as a support for a future manned flight to Mars, while Brown argued primarily its usefulness as a research laboratory for a variety of NASA research elements), both agreed on the desirability of bringing all of the Agency's Program Offices (such as the Office of Space Science and Applications) into the planning picture. All the participants at this meeting agreed that a paramount objective for immediate planning was to define program objectives for a space station—what roles it would fill and what purposes it would be designed to accomplish.

Memorandum, W. E. Stoney, NASA Hq, to R. L. Bisplinghoff, NASA Hq, "OART-OMSF and Center Meeting on Space Station Studies," 5 October 1962.

October

17

Joseph F. Shea, Deputy Director for Systems, Office of Manned Space Flight, solicited suggestions from each of the Headquarters' Program Offices and the various NASA Centers on the potential uses and experiments for a manned space station. Such ideas, Shea explained, would help determine whether adequate justification existed for such a space laboratory, either as a research center in space or as a functional satellite. Preliminary studies already conducted, he said, placed such spacecraft within the realm of technology feasibility, and, if a decision were made to go ahead with such a project, NASA could conceivably place a station in Earth orbit by about 1967. Shea emphasized, however, that any such decision depended to a great extent on whether adequate justification existed for a space station. In seeking out ideas from within the agency, Shea called for roles, configurations, system designs, and specific scientific and engineering uses and requirements, emphasizing (1) the importance of a space station program to science, technology, or national goals; and (2) the unique characteristics of such a station and why such a program could not be accomplished by using Mercury, Gemini, Apollo, or unmanned spacecraft. Finally, he stated that general objectives currently envisioned for a station were as a precursor to manned planetary missions and for broad functional and scientific roles.

Memorandum, Joseph F. Shea to Dist., "Definition of Potential Applications for Manned Space Station," 17 October 1962.

1962
December
12

Owen E. Maynard, Head of MSC's Spacecraft Integration Branch, reported on his preliminary investigation of the feasibility of modifying Apollo spacecraft systems to achieve a 100-day Earth-orbital capability. His investigation examined four basic areas: (1) mission, propulsion, and flight time; (2) rendezvous, reentry, and landing; (3) human factors; and (4) spacecraft command and communications. Although modifications to some systems might be extensive—and would involve a considerable weight increase for the vehicle—such a mission using Apollo hardware was indeed feasible.

Memorandum, Owen E. Maynard to Chief, Spacecraft Technology Div., "Systems Investigation of a 100-Day Earth Orbital Operation for Apollo," 12 December 1962, with enclosure, same subject.

15

MSC researchers compiled a preliminary statement of work for a manned space station study program in anticipation of study contracts to be let to industry for a supportive study. The study requirements outlined the general scope of such investigations and suggested guidelines for research areas such as configurations, onboard spacecraft systems, and operational techniques. Ideally, studies by aerospace companies would help NASA formulate a logical approach for a space station program and how it might be implemented. Throughout the study, an overall objective would be simplicity: no artificial gravity and maximum use of existing launch vehicles and spacecraft systems to achieve the earliest possible launch date.

MSC, *General Requirements for a Study Proposal for a "Zero-Gravity" Manned Orbital Laboratory,* 15 December 1962.

1963
January
22

Addressing an Institute of Aerospace Science meeting in New York, George von Tiesenhausen, Chief of Future Studies at NASA's Launch Operations Center, stated that by 1970 the United States would need an orbiting space station to launch and repair spacecraft. The station could also serve as a manned scientific laboratory. In describing the 91-m-long, 10-m-diameter structure, von Tiesenhausen said that the station could be launched in two sections using Saturn C–5 vehicles. The sections would be joined once in orbit.

Future Studies Branch Activities Report, Fiscal Year 1963, TR–4–17–3–D, 19 August 1963, p. 31.

March
1

MSC proposed building a manned space station using hardware already under development for the Apollo program. MSC's plan called for an orbiting station with a capacity for 18 crewmen. Manning would be accomplished through successive flights of six-man, modified Apollo-type spacecraft that would rendezvous with the station in orbit.

Astronautics and Aeronautics, 1963, pp. 77–78; Baltimore *Sun,* 2 March 1963.

4

Testifying before the House Committee on Science and Astronautics, NASA Deputy Administrator Hugh L. Dryden described the Agency's studies of post-

1963

March

Apollo space projects. Among "obvious candidates," Dryden cited a manned Earth-orbiting laboratory, which was a prerequisite for manned reconnaissance of the planets. Many preliminary design studies of the technological feasibility of a large space laboratory had been made, Dryden said. But technical feasibility alone could not justify a project of such magnitude and cost. "We are attempting to grasp the problem from the other end," he said, ". . . to ask what one can and would do in a space laboratory in specific fields of science and technology with a view to establishing a realistic and useful concept. . . . The program must be designed to fulfill national needs."

U.S. Congress, House, Committee on Science and Astronautics, *1964 NASA Authorization: Hearings on H.R. 5466 (Superseded by H.R. 7500)*, 88th Cong., 1st sess., 4–5 March 1963, p. 20.

28

Associate Administrator Robert C. Seamans, Jr., asked Abraham Hyatt of Headquarters to organize a task team to study the concept of a Manned Earth Orbiting Laboratory.

Seamans pointed out that such a laboratory was under consideration by several government agencies and that NASA and the Department of Defense were at that time supporting a number of advanced feasibility studies. He said that such a laboratory bore a very heavy interrelationship between manned space flight, space sciences, and advanced research and technology and that NASA's top management was faced with the decision whether to initiate hardware development. Hyatt's team thus must examine broadly the needs of an orbiting laboratory from NASA's viewpoint, as well as that of outside agencies, and the operational and scientific factors impinging on any possible decision to undertake hardware development.

Memorandum, Robert C. Seamans, Jr., to Dist., "Special Task Team for Manned Earth Orbiting Laboratory Study," 28 March 1963.

April

11

Christopher C. Kraft, Jr., John D. Hodge, and William L. Davidson of MSC's Flight Operations Division met at Langley with a large contingent of that Center's research staff to discuss LaRC's proposed Manned Orbital Research Laboratory (MORL). Langley spokesmen briefed their Houston visitors on the philosophy and proposed program phases leading to an operational MORL. Kraft and his colleagues then emphasized the need for careful study of operational problems involved with the MORL, as well as those associated with the smaller crew ferry and logistics supply vehicles. Specifically, they cited crew selection and training requirements, the need for a continuous recovery capability, communications requirements, and handling procedures for scientific data.

Memorandum, William L. Davidson to Chief, Flight Operations Div., "Notes on Langley Research Center's (LaRC) Proposed Manned Orbital Research Laboratory (MORL)," 18 April 1963.

1963

June

1 MSC announced two space station study contracts to compare concepts for a 24-man orbital laboratory: one with the Lockheed Aircraft Corporation and another with Douglas Aircraft Company, Inc., Missiles and Space Systems Division. The stations were to be designed for a useful orbital lifetime of about five years, with periodic resupply and crew rotations.

Douglas Aircraft Co., Report SM–45878, *Douglas Orbital Laboratory Studies*, January 1964.

20 In a meeting with a number of people from MSC's Spacecraft Technology and Instrumentation and Electronic Systems Divisions, J. E. Clair from Bendix Eclipse-Pioneer Division gave a progress report on the company's study of stabilization techniques for high-resolution telescopes aboard manned space vehicles (work done under a contract awarded 9 November 1962). In part, MSC's purpose was to ensure that Bendix's study reflect the Center's current definition of space stations. Clair and the MSC contingent explored a number of technical problems for different vehicle configurations, including pointing accuracy, fields of view, and physical location aboard the vehicle.

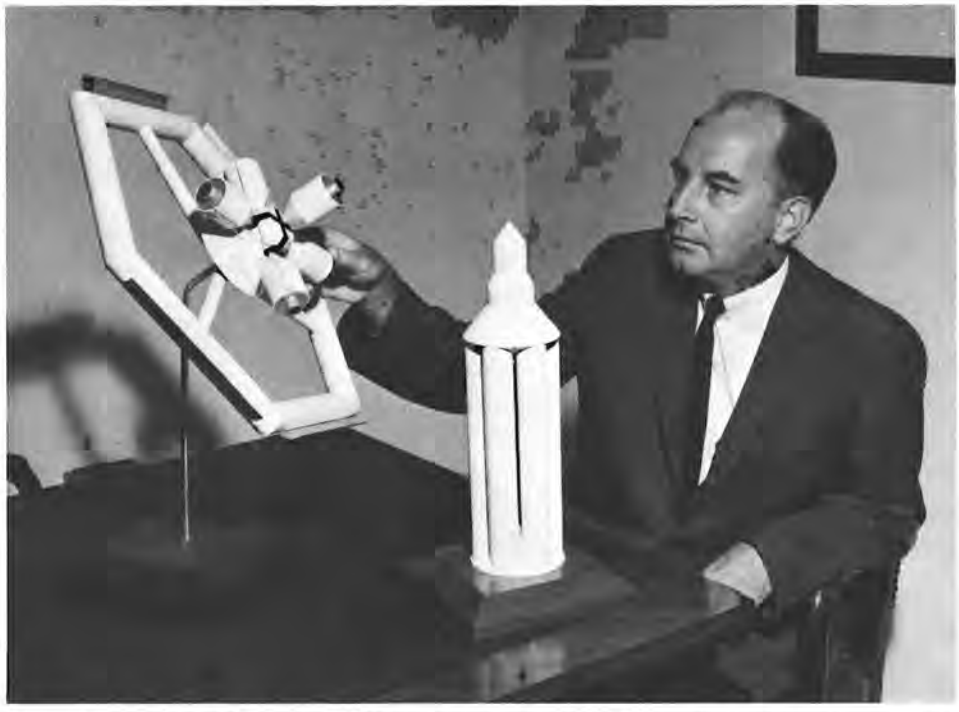
Memorandum, R. L. LaBlanc, MSC, to Deputy Chief, Instrumentation and Electronic Systems Div., "Conference with Bendix Eclipse-Pioneer Representatives on June 20, 1963," 17 July 1963.

24 LaRC Director Floyd L. Thompson announced that two aerospace firms, The Boeing Company of Seattle and Douglas Aircraft Company, Inc., of Santa Monica, had been selected for final negotiations for study contracts of a Manned Orbital Research Laboratory (MORL) concept. Results of the comparative studies would contribute to NASA's research on ways to effectively use man in space. Although no officially approved project for an orbital laboratory existed at the time, research within the agency over the past several years had developed considerable technology applicable to multimanned vehicles and had fostered much interest in such a project. Langley's MORL concept envisioned a four-man Workshop with periodic crew change and resupply, with at least one crew performing a year-long mission to evaluate the effect of weightlessness during long-duration space flights.

Douglas Aircraft Co., Report No. SM–45878, *Douglas Orbital Laboratory Studies*, January 1964.

July

10 In a report to the Aeronautics and Astronautics Coordinating Board, Director of Manned Space Flight D. Brainerd Holmes and Air Force Undersecretary Brockway McMillan, cochairmen of the Manned Space Flight Panel, set forth a number of recommendations for bringing about a closer coordination between NASA and the Department of Defense (DOD) in manned space station studies. Although some coordination between the two agencies already existed, direct contact was inadequate, especially at the technical level. Holmes requested all NASA program offices and those field centers involved in space station work to



Rene A. Berglund, Chief of MSC's Space Vehicle Design Branch, is shown with models of the modular space station he designed, for which he earned a cash award from the NASA Inventions and Contributions Panel in July 1963. The one on the right is the launch configuration for the orbital revision on the left.

1963

July

comply with the Panel's recommendations for thorough interchange of study work and information with DOD.

Memorandum, D. Brainerd Holmes to Dist., "NASA/DOD Coordination on Space Station Programs," 10 July 1963, with enclosure, "Report to the Aeronautics and Astronautics Coordinating Board from the Manned Space Flight Panel."

16

At Seattle, five men began a 30-day engineering test of life support systems for a manned space station in The Boeing Company space chamber. The system, designed and built for NASA's Office of Advanced Research and Technology, was the nation's first to include all life-support equipment for a multimanned, long-duration space mission (including environmental control, waste disposal, and crew hygiene and food techniques). In addition to the life support equipment, a number of crew tests simulated specific problems of space flight.

Five days later, however, the simulated mission was halted because of a faulty reactor tank.

NASA News Release 63–155, "Thirty-Day Life Support System Being Tested for NASA," 16 July 1963; Cleveland *Plain Dealer,* 21 July 1963.

1963

July

30

At the request of NASA Hq, MSC contracted with North American to determine what engineering modifications to the basic Apollo spacecraft would be required to extend that vehicle's mission capabilities to a 100-day orbital lifetime. Although the study contract was handled chiefly by the Space Vehicle Design Branch of the Spacecraft Technology Division, Engineering and Development Director Maxime A. Faget requested that all elements of his directorate lend support as required to achieve a meaningful and useful effort, including in-house study efforts if needed. Also, Faget described the vehicle model that served as the basis for the study: a space laboratory for either a two- or three-man crew; an orbital altitude of from 160 km to 480 km; an orbital staytime of about 100 days without resupply; and launch aboard a Saturn IB. He stated that two separate vehicles were under consideration, an Apollo command module and a command module and separate mission module to be used as living quarters.

Memorandum, Maxime A. Faget to Dist., "100-day Apollo, study support," 30 July 1963.

August 17–

September 14

NASA and the DOD concluded a joint agreement to coordinate all advanced space exploration studies and any actual programs undertaken in the area of a manned orbital research station. The two agencies agreed that, to the greatest extent possible, future requirements in this area should be encompassed in a single project.

"Agreement Between the Department of Defense and the National Aeronautics and Space Administration Covering a Possible New Manned Earth Orbital Research and Development Project"; NASA News Release 63-231, "NASA-DOD Agree on Common Approach to a Manned Orbital Research and Development Project," 17 October 1963.

October

9

A "flying carpet" escape system from orbital space stations had been proposed by Douglas Aircraft Company. The escape system would be a saucer shape that would expand into a blunt-nosed, cone-shaped vehicle 7.6 m across at its base. The vehicle would act as its own brake as it passed through the atmosphere. Reentry heating problems would be met by using fabrics woven with filaments of nickel-based alloys.

Space Business Daily, 9 October 1963, p. 52; *Astronautics and Aeronautics, 1963*, p. 383.

18

NASA announced the selection of 14 new astronauts: Edwin E. Aldrin, Jr., William A. Anders, Charles A. Bassett II, Michael Collins, Donn F. Eisele, Theodore C. Freeman, and David R. Scott from the Air Force; Alan L. Bean, Eugene A. Cernan, Roger B. Chaffee, and Richard F. Gordon, Jr., of the Navy; Clifton C. Williams, Jr., United States Marine Corps; and R. Walter Cunningham and Russell L. Schweickart, civilians. This latest addition to the astronaut corps brought the total number of NASA astronauts to 30.

MSC News Release 63-180, 18 October 1963.

1963

October

31 The Director of Advanced Research and Technology, Raymond L. Bisplinghoff, asked the several field centers to conduct a thorough assessment of the potential utility of a manned orbiting laboratory to conduct scientific and technological research in space. To date, Bisplinghoff said, the prevailing view (based primarily on intuitive judgment) saw such research as one of the most important justifications for an orbital laboratory. An accurate assessment of its potential was essential so that, as a preliminary to undertaking such a project, any such decision would rationally examine whether such a project should be undertaken and what type of laboratory should be built.

Letter, Raymond L. Bisplinghoff, NASA Hq, to Dist., "Request for assistance in defining the scientific and technological research potential of a manned orbital laboratory," 31 October 1963.

November

24 North American issued the final report of its study for MSC on extended missions for the Apollo spacecraft. In stressing the supreme importance of man's role in the exploration of space—and the uncertainties surrounding the effects of prolonged exposure to the zero-gravity environment of space—the company suggested that an Earth-orbital laboratory would be an ideal vehicle for such long-term experimental evaluation, with missions exceeding a year's duration. The more immediate approach to meeting the demands for such missions was through modification of existing vehicle systems rather than the development of completely new space hardware. In the remainder of the report, the company gave detailed descriptions of how Apollo systems might be modified to meet the requirements of extended missions, ranging from the basic command and service module to a separate laboratory and habitable module with self-contained systems and life-support equipment. All such basic concepts were technically sound and could satisfy mission objectives with minimum costs and development time.

North American, SID Report 63-1370-12, *Extended-Mission Apollo Study, Final Report,* 24 November 1963, pp. 1–5, 19–20.

December

10 Secretary of Defense Robert S. McNamara announced cancellation of the X–20 Dyna Soar project at a news briefing at the Pentagon. McNamara stated that fiscal resources thereby saved would be channeled into broader research on the problems and potential value of manned military operations in space, chiefly the Manned Orbiting Laboratory (MOL) project. These decisions on the X–20 and MOL had been discussed and coordinated with NASA, and, although the Air Force received responsibility for the MOL project, NASA would continue to provide technical support.

DOD News Briefing with Hon. Robert S. McNamara, Secretary of Defense, The Pentagon, 10 December 1963.

19 NASA Hq advised the centers regarding the agency's official position vis-à-vis the Defense Department's Manned Orbiting Laboratory project. Both NASA and DOD viewed MOL as a project designed to fulfill immediate military re-

1963

December

quirements. The project could not be construed as meeting the much broader objectives and goals of a national space station program being studied by both organizations under post-Apollo research and development program policy agreements between NASA Administrator James E. Webb and Secretary of Defense Robert S. McNamara (dated 14 September 1963).

TWX, NASA Hq to Dist., 19 December 1963.

26

MSFC Director Wernher von Braun described to Apollo Spacecraft Program Manager Joseph F. Shea a possible extension of Apollo systems to permit more extensive exploration of the lunar surface. Huntsville's concept, called the Integrated Lunar Exploration System, involved a dual Saturn V mission (with rendezvous in lunar orbit) to deliver an integrated lunar taxi/shelter spacecraft to the Moon's surface. Wernher von Braun stated that, though this concept was most preliminary, such a vehicle could bridge the gap between present Apollo capabilities and the longer term goal of permanent lunar bases. (Although this suggestion never found serious favor elsewhere within the agency, such thinking and ideas were indicative of speculation throughout NASA generally regarding possible applications of Apollo hardware to achieve other space goals once the paramount goal of a lunar landing was achieved.)

Letter, Wernher von Braun, MSFC, to Shea, MSC, 26 December 1963.

31

MSC Director Robert R. Gilruth apprised George E. Mueller, Associate Administrator for Manned Space Flight, of recent discussions with officers from the Air Force's Space Systems Division regarding MSC's joint participation in the MOL project in the area of operational control and support. Such joint cooperation might comprise two separate areas: manning requirements for the control center and staffing of actual facilities. Gilruth suggested that such joint cooperation would work to the benefit of both organizations involved. Furthermore, because a number of unidentified problems inevitably existed, he recommended the creation of a joint NASA–Air Force group to study the entire question so that such uncertainties might be identified and resolved.

Letter, Robert R. Gilruth to George E. Mueller, NASA Hq, "Operational Support for the USAF Manned Orbiting Laboratory," 31 December 1963.

1964

January

8

In an interview for *Space Business Daily*, Edward Z. Gray, Director of Advanced Studies in NASA's Office of Manned Space Flight, predicted that NASA's manned space station would be more sophisticated than the Defense Department's Manned Orbiting Laboratory. NASA had more than a dozen study projects under way, Gray said, that when completed would enable the agency to appraise requirements and pursue the best approach to developing such a space station.

Space Business Daily, 8 January 1964, p. 34.

1964

January

10 James J. Haggerty, Jr., Space Editor for the *Army-Navy-Air Force Journal and Register,* called the assignment of the Manned Orbiting Laboratory to the Department of Defense "an ominous harbinger of a reversal in trend, an indication that the military services may play a more prominent role in future space exploration at NASA's expense. . . . Whether you label it development platform, satellite platform, satellite or laboratory, it is clearly intended as a beginning for space station technology. It is also clearly the intent of this administration that, at least in the initial stages, space station development shall be under military rather than civil cognizance. . . ."

Army-Navy-Air Force Journal and Register, 11 January 1964, p. 10.

15 Following completion of feasibility studies of an extended Apollo system at MSC, Edward Z. Gray, Advanced Manned Missions Program Director at Headquarters, told MSC's Maxime A. Faget, Director of Engineering and Development, to go ahead with phase II follow-on studies. Gray presented guidelines and suggested tasks for such a study, citing his desire for two separate contracts to industry to study the command and service modules and various concepts for laboratory modules.

Letter, Edward Z. Gray to Maxime A. Faget, 15 January 1964, with enclosure, "Extended Apollo, Phase II."

January–March In the wake of the Air Force's Manned Orbiting Laboratory project and the likelihood of NASA's undertaking some type of manned orbiting research laboratory, Director of Advanced Manned Missions Studies Edward Z. Gray sought to achieve within NASA a better understanding of the utility of such projects as a base for experiments in space. Accordingly, he created three separate working groups to deal with possible experiments in three separate categories: (1) bio-medical, (2) scientific, and (3) engineering.

Memorandum, Edward Z. Gray, NASA Hq, to Wernher von Braun, MSFC, "Establishment of an Orbital Research Laboratory Engineering Experiments Working Group," 3 March 1964.

February

26 The Lockheed-California Company released details of its recommendations to MSC on a scientific space station program. The study concluded that a manned station with a crew of 24 could be orbiting the Earth in 1968. Total cost of the program including logistics spacecraft and ground support was estimated at $2.6 billion for five years' operation. Lockheed's study recommended the use of a Saturn V to launch the unmanned laboratory into orbit and then launching a manned logistics vehicle to rendezvous and dock at the station.

MSC *Roundup,* 4 March 1964, p. 8.

March

12 Edward Z. Gray, Advanced Manned Missions Director in the Office of Manned Space Flight, asked LaRC Director Charles J. Donlan to prepare a Project

1964

March

Development Plan for the Manned Orbital Research Laboratory, studies for which were already underway at the Center and under contract. This plan was needed as documentation for any possible decision to initiate an orbital research laboratory project. (Gray had also asked MSC to submit similar plans for an Apollo X, an Apollo Orbital Research Laboratory, and a Large Orbital Research Laboratory.) In addition to the Project Development Plan, Gray asked for system specifications for each candidate orbital laboratory system; both of these would form the basis for a project proposal with little delay "should a climate exist in which a new project can be started."

Letter, E. Z. Gray to C. J. Donlan, 12 March 1964.

During the Month

A study to recommend, define, and substantiate a logical approach for establishing a rotating manned orbital research laboratory for a Saturn V launch vehicle was made for MSC. The study was performed by the Lockheed-California Company, Burbank, California. It was based on the proposition that a large rotating space station would be one method by which the United States could maintain its position as a leader in space technology. Study results indicated that no major state-of-the-art advances would be required for a rotating space station program. If the program was to be implemented, maximum utilization could be made of the technologies, equipment, and facilities developed for the Mercury, Gemini, and Apollo programs. Significant reductions in cost, development time, and technological risk for a large rotating space station program would thereby be obtained.

Four principal objectives were established for the study: study of alternate configurations, conceptual design of a rotating station, selection of station systems, and a program plan for the rotating station. Ground rules and guidelines were established to limit, define, and focus the studies. A summary of these follows.

- The launch vehicle was to be a two-stage Saturn V. Launch was to be from Cape Canaveral, Florida, in July 1968; the period from 1967 to 1970 was to be considered.
- The station was to be fully operational for one to five years.
- The space station was to be launched unmanned.
- Crew size was to be 24 men.
- The space station would be capable of remaining in the unmanned condition for a minimum period of one month.
- Meteoroid and radiation environment was as specified by NASA–MSC.
- Cabin pressure was to be variable from 24 to 101 kilonewtons per sq m (3.5 to 14.7 psia) within any one module or the zero-gravity laboratory, with the normal value being 48 kilonewtons per sq m (7.0 psia).
- Design criteria for the life support system were those specified by NASA.
- The space station was to be designed to accommodate emergencies, and rapid egress would not be a primary design constraint.
- Crew duty cycles would vary between three months and one year.

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• The basic resupply period would be 90 days; however, variations to this period would be considered.

• Logistic spacecraft to be considered would include the 12-man ballistic or lifting body designs or a 6-man modified Apollo.

• Maximum use would be made of already available or planned equipment and technology or modest extensions thereof.

If the Gemini and Apollo programs were continued at the current pace, research requirements for implementing a large rotating space station were few. These requirements were

Aeronautics

No aeronautics problems, as such, were anticipated; however, continuing research on the properties of the atmosphere at the orbital altitude would allow more accurate prediction of orbit decay rates.

Biotechnology and Human Research

Research to define more precisely the radiation environment and its effects on man should be continued. In connection with this work, better methods of measuring radiation dosage to man and of prognosis of potential damage were required.

Continuing research on the long-term effects of reduced gravity and methods of counteracting such effects were necessary. Major contributions would be made in the Gemini and Apollo programs.

Analysis and experimentation in the area of crew performance under reduced or zero gravity would aid in the design of equipment for both operations and maintenance.

Environmental and Stabilization Controls

Active systems had been proposed for stabilizing the rotating space station. Research in the area of passive stabilization devices would provide both increased reliability and decreased power consumption.

Environmental control on the space station would use currently available hardware, with the exception of the oxygen regeneration unit. The proposed arrangement would make use of the Bosch process, which requires a large amount of electrical power for the electrolysis of water. Research would be required on the electrolysis process and on alternative means of reclaiming oxygen.

Materials and Structures

Continuing research on the meteoroid environment and on penetration mechanics and hazards of penetration, based on representative space station

1964
March

structures and operating pressures, would be required to permit more accurate evaluation of station and crew survival.

The effect of long-term exposure of materials to the space environment would aid in reducing the space station development span. Of primary interest were sealing, materials, lubricants, repair techniques, and surface coatings for preserving thermal properties and for preventing or facilitating vacuum welding.

Current toxicity data on materials dealt only in terms of industrial exposure times. The toxicity of the various materials that would be used in the space station should be evaluated for long-term human exposure in a representative environment.

Nuclear Systems

Nuclear power devices offered many attractive advantages for space station use; however, at that time, their development status, shielding requirements, and cost had prevented their use. Further research in both nuclear and radioisotope systems appeared justified in view of the potential benefits that could be realized.

Propulsion and Power Generation

One of the major logistic requirements for the space station would be propellants. The possibility of reducing propellant resupply requirements existing in the use of high-specific-impulse devices was now under development. Further research would be required to make the weight, size, thrust, and power consumption more compatible with space station requirements.

In the existing space station design, the primary power source, solar cells, needed to be complemented with power storage devices in the form of silver-cadmium batteries. Research, aimed at increasing battery life as a function of depth of discharge, would result in a marked reduction of power system weight and logistic requirements.

The study recommended that effort in the following areas would provide critically needed technology:

- Development of a flight-rated oxygen regeneration system.
- Development of water reclamation components.
- Construction of a full-scale mockup.
- Design and testing of candidate wall constructions.
- Determination of the effect on materials of long-term exposure to the space environment.
- Increased battery life to minimize logistics.

Lockheed-California Co., Report No. LR 17502, Vol. XI, Summary, "Study of a Rotating Manned Orbital Space Station," March 1964.

1964

April

29 C. Howard Robins, Jr., and others in the MSC Advanced Spacecraft Technology Division investigated the suitability of and formulated a tentative mission flight plan for using a Gemini spacecraft to link up with an orbiting vehicle to achieve a long-duration space mission (dubbed the "Pecan" mission). The two crewmen were to transfer to the Pecan for the duration of the mission. As with similar investigations for the application of Apollo hardware, the scheme postulated by Robins and his colleagues emphasized maximum use of existing and planned hardware, facilities, and operational techniques.

Howard C. Robins, Jr., "On the Establishment of a Nominal Flight Plan for the Gemini-Pecan Mission," MSC Internal Note No. 54–EA–22, 29 April 1964.

June

5 Secretary of the Air Force Eugene M. Zuckert announced that three firms, Douglas Aircraft Company, General Electric Company, and The Martin Company, had received authorization to begin work on space station studies. Zuckert predicted also that the Titan III would be test-flown that summer and would launch the Manned Orbiting Laboratory sometime in 1967 or 1968.

Astronautics and Aeronautics, 1964, p. 205.

During the Month The recent creation of the Apollo Logistic Support System Office in Washington prompted the formal investigation of a variety of extensions of Apollo hardware to achieve greater scientific and exploratory dividends from Apollo hardware. Director of Special Manned Space Flight Studies William B. Taylor suggested to William E. Stoney and others in Houston that Grumman receive a study contract to investigate possible modifications to the lunar excursion module (LEM) to create a LEM truck (concepts which the company had already investigated preliminarily on an in-house basis). The time was appropriate, Taylor said, for more intensive and formal efforts along these lines.

Letter, William B. Taylor, NASA Hq, to William E. Stoney, MSC, "LEM Truck," 24 June 1964.

July

14 A study submitted to NASA by Douglas Aircraft Company concluded that a six-man space research station, capable of orbiting for one year, could be orbiting the Earth within five years. The crew, serving on a staggered schedule, would travel to and from the station on modified Gemini or Apollo spacecraft. The station would provide a small degree of artificial gravity by rotating slowly and would include a centrifuge to simulate reentry forces.

Douglas Aircraft Co., Report No. SM–45878, *Douglas Orbital Laboratories Studies,* July 1964.

21 Commenting on Republican Presidential candidate Barry Goldwater's views on the space program, Warren Burkett, science writer for the Houston *Chronicle,* observed that a great deal of research being conducted as part of NASA's Apollo program could be of direct value to the military services. Burkett contended that

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an orbital laboratory using Apollo-developed components could be used for such military applications as patrol and orbital interception. He suggested that, with Apollo, NASA was generating an inventory of "off-the-shelf" space hardware suitable for military use if needed.

Houston *Chronicle*, 26 July 1964.

August

3

Willis B. Foster, Director of Manned Space Science in the Office of Space Science and Applications, distributed a preliminary draft report of the Ad Hoc Astronomy Panel of the Orbiting Research Laboratory (ORL). The panel, which met on 26 October 1963 and again on 24 June 1964, was created to sound out the American scientific community on the validity of manned astronomy in space and to define astronomy objectives for the ORL mission. The panel promulgated a broad statement on the scope and direction of the manned space astronomy program. Although sounding rocket and unmanned satellite programs had merit, the panel stated that broader, more flexible—and ultimately more economical—astronomy programs required the presence of man in space. Initial manned astronomy programs should be carried out as soon as possible, and, although primary interest was on Earth-orbital systems, the panel clearly was looking forward to the eventual possibility of lunar surface observatories.

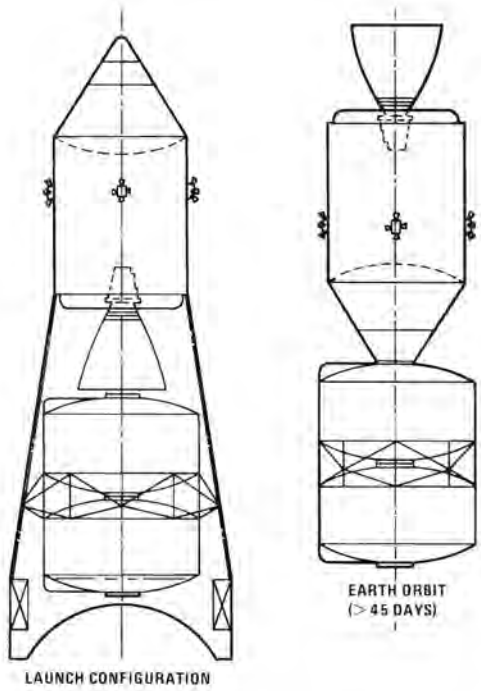
The Ad Hoc Astronomy Panel also presented a comprehensive rationale for man's role in space astronomy: assembly of large, bulky, or fragile equipment in space; maintenance, repair, and modification of equipment; and direct monitoring of scientific apparatus and immediate data feedback during critical periods and for specialized operations. While recognizing that the presence of flight-oriented astronauts was mandatory aboard an ORL, the panel recommended inclusion in the crew of a qualified astronomer to direct scientific operations aboard the laboratory.

Letter, Willis B. Foster, OSSA, to A. D. Code, University of Wisconsin, 3 August 1964.

17

MSC's Spacecraft Integration Branch proposed an Apollo "X" spacecraft to be used in Earth orbit for biomedical and scientific missions of extended duration. The spacecraft would consist of the lunar Apollo spacecraft and its systems, with minimum modifications consisting of redundancies and spares. The concept provided for a first-phase mission which would consider the Apollo "X" a two-man Earth-orbiting laboratory for a period of 14 to 45 days. The spacecraft would be boosted into a 370-km orbit by a Saturn IB launch vehicle. Variations of configurations under consideration provided for Configuration A, a two-man crew, 14- to 45-day mission, no lab module; Configuration B, a three-man crew, 45-day mission, single lab module; Configuration C, a three-man crew, 45-day mission, dependent systems double lab module; and Configuration D, a three-man crew, 120-day mission, independent systems lab module.

MSC Internal Note No. 64-ET-53, "Apollo Systems Extension, Apollo 'X,' Description and Mission Interrelationships," 17 August 1964.



The Apollo "X" spacecraft as it was visualized in both launch and Earth-orbit configurations by personnel of the MSC Spacecraft Integration Branch in August 1964.

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24

A background briefing for the press regarding astronomy programs was held in Washington. Nancy Roman, who directed the agency's astronomy activities, disclosed that NASA was studying the feasibility of a manned orbiting telescope. Although the telescope would be designed to operate automatically, man would adjust its focus, collect film packets, and make any necessary repairs. The space agency had already invited members of the scientific community to propose astronomical studies suitable for use in space, and several NASA centers were performing related engineering support studies.

Astronautics and Aeronautics, 1964, p. 327.

October

26

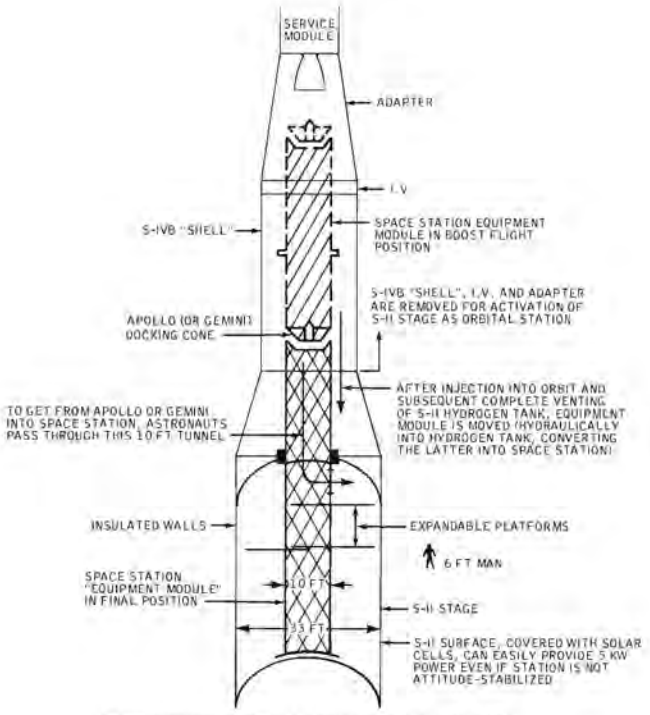
In an interview for *Missiles and Rockets* magazine, Associate Administrator Robert C. Seamans, Jr., stated that NASA planned to initiate program definition studies of an Apollo X spacecraft during Fiscal Year 1965. Seamans emphasized that such a long-duration space station program would not receive funding for actual hardware development until the 1970s. He stressed that NASA's Apollo X would not compete with the Manned Orbiting Laboratory program: "MOL is important for the military as a method of determining what opportunities there are for men in space. It is not suitable to fulfill NASA requirements to gain scientific knowledge."

Missiles and Rockets, 26 October 1964, p. 14.

December

1

In a letter to Apollo Program Director Samuel C. Phillips regarding tentative spacecraft development and mission planning schedules, Joseph F. Shea, Apollo



Above is a draftsman's completed work, taken from a rough sketch prepared by Wernher von Braun on 24 November 1964. All the descriptive material on either side of the conceptual space station was taken directly from von Braun's penciled sketch.

Spacecraft Program Manager, touched upon missions following completion of Apollo's prime goal of landing on the Moon. Such missions, Shea said, would in general fall under the heading of a new program (such as Apollo X). Although defining missions a number of years in the future was most complex, Shea advised that MSC was planning to negotiate program package contracts with both North American and Grumman through Fiscal Year 1969, based upon the agency's most recent program planning schedules.

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Letter, Joseph F. Shea, MSC, to Samuel C. Phillips, NASA Hq, 1 December 1964.

In a letter to President Lyndon B. Johnson, Senator Clinton P. Anderson, Chairman of the Committee on Aeronautical and Space Sciences, recommended that the Air Force's MOL and NASA's Apollo X programs be merged. Senator Anderson argued that a jointly operated national space station program would most effectively use the nation's available resources. He claimed that $1 billion could be saved during the next five years if the MOL were canceled and those funds applied to NASA's Apollo-based space station program.

7

In mid-December, Anderson issued a statement saying that the Department of Defense and NASA had worked out an agreement on MOL and Apollo X that in

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large measure answered the questions he had earlier raised. "The Air Force and NASA will take advantage of each other's technology and hardware development," Anderson said, "with all efforts directed at achievement of a true space laboratory as an end goal."

Astronautics and Aeronautics, 1964, pp. 382, 425.

11

LaRC announced award of a 10-month contract to The Boeing Company to study the feasibility of designing and launching a manned orbital telescope and to investigate ways in which such an astronomical observatory might be operated, particularly the role that man might play in scientific observations. The study presumed that the telescope would be operated in conjunction with the proposed Manned Orbital Research Laboratory being investigated by Langley.

Astronautics and Aeronautics, 1964, p. 415, cites LaRC Release.

1965

January

23

Defense Secretary Robert S. McNamara announced that the Department of Defense was requesting proposals from the aerospace industry for design studies to support development of the MOL (especially cost and technical data). Three contractors would be chosen to conduct the studies, a step preliminary to any DOD decision to proceed with full-scale development of the space laboratory.

Astronautics and Aeronautics, 1965, p. 27, cites DOD News Release 42–65.

February

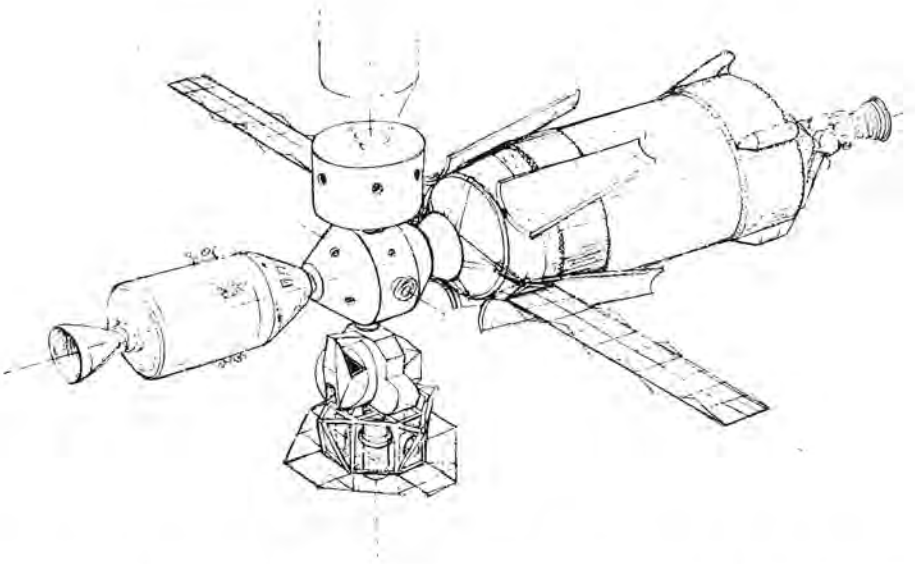
18

Testifying before the House Committee on Science and Astronautics during hearings on NASA's Fiscal Year 1966 budget, Associate Administrator for Manned Space Flight George E. Mueller briefly outlined the space agency's immediate post-Apollo objectives: "Apollo capabilities now under development," he said, "will enable us to produce space hardware and fly it for future missions at a small fraction of the original development cost. This is the basic concept in the Apollo Extension System (AES) now under consideration." Mueller stated that the Apollo Extension System had "the potential to provide the capability to perform a number of useful missions utilizing Apollo hardware developments in an earlier time frame than might otherwise be expected. This program would follow the basic Apollo manned lunar landing program and would represent an intermediate step between this important national goal and future manned space flight programs."

U.S. Congress, House, Committee on Science and Astronautics, *1966 NASA Authorization: Hearings on H.R. 3730 (Superseded by H.R. 7717),* 89th Cong., 1st sess., 1965, pp. 111–115.

23

In a major policy meeting at Headquarters, among George E. Mueller, Associate Administrator for Manned Space Flight (OMSF), Homer E. Newell, Associate Administrator for Space Science and Applications (OSSA), and members of their staffs, a fundamental policy agreement was worked out regarding responsibilities for scientific experiments aboard manned space flights. Basically, OSSA had re-



This original spacecraft design concept prepared in early 1965 by Willard M. Taub, MSC, for William E. Stoney, Jr., Chief of MSC's Spacecraft Technology Division, was used as a basis for later, more detailed spacecraft designs of the S–IVB Workshop. It has also been referred to extensively in discussing the most practical space station configurations.

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sponsibility for definition of experiments, selection and coordination with experimenters, and, after the flight, analysis and dissemination of scientific data; OMSF was responsible for actual flight hardware, as well as integration into the space vehicles and actual conduct of the mission. Funding responsibilities between the respective offices followed the same pattern.

Memorandum, R. J. Allenby, NASA Hq, to George E. Mueller, OMSF, and Homer E. Newell, OSSA, "Minutes of Newell-Mueller Meeting of 23 February 1965," 19 April 1965, with enclosure, "Memorandum of Agreement Between Office of Manned Space Flight [and] Office of Space Sciences and Applications, Scientific Interfaces."

May

4

MSC Assistant Director for Engineering and Development Maxime A. Faget submitted to NASA Hq the Center's plans for Fiscal Year 1966 Apollo Extension System program definition and subsystems development efforts. The information submitted was based on MSC's AES study and supporting development efforts and was broken down into several categories in line with guidelines laid down by the Office of Manned Space Flight: program definition, verification of the capabilities of Apollo subsystems for AES; definition and initial development of experiment payloads and payload support; long leadtime development of primary spacecraft systems critical to achieving minimum AES objectives (i.e., four to six weeks orbital capability and up to two weeks on the lunar surface); and development of improved or alternate subsystems that would extend AES capabilities up

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to three months in Earth orbit. Tasks in support of these objectives, Faget stated, fell into two priorities: (1) those tasks required to verify an early AES capability; and (2) tasks in support of later AES missions and for system improvement. Those tasks having immediate priority, therefore, demanded the "hard core" of AES funding essential to meet the early AES flight dates.

Letter, Maxime A. Faget, MSC, to E. Z. Gray, NASA Hq, "FY 1966 AES program definition and subsystem development program submission (905)," 4 May 1965.

June

18

LaRC awarded Douglas Aircraft Company a follow-on study contract for the MORL, emphasizing use of the AES program as a prerequisite to the MORL. Douglas was to examine particularly interfaces between AES experiments and missions and the MORL program.

LaRC Contract NAS 1-3612.

28

NASA announced selection of six scientist-astronauts to begin specialized training at MSC for the Apollo program. The men, chosen by NASA from a group of 16 nominated by the National Academy of Sciences, included one geologist, two physicians, and three physicists. The six new spacemen were Owen K. Garriott of Stanford University; Edward G. Gibson of the Aeronutronic Division of Philco; Duane E. Graveline, a flight surgeon at MSC; Joseph P. Kerwin, a Navy flight surgeon; Frank C. Michel of Rice University; and Harrison H. Schmitt, an astrogeologist for the U.S. Geological Survey.

NASA News Release 65-212, "NASA Selects Six Scientist-Astronauts for Apollo Program," 28 June 1965.

July

8

NASA Associate Administrator Robert C. Seamans, Jr., named the Deputy Associate Administrator for Programming to coordinate the agency's responses to other governmental agencies regarding post-Apollo program planning and review. At present, Seamans said, considerable interest concerning NASA's post-Apollo plans existed in the space committees of both the Senate and the House of Representatives; the President's Science Advisory Committee; the Office of Science and Technology; the National Aeronautics and Space Council; and the Bureau of the Budget. All were deeply involved in policy planning of direct concern to NASA. During forthcoming months, he emphasized, it was imperative that various program presentations and agency planning statements accurately reflect thinking of the agency's top leadership and that no contradictory positions be made outside the agency. This was essential, he said, "because of the very sensitive nature of many of the program options open to us and because of the intimate links between the NASA program and those of other major agencies."

Memorandum, Robert C. Seamans, Jr., to Deputy Associate Administrator for Programming, "Post-Apollo Planning Reviews," 8 July 1965.

22

Edward Z. Gray, Director, Advanced Manned Missions Program at NASA Hq, informed the Center Directors at MSC, MSFC, and KSC of significant recent

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July

program decisions on the approach to be followed during Fiscal Year 1966 in defining payload integration for the AES to the extent necessary for awarding major project contracts approximately a year later. In defining AES activity, Gray said, the Centers must follow the phased approach, with definition phase contracts to be awarded competitively to industry about the first of 1966. These contracts, to run for about five months, were to include the several companies' proposals for accomplishing the payload integration effort for all AES flights and would form the basis for NASA's final choice of integration contractors. Current plans, Gray said, were based on selection of two such payload integration contractors, one at MSC and the second at MSFC, each responsible for about half of all AES flights. (During the integration definition phase contracts, however, MSC had lead responsibility for competition and selection of study contractors, with participation by MSFC and KSC. Gray authorized MSC to supplement the existing AES study contracts with North American and Grumman to assist in the payload integration definition effort.)

Letter, Edward Z. Gray, NASA Hq, to Directors, MSC, MSFC, and KSC, "AES Mission Planning and Payload Integration," 22 July 1965.

30

The final report on a modular multipurpose space station was delivered to MSC by the Spacecraft Organization of Lockheed-California Company. The concept provided for a sequential evolution of space vehicles ranging from small Apollo-dependent laboratories, through larger, more versatile laboratories, to a semi-permanent space station.

Initial objectives of the study were to refine and optimize the design of the large orbital research laboratory. Eight tasks were defined by NASA to fulfill the intent of those objectives; but later, at NASA direction, efforts were concentrated on "Experiments and Utilization" and "Design of Modular Concepts," two of the original tasks. The other tasks were reduced in scope or terminated.

The ultimate objectives of the program were conceptual investigation of a family of space stations utilizing the modular, or building block, concept and integration of a broad spectrum of experiments and applications into this family of space stations. The study was a follow-on effort to "Study of a Rotating Manned Orbital Space Station," performed for MSC by Lockheed. (See March 1964 entry.)

The modular concept, as defined in the study, could be applied to a wide variety of missions and configurations, but only six missions using four configurations were developed:

- A 45-day mission, three-man crew, 370-km orbit at 28.5-degree inclination; one compartment laboratory.
- A 1-year mission, six-man crew, 370-km orbit at 28.5-degree inclination; two compartment laboratory.
- A 90-day mission, three- to six-man crew, 370-km orbit at 90-degree inclination; two compartment laboratory.

PART II

Apollo Applications Program

August 1965–February 1970

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August
6–10

Associate Administrator for Manned Space Flight George E. Mueller advised the Center Directors at MSC, MSFC, and KSC of the establishment within the Office of Manned Space Flight of the Saturn/Apollo Applications (SAA) Office, which would have responsibility for both the Saturn IB–Centaur program and the Apollo Extension System (AES) effort. David M. Jones, Deputy Assistant Administrator for Manned Space Flight (Programs), assumed the additional duties of SAA Acting Director. John H. Disher, formerly Test Director in the Apollo Program Office, was named Deputy Director.

Mueller sent Center Directors planning guidelines for proceeding with the definition phase of the AES program, including schedules, missions, organizational responsibilities, payload integration, and experiment definition and development. (These guidelines envisioned a buildup to four AES missions per year during 1970 and 1971.) Mueller also requested that each manned space flight center prepare a plan for implementing the AES program definition phase based on these guidelines and including planned procurements, facility modifications, staffing requirements, and an assessment of the definition program's impact on the Apollo program.

Letter, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, "Saturn/Apollo Applications Program," 10 August 1965; NASA News Release 65–265, 6 August 1965.

20

As part of MSFC's activities related to the AES program, designers at the Center began serious investigation of the concept of an S–IVB Orbital Workshop (OWS). This concept, which involved "in-orbit" conversion of a spent S–IVB stage to a shelter suitable for extended stay and utilization by man, showed great potential for experiment work during the Earth-orbital phase of the AES program. Accordingly, MSFC officials planned a four-month conceptual design effort, to begin immediately, with help and participation from both MSC and the S–IVB stage builder, Douglas Aircraft Company.

On 25 August, program planners met to initiate the OWS conceptual design study. Participants reviewed previous NASA and industry studies pertaining to

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rocket stage–laboratory ideas (essentially those as presented to the Manned Space Flight Management Council on 20 July 1965). These studies formed the point of departure for the four-month OWS study. Those present agreed that serious consideration must be given to simplified versions of the Workshop to achieve early launch dates and to hold down program costs.

A technical working group was created to oversee the conceptual design study, with J. H. Laue as chairman. Laue divided areas of responsibility among the group members and planned to hold biweekly meetings for the duration of the study.

Memoranda, F. L. Williams, MSFC, to Dist., "S–IVB Orbital Workshop Design Study," 20 August 1965; J. H. Laue, MSFC, to Dist., "Minutes of August 25, 1965, S–IVB Orbital Workshop Conceptual Design Study Meeting," 30 August 1965.

25

At a White House news conference, President Lyndon B. Johnson announced approval for the Department of Defense's development of the $1.5-million Manned Orbiting Laboratory (MOL). Such a program, the President said, would bring "new knowledge about what man is able to do in space." Further, MOL "will enable us to relate that ability to the defense of America."

Public Papers of the Presidents of the United States, Lyndon B. Johnson, 1965, Book II, 1 June to 31 December 1965, p. 917.

27

George E. Mueller, Associate Administrator for Manned Space Flight, requested MSC Director Robert R. Gilruth to identify the requirements for a spacecraft atmosphere selection and validation program to support the longer duration phase II missions of the AES program. (Mueller's request stemmed from a series of discussions and AES planning meetings between him and the Director of Advanced Manned Missions Studies, Edward Z. Gray, during June and July.) Although nominal mission duration for the phase II flights was pegged at 45 days, Mueller affirmed the likelihood that, with the conduct of rendezvous missions, flight times for some crewmen could be as long as 135 days. Accordingly, he asked that MSC evaluate the question of spacecraft atmospheres based upon mission durations of 45, 60, 90, and 135 days. Mueller requested MSC to complete the atmosphere cabin validation program expeditiously so that results could be readily incorporated into the design of the vehicle and integrated into mission planning.

In his reply, Gilruth stated that studies of single, as well as two-gas atmospheres were required. Continued research on a 34-kilonewton-per-sq-m (5-psia), 100-percent oxygen atmosphere was desirable both scientifically and operationally. Such a cabin atmosphere was very attractive because of attendant simplicity of the environmental control system. However, Gilruth said, recent data indicated possible impairment of vital body processes that necessitated additional study to validate the pure oxygen environment for flights of longer than 30 days. MSC researchers had begun investigating various combinations of two-gas atmospheres,

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chiefly mixtures of 50-percent oxygen and 50-percent nitrogen; 70-percent oxygen and 30-percent nitrogen; and 70-percent oxygen and 30-percent helium. MSC had underway, both in house and under contract, engineering studies of two-gas environmental control systems, and AiResearch Corporation was already developing such a system using as many existing command and service module components as possible. Houston was also working closely with the Air Force's School of Aviation Medicine during that agency's investigations of various cabin atmospheres. Finally, Gilruth stated, Houston planned to hold a Workshop conference with engineering and pulmonary physiology specialists to establish the basis for atmosphere selection and to discuss implementation of experimental programs.

Letters, George E. Mueller to Robert R. Gilruth, 27 August 1965; Robert R. Gilruth to George E. Mueller, "Requirements for a spacecraft atmosphere selection and validation program," 12 November 1965.

During the Month

During several visits to MSC, NASA Administrator James E. Webb raised a number of technical and policy questions relating to programs and management practices. Webb seemed particularly concerned about the difficulty of getting the program offices at Headquarters and the Centers to take an active interest in NASA's potential influence in the national economy and world affairs. During his second visit (20 August), he again expressed his interest in a spacecraft using true "off-the-shelf" technology as a method of reducing costs and repeated his belief that the time was right to begin serious study of a Saturn V space station.

Early the following month, MSC Director Robert R. Gilruth scheduled planning sessions to discuss the part MSC management might play in helping shape NASA decisionmaking regarding the next major mission to be undertaken in the manned space flight program. Gilruth was particularly interested in the ideas raised by Webb during his recent visits to Houston. Gilruth stated his conviction that any decision on the next major mission must recognize two chief constraints: (1) maximum use of existing hardware and technology and (2) maximum use of existing NASA facilities, particularly the manned field centers. The MSC Director put forth several points for consideration: what the next major mission should be; how Apollo Extension Systems and the Saturn V might best be incorporated into that mission; and how Houston might divide responsibility for workloads and program with MSFC and KSC without relinquishing any of its traditional responsibilities.

Memorandum, Robert R. Gilruth to Dist., "Discussion on Future Missions," 7 September 1965, with enclosure, memorandum, P. E. Purser, MSC, to Robert R. Gilruth and G. M. Low, MSC, "Notes on Visits of Mr. Webb to MSC During August 1965," 2 September 1965.

September

10

At Headquarters, Saturn/Apollo Applications Deputy Director John H. Disher formally redesignated Apollo Extension System the Apollo Applications Program. (See 6–10 August 1965 entry.)

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Memorandum, John H. Disher to J. P. Field, Jr., and W. Taylor, NASA Hq, 10 September 1965.

September

13

Associate Administrator for Manned Space Flight George E. Mueller officially informed the Directors of MSC, MSFC, and KSC of changed management guidelines for Center roles in AES as informally agreed upon during discussions in Washington (see 6–10 August 1965):

- MSC—responsible for spacecraft development, flight crew activities, mission control and flight operations, and command and service modules payload integration.
- MSFC—responsible for launch vehicle development and payload integration for all lunar excursion module AES-modified vehicles (termed "derivatives").
- KSC—responsible for prelaunch assembly, checkout, and launch of all AES vehicles.

Final decision on the Apollo-type versus contractor approach for payload integration was deferred pending results of phase I mission studies underway at North American and Grumman and of a payload integration definition study to be let by MSFC. These guidelines, said Mueller, should be incorporated into the Centers' planning efforts for AES implementation.

TWX, George E. Mueller to MSC, MSFC, and KSC, 13 September 1965.

14

NASA selected the Perkin-Elmer and Chrysler corporations to study feasibility of including optical-technology experiments, particularly lasers and large telescopes, in future extended Apollo flights. NASA was also interested in optical communication in deep space, the effects of space environment on optical systems, and related experiments. The program would be directed by MSFC.

MSFC News Release 65–223, 14 September 1965.

21

William B. Taylor and other Apollo Applications Program planners made a major presentation on AAP plans to James Webb, Hugh L. Dryden, and Robert C. Seamans, Jr., of NASA Hq. Webb made a number of comments regarding the direction of AAP planning. He emphasized that AAP planning must remain extremely flexible to meet not only changing mission objectives and goals, but also broader changes in national policy, resources, and manned space flight objectives generally. Webb disapproved of tying any AAP schedules to a date for accomplishment of the Apollo lunar landing objective, since that goal was not inviolate.

Memorandum, S. Ingram to George E. Mueller, "AES (AAP) Presentation to Mr. Webb, September 21, 1965, Afternoon Session," 24 September 1965.

During the Month

A plan for orbital space station development responsive to the research and development needs of a broad-based space exploration program was presented

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to the Deutsche Gesellschaft für Rakententechnik und Raumfarht, Munich, Germany. The paper was prepared by Douglas Aircraft Company, Inc., Santa Monica. The main theme of the paper centered on low-Earth-orbital applications of space stations. It suggested that the space station system would start with limited life laboratories and evolve into extended life, continuously manned space stations.

In the development of the space station, four major subsystems would be required: life support, power, stabilization and control, and communications. Of these, the life support and power subsystems would require significant extensions to current technology.

While touching on lunar-orbital and interplanetary missions, it was indicated that in the evolution of the space station the low-Earth-orbital missions were of primary importance because they could accommodate applications development, capability-engineering development, biomedical behavioral experiments, and scientific experiments. Polar orbits would be required for cartographic, meteorologic, geologic, and natural resources surveys. Synchronous orbits would be useful primarily for communications, allowing continuous communications without the necessity of vast ground or orbital relay networks.

C. J. Dorrenbacher, *The Evolution of Manned Space Stations and Their Development Problems*, Douglas Aircraft Co., Paper No. 3633, September 1965.

During the Month

The Stanford Research Institute, Menlo Park, California, performed a study on a manned orbital research laboratory (MORL) for Douglas Aircraft Company, Inc., Santa Monica. Major conclusions of the study included the following:

- The MORL mission was highly desirable for the posture of the United States in the international community. The improvement of this position would represent, perhaps, MORL's greatest contribution to our nation.
- The greatest social benefits would come from fundamental research experiments and missions that would hold promise of great economic returns.
- Economic benefits likely to accrue from certain MORL experiments would range up to several hundred million dollars per year.
- A priority of MORL missions could be established; the highest ranking category contained selected fundamental research experiments and Earth-oriented application experiments arranged in order of decreasing anticipated economic payoffs.
- The great value of an MORL—in comparison with (an) unmanned orbital station(s)—resided (1) in the vast complexity of tasks a man could perform reliably, e.g., research, and (2) in the efficiency of a man in collecting only pertinent information, again during the research phase. Man would provide a unique recognition element, and any response times involved in manned experiments would be equal to real time. The reliability of satellite experimentation that was initially very complicated could therefore be provided by manned missions at less than the prohibitive costs involved in unmanned missions.

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Stanford Research Institute, *Priority Analysis of Manned Orbital Research Applications*, Vol. 1, *Summary Report*, September 1965.

October

8

AAP Director William B. Taylor named Joseph G. Lundholm to fill the newly created position of Manager, Apollo Applications Experiments. In his new job, Lundholm represented Taylor in all cases involving definition, development, test, and operation of experiments for AAP missions.

Memorandum, William B. Taylor to Dist., "Apollo Applications Experiments Manager," 8 October 1965.

11

In a paper presented at the American Institute of Aeronautics and Astronautics' fourth manned space flight meeting in St. Louis, AAP Director William B. Taylor described the focus and importance of the AAP. In contrast to Apollo, with its clear objective of landing on the Moon, AAP's objectives were much less obvious. Under AAP, Taylor said, NASA planned to exploit the capabilities being developed for Apollo as a technological bridge to more extensive manned space flight missions of the 1970s and 1980s. AAP was not an end in itself, but rather a beginning to build flight experience, technology, and scientific data. Internal studies within NASA had identified the practical limits of the capabilities of Saturn/Apollo systems for extended space missions without fundamental modification of spacecraft and launch vehicles: (1) Earth-orbital missions of up to 45 days and at inclinations of 0 to 90 degrees and altitudes of from 185 km up to synchronous orbits (orbital resupply could extend the duration of such missions to three months or more); (2) lunar orbital missions of up to 28 days (including lunar polar orbits) at altitudes as low as 45 to 55 km; and (3) lunar surface missions of up to 14 days at any point on the lunar surface. Through these space activities, stated Taylor, AAP would lay the foundation for later, major ventures in space and thus would contribute significantly to the national goal of preeminence in space.

William B. Taylor, *Saturn/Apollo Applications*, paper presented at the AIAA meeting, St. Louis, 11 October 1965.

20

MSC and MSFC program officials and engineers held their first coordination meeting on the S–IVB Orbital Workshop and related Apollo Applications Program experiment activities. Among the most significant results of this meeting was a request by Houston for inclusion of an artificial gravity experiment as part of the S–IVB–command and service module concept of the Workshop. MSFC officials undertook to define the feasibility of such an experiment, examining several possible technical approaches (including cables—a concept that MSC found less than appealing). MSFC investigators also sought help from LaRC, where considerable work along this line had been done as part of that Center's MORL study program.

Memorandum, J. W. Carter, MSFC, to Dist., "Artificial Gravity Experiment for the S–IVB Workshop," 29 October 1965.

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21

MSC Deputy Director George M. Low advised NASA Hq of Houston's planning schedule for follow-up procurement of Apollo spacecraft for the AAP. Based upon the most recent delivery schedules for the last several command and service modules and lunar excursion modules for Apollo, contract award for those vehicles was scheduled for July and August 1966. In accordance with a 14 July directive from Headquarters, MSC was preparing a procurement plan for the extended CSM and the LEM derivatives covering both the final definition and development and operational phases of AAP. Approval of this plan by Headquarters, Low stated, was anticipated for mid-December, while award of contracts for the program definition phase was set for late January 1966. The contract award date for actual development of the extended CSM was slated for October 1966, while that for the LEM derivatives was postponed until mid-1967 (in line with revised funding directives from Washington).

TWX, George M. Low to J. H. Disher, NASA Hq, "Follow-on Procurement of Apollo Hardware," 21 October 1965.

28–29

Saturn Apollo Applications officials reached an understanding on several program issues during discussion at MSFC:

- MSFC's responsibility for payload integration included coordination of interleaving of CSM and LEM experiment requirements when both modules carried experiments on the same mission. (Assignment of missions and experiments to the respective Centers was to be made by the program office at Headquarters.)
- The astronauts would use tethers during all extravehicular activities except where not feasible.
- MSFC was to proceed with work on a procurement plan and a request for proposals for two or three phase C integration contractors, with the idea that one of the definition contractors would receive the final phase D development contract (though no firm commitment to this course was yet made); also, concurrently with the phase C definition effort, MSFC would conduct parallel in-house studies to better evaluate the contractors' phase C work.

Memorandum, J. H. Disher, NASA Hq, to Files, "AAP Discussions at MSFC on October 28–29, 1965," 4 November 1965.

November

1

Saturn/Apollo Applications Deputy Director John H. Disher summarized for the Director of Advanced Manned Missions those tasks of highest priority for supporting development during Fiscal Year 1966. Those tasks, Disher explained, had been examined in great detail because of stringent funding constraints for Apollo Applications during 1966 and 1967. Therefore, he had listed only those tasks mandatory for the program's "mainstream" requirements. They included such areas as low-thrust reaction control engines, structural and hatch seals, navigation computer modifications, and study of space rescue systems.

Letter, John H. Disher to Director, Advanced Manned Missions Program, "Apollo Application Program (AAP) Supporting Development," 1 November 1965.

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16 Following MSC's receipt of the technical proposal for phase C of the AAP from North American Aviation, Inc., covering final definition of the AAP CSM, William A. Lee, Assistant Manager of the Apollo Spacecraft Program Office, asked several of his staff members to assist in evaluation of the proposal. Such help, he said, would be invaluable in bringing to bear on AAP the experience that the Apollo office had obtained during the effort to develop the block II lunar version of the spacecraft. The technical proposal by North American described those tasks that the company believed were required to define the CSM configuration and to formulate hardware specifications for the development and operations phase of the program. Paralleling these efforts by the contractor, MSC had established a baseline AAP–CSM configuration and had laid down several configuration guidelines believed fundamental tenets of AAP objectives: no spacecraft modifications to achieve "product improvement" or to obtain a statistical "mission success."

Memorandum, William A. Lee to Chiefs, Systems Engineering and Reliability and Quality Assurance Divisions, "ASPO Assistance on review of North American Aviation AAP Phase C study proposal," 16 November 1965.

18 Following formal establishment of the Apollo Applications Program at NASA Hq (see 6 August 1965), Associate Administrator for Manned Space Flight George E. Mueller recommended to Administrator James E. Webb and Associate Administrator Robert C. Seamans, Jr., assignment of basic roles and responsibilities to the field centers for carrying out the program. Although such responsibilities were delineated in the traditional manner, the new program responsibility of experiment and payload integration was split between MSFC and MSC.

On 13 December, following discussions with Webb, Seamans approved Mueller's recommended assignments of experiment management and payload integration.

Memoranda, George E. Mueller to Administrator, "Recommendations for Apollo Applications Program Field Center Responsibilities," 18 November 1965; Robert C. Seamans, Jr., to Associate Administrator for Manned Spaceflight, "Apollo Applications Management," 13 December 1965.

18 John H. Disher, Saturn/Apollo Applications Deputy Director, requested the Manned Space Flight Management Operations Director to officially change the designation of the Saturn IB/Centaur Office to Saturn Applications. This change, Disher said, reflected the change in status of the office and provided for necessary management of potential Saturn Applications such as the Saturn V/Voyager by the Office of Manned Space Flight. However, on the same day, Disher ordered E. F. O'Connor at MSFC to halt all Saturn IB/Centaur efforts (except those already underway that could not be recalled) and disapproved the request for an additional $1.1 million for the program. (Any funds required for definition of a Saturn V/Voyager mission, he said, would be authorized separately.)

Memorandum, John H. Disher to Director, MSF Management Operations, "Renaming of Saturn IB/Centaur Office to Saturn Applications," 18 November 1965; TWX, John H. Disher to E. F. O'Connor, 18 November 1965.

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David M. Jones, Acting Saturn/Apollo Applications Director, solicited from the chief executives of the various companies participating in Apollo their views on proposed goals for the Apollo Applications Program. Alternative goals postulated for AAP were (1) to explore and utilize world resources for the benefit of mankind; (2) to define and develop the operational capabilities for the next generation of space vehicles beyond Apollo; (3) to broaden knowledge of near-Earth and lunar environments; (4) to enhance the security of the United States through space operations; and (5) to develop the capability for manned flights of up to one year.

Jones asked the executives to weigh the pros and cons of these alternative goals and to make a qualitative assessment of the benefits which might accrue to the American taxpayer. NASA would include these assessments in congressional hearings early in 1966.

On 16 December, MSFC Director Wernher von Braun (though not specifically called upon to do so) responded to Jones' request for ideas. Of all the alternative goals for AAP, von Braun said, that of exploring world resources for man's benefit was by far the most important. For its manned space program, he said, NASA cannot forever depend upon the thrill of adventure nor upon "sophisticated truths" such as the value of spinoff results or the blessings of more scientific knowledge. To place the idea of space flight firmly in the minds of the taxpaying public, therefore, NASA must produce solid results and material benefits that are readily visible and comprehensible. And AAP goal number one neatly combined both broad popular appeal and true humanitarian needs. In view of the world's population explosion, with all its attendant resulting effects, von Braun stated, America's failure to avail itself of the vitally needed tools for a global resources management system would be a tragic mistake. Viewed in this perspective, the other alternative goals proposed for AAP thus became elements and stepping stones within this broader long-range objective.

Memorandum, David M. Jones, NASA Hq, to Apollo Executives, "Apollo Applications Goals," 22 November 1965; letter, Wernher von Braun to David M. Jones, 16 December 1965.

29

Associate Administrator for Manned Space Flight George E. Mueller requested of MSC Director Robert R. Gilruth that his Center identify additional Apollo subsystems testing and the best method of conducting such tests on the basic subsystems of the spacecraft beyond the 14-day requirements of the Apollo lunar mission. Mueller explained that planning for the Apollo Applications Program projected that extended missions could be performed using basic Apollo hardware and that significant advantages might be realized by testing subsystems to determine their duration limits, thereby avoiding the burden of additional test units and test facilities.

Letter, George E. Mueller to Robert R. Gilruth, "Basic Apollo/Apollo Applications Spacecraft Subsystem Tests," 29 November 1965.

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In response to a telegram from Deputy Associate Administrator for Manned Space Flight James C. Elms regarding procurement plans for the AAP, MSC Deputy Director George M. Low described a plan being seriously considered by Houston that would permit competitive procurement of follow-on Apollo hardware. The plan called for awarding the phase C contract to North American to define AAP changes to the CSM and letting what Low termed "phase-in" contracts leading to proposals on how the spacecraft could be manufactured by other companies. Upon completion of both the phase C work at North American and the phase-in contracts with other firms, MSC would enter into competitive negotiations with all parties to determine which firm should build the AAP version of the CSM. (According to Low, it was premature to undertake a phase C definition effort with Grumman at this time, but he suggested that a competitive effort similar to that proposed for the CSM could be implemented somewhat later.)

Letter, George M. Low to James C. Elms, 29 November 1965.

During the Month

The Boeing Company submitted a utilization study report to MSC for the proposed multipurpose mission module. The report was one of 13 volumes prepared by Boeing's Aerospace Group–Space Division under an MSC contract.

Guidelines observed in the study were: (1) minimum interference with the Apollo program; (2) use of either Saturn IB or V launch vehicles; (3) laboratory to be sized so that the one module, two modules, or one module on a LEM descent stage could fit into an unmodified LEM adapter; (4) use of a three-man crew; (5) capability to dock to either end of the module and to rendezvous modules; and (6) mission lengths of 14 to 45 days, with growth capacity for longer durations.

The study was made on the presumption of a laboratory module launched in the LEM adapter area which would be aligned with an access hatch in the module. An expandable airlock could also be incorporated when desired. The external envelope would be 465 cm, which would permit three modules to be placed in the S–II stage that was 10 m in diameter; the floor to ceiling height would be 213 cm; the total pressurized volume of the module would be 39 cu m; and total floor area 16 sq m.

The module would be designed for an internal pressure of 48 kilonewtons per sq m (7 psia) for a 180-day mission. It would weigh 1313 kg, and its support rack would weigh 413 kg. For lower gross weights expected with Saturn IB launches, the support rack weight could be reduced to 261 kg. The multipurpose mission module, as proposed, would allow much flexibility in missions, including formation of large space stations, and would permit use of an assortment of internal and external equipment without affecting the integrity of the shell and requiring only minor structural additions or changes.

A feature of the Boeing report was the section devoted to volume. It said that ". . . after reserving the requirements for module subsystems, experiment report,

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and 5.6 cu m (200 cu ft) for each astronaut, about 16.9 cu m (600 cu ft) of pressurized and 62.2 cu m (2200 cu ft) of unpressurized volume would be available for experiment equipment. . . ." The report then listed some of the advantages of providing adequate pressurized volume:

- Volume Equals Economy: Maximum use of standard hardware; no miniaturization required; allows standard subsystem modules for varying missions; protected environment simplified equipment design.
- Volume Equals Manned Participation: Equipment accessible for direct manual operation; man's capability to participate can be evaluated.
- Volume Equals Efficiency: Minimum interference work-area layouts possible; experiment setup and tear-down time reduced or eliminated; improved crew morale increases efficiency.
- Volume Equals Reliability: Inside equipment can be adjusted and maintained by the crew; equipment is protected from temperature cycles and hard vacuum of space.
- Volume Equals Experiment Flexibility: Volume allows modular approach to experiment and subsystem design; experiment substitution requires no rearrangement of other equipment; minimized lead time for changes.
- Volume Equals Increased Experiment Capabilities: Enough room for crew movement and locomotion tests; allows volume for centrifuge or double trampoline.
- Volume Equals Safety: Eliminates extravehicular activities for normal laboratory operation.

The Boeing Co., Report D2–84010–1, *Multipurpose Mission Module—Utilization Study,* November 1965.

December

1

George E. Mueller, Associate Administrator for Manned Space Flight, and MSFC Director Wernher von Braun discussed Marshall's briefing on the S–IVB Workshop concept presented at Headquarters the previous day. Mueller asked that MSFC formulate a program development plan and present it at the next meeting of the Manned Space Flight Management Council. Specifically, Mueller demanded that the plan include experiments to be carried aboard the Workshop; funding arrangements; and where development work should be done (in house, or elsewhere). In addition, he asked that MSFC submit two such plans, one for the unpressurized and another for the pressurized version of the Workshop. In effect, Mueller gave Marshall the "green light" to begin the Orbital Workshop program.

At von Braun's request, the Workshop received the status of a separate project, with William Ferguson as Project Manager.

Memorandum, J. T. Shepherd, MSFC to Dist., "S–IVB Workshop," 1 December 1965.

2

Harold E. Gartrell, Chairman of MSC's AAP mission planning task force, distributed within the Center extracts from a contractor study report that had been

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prepared in anticipation of the request for proposals to be issued by MSFC for an AAP payload integration contract. Gartrell voiced concern over what he called a "fundamental question" of MSC's responsibility for mission definition, the requirements for spacecraft systems, mission simulations, and technical direction of flight operations (a result, he said, of the payload responsibility at MSFC's not being limited to development, test, and checkout of the AAP lunar excursion module vehicle). Gartrell stated that MSC was initiating an effort during this phase C of the AAP to define mission-spacecraft-operations requirements, thus establishing a foundation for Houston input into the payload integration function at MSFC.

Memorandum, Harold E. Gartrell to Dist., "MSC Mission Definition Programs for the Apollo Applications Program," 2 December 1965.

Mid-December

MSC designers and long-range planners put forth conceptual ideas on the next logical steps to be taken in man's exploration of space. Recognizing the enormous potential benefits to be derived from Earth resources and sensing systems—not only for the United States, but for the entire world—those planners suggested semipermanent manned stations in Earth orbit. The question of how this might be accomplished, they suggested, could be met through suitably modified AAP hardware and systems. Such a space station could be used as an observation platform, with incalculable benefits to be derived; as a scientific laboratory in space; and as an engineering laboratory for the development of systems for planetary explorations through inclusion of commodious living quarters and workshops. Just as significant for the future, the large size of the station and crew complement would afford unprecedented opportunities for international cooperation in space by inclusion of foreign scientists in the crew.

MSC, "Some Considerations of the Future of Manned Space Flight," 14 December 1965.

23

At the December Manned Space Flight Management Council meeting, Associate Administrator for Manned Space Flight George E. Mueller voiced a desire to have McDonnell examine the feasibility of using Gemini subsystems on an airlock experiment in conjunction with the Apollo Applications Program S–IVB Workshop concept. Accordingly, F. L. Williams of the Advanced Systems Office at MSFC solicited the assistance of MSC's Gemini Program Manager, Charles W. Mathews (since his office had procurement responsibility for Gemini), in getting McDonnell to conduct such an analysis. Williams stated that several designs needed investigation and that, of all Gemini hardware, the environmental control system and perhaps the fuel cells would be incorporated into the airlock design. In order to discuss technical details, he asked whether Mathews might arrange a briefing at Huntsville as soon as possible, since deadlines for presenting final experiment plans to Headquarters were most pressing.

Memorandum, F. L. Williams to Charles W. Mathews, "December 1965 OMSF Management Council Executive Session," 23 December 1965.

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29

In the initial activity report outlining MSC's support to the Air Force on the MOL, Gemini Program Manager Charles W. Mathews summarized activity to date. He cited receipt on 20 November 1965 of authority to transfer surplus Gemini equipment to the MOL project. Since that time, he said, MSC had delivered to the Air Force several boilerplate test vehicles and a variety of support and handling equipment. MOL program officials and astronauts had also visited Houston for technical discussions and briefings.

Memorandum, Mathews, MSC, to Director, "Weekly Activity Report Number 1 on NASA Manned Spacecraft Center, Support to the USAF Manned Orbiting Laboratory Program (December 13–17, 1965)," 29 December 1965.

29

Associate Administrator for Manned Space Flight George E. Mueller advised John H. Disher, Deputy Director of Saturn/Apollo Applications, that, in preparing NASA's AAP budget statement for Fiscal Year 1967 for presentation to Congress, he wanted to lessen emphasis upon AAP's value in working out operational capabilities required for the next major step in manned space flight. The congressional statement, Mueller said, should emphasize the importance of continuity in manned space flight and should explain the lead times involved in such efforts. Mueller asked Disher to prepare an analysis of total costs versus year of completion for the operationally oriented program for inclusion in the budget statement.

Memorandum, John H. Disher to J. P. Field, Jr., "Saturn/Apollo Applications Program FY 67 Budget Statement," 29 December 1965.

During the Month

The Advanced Missions Division, Manned Space Science Program, in the Office of Space Sciences and Applications, released details of experiment proposals submitted by teams of potential experimenters for the immediate post-Apollo Earth-orbital phase of manned space exploration, as part of the AES program. As well as detailed descriptions of the various scientific experiments themselves, the report examined the justification for AES in relation to other space programs, mission objectives, operational constraints, and long-range plans and goals.

Advanced Missions Division, "Preliminary Mission Definition for Post-Apollo Manned Exploration of Space, Manned Earth Orbital Missions," Part II, Revised Submissions from Potential Experimenters, December 1965.

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1

Homer E. Newell, Associate Administrator for Space Science and Applications, announced opportunities for study grants to competent astronomers for conceptual and preliminary design work leading to instrumentation to be flown in the 1969–1975 period. A description of the Apollo telescope mount was included.

Letter, Homer E. Newell to Dist., 1 January 1966.

1–6

KSC announced appointment of John P. Claybourne as Chief of the newly created Future Studies Office within the KSC Engineering and Development Direc-

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torate. Claybourne's office was assigned responsibility for overall planning and coordination of the Center's studies in this area, which would parallel continuing development of Apollo-Saturn and Apollo Applications programs at MSFC and MSC. John G. Shinkle succeeded Claybourne as Deputy Director for Plans, Programs, and Resources.

Spaceport News, Vol. 5, 6 January 1966, pp. 2–3.

6

In a letter to the Associate Administrators for Manned Space Flight, Space Science and Applications, and Advanced Research and Technology, NASA Deputy Administrator Robert C. Seamans, Jr., queried them on several alternate approaches for experiment payload planning for AAP. His inquiry was prompted by discussions with several individuals from RCA, who suggested a novel approach for NASA to interest the scientific community in NASA's programs through direct participation in the development of scientific equipment. A central problem was the difficulty inherent in incorporating science payloads into such a complex program as AAP, especially in meeting well defined schedules. Because most teams of university-based scientists were not sufficiently experienced in fabrication and testing to assume this "cradle-to-grave" responsibility for experiment development, the RCA spokesmen put forward the concept of mission-optimized space laboratories wherein actual payload integration planning would occur very early in the hardware planning stage, before any actual development was undertaken. In this manner, logical broad-purpose groupings of laboratory equipment would appear. Such an approach, they contended, would afford significant payload weight and volume reductions and cost benefits. Also, standardization of equipment and sensors would simplify greatly the integration task per se.

Mueller replied to Seamans on 12 April. He compared RCA's suggested approach—broad-purpose laboratories that could be adapted to individual missions by addition of special sensors—to NASA's present method of experiment planning and development; i.e., Principal Investigators who were individually responsible for all aspects of experiment development, including sensors. The present NASA approach, Mueller contended, generated a technical continuity by competent scientists and engineers, thus paying off in "good" science returns from flight missions. He admitted, however, that the Principal Investigators approach demanded the commitment of scientists to their projects over quite lengthy periods of time. The approach therefore tended to limit the number of experiment proposals received (a trend already encountered in the medical and behavioral fields, Mueller noted). In fact, most experiment proposals in these areas came from "in-house" sources, while only a few were received from the scientific community. Further, the Principal Investigators approach tended toward duplication of in-flight operations and equipment. Mueller admitted that the RCA full-laboratory concept had some merit, especially in producing the maximum number of experiments per mission and in fostering early experiment program planning. However, it tended to remove scientists and engineers from the mainstream of experiment development, which could result in loss of continuity over long developmental periods.

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Mueller put forth a third approach that lay between NASA's present program and the RCA proposal. It was similar to the RCA scheme except that NASA could accept experiments on an individual basis as presently done. The Principal Investigator, while fully responsible for experiment procedure and for data analysis and publication, would also serve as consultant to NASA during development of experiment equipment and crew training. But the NASA experiment payload integration center would oversee the effort to integrate experiments into the configured inflight laboratory. Mueller observed that NASA was in fact moving toward this middle road in the manned space flight program. The medical and behavioral experiments were already being planned for configuration into space laboratories, he noted. Nor were the three approaches mutually exclusive. Through "judicious" integration of experiments and mission objectives, Mueller prophesied that NASA could evolve from its current approach to the full-laboratory concept in harmony with the agency's space flight capabilities.

Memoranda, Robert C. Seamans, Jr., to Associate Administrators, "Alternative Approach to Experiment Payload Planning on Apollo Applications Program," 6 January 1966, with attachment, [RCA,] "An Alternative Approach to Experiment Payload Planning on Apollo Applications Program"; George E. Mueller to Deputy Administrator, "Alternative Approaches to Experiment Payload Planning on Apollo Applications Program," 12 April 1966.

14

MSFC issued requests for proposals to the aerospace industry for definition studies of integrating experiment hardware into AAP space vehicles—i.e., payload integration in the Apollo lunar module, the Saturn instrument unit, and the S–IVB stage of the Saturn IB and Saturn V launch vehicles. Following evaluation of the proposals, MSFC would select two or more firms for negotiation of nine-month study contracts to be managed by Huntsville as the Center responsible for payload integration of this portion of AAP. (MSC was responsible for payload integration of the Apollo CSM.)

NASA News Release 66–14, "Definition Studies Sought for Apollo Applications Missions," 14 January 1966.

14

In a note to Apollo Director Samuel C. Phillips, Staff Assistant Leonard Reiffel pointed to a number of weaknesses in the organizational structure of the Manned Space Flight Experiments Board and suggested several ways in which the Board might be made less cumbersome and more effective. Reiffel suggested beefing up the board's influence in decisionmaking on experiments; improving the quality of briefings and technical support to the board; and improving communications and coordination between the board and the NASA program offices, as well as the Department of Defense. (See entry 21 March 1966.)

Memorandum, Leonard Reiffel to Samuel C. Phillips, "Comments on Functions and Operation of the MSFEB," 14 January 1966.

16

The Space Science Board of the National Academy of Sciences issued a report outlining research objectives in lunar and planetary exploration for the 1970s and

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early 1980s. (The report, first of a series entitled *Space Research: Directions for the Future*, had been prepared by a group of scientists and engineers led by Gordon J. F. MacDonald of the University of California, Los Angeles.) The report affirmed earlier recommendations by the Space Science Board to NASA that unmanned exploration of Mars should have first priority in the post-Apollo space era. Secondary importance was assigned to detailed investigation of the lunar surface and to unmanned Venus probes. Clearly, the report reflected a predominant mood within the scientific community that scientific research in space take predominance over manned programs whose chief objectives, said the report, were "other than scientific."

National Academy of Sciences news release, "Space Scientists Recommend Post-Apollo Research Goals," 16 January 1966.

27

For planning information and as a challenge to the space agency, Senator Clinton P. Anderson, Chairman of the Committee on Aeronautical and Space Sciences, outlined his views and those of other members of the Committee regarding NASA's space goals in the post-Apollo period. In a letter to Administrator James E. Webb, Anderson conceded the significant national import of space exploration and research, particularly as it strengthened the nation's scientific and technical competence and contributed to America's position of world leadership. Although new space projects inevitably hinged on the results of existing programs, he told Webb, NASA must be prepared to move on to other programs without interruption once the Apollo program was completed. While the exploitation of Apollo hardware in AAP had real validity, "NASA should not continue such exploitation so long into the future that it prevents the development of new systems."

Letter, Clinton P. Anderson to James E. Webb, 27 January 1966.

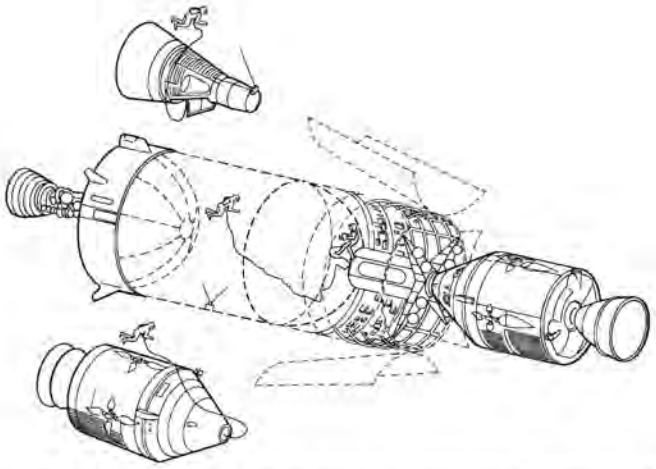
27

Jesse L. Mitchell, Acting Director of Physics and Astronomy Programs, solicited proposals from MSFC, MSC, LaRC, and Goddard Space Flight Center regarding the creation at their Centers of a project office for the Apollo telescope mount. (Mitchell's action followed visits by several staff members from his office to each of the candidate locations during which stress was placed on a "sound and efficient, yet, imaginative project management team . . . in view of the short development time available to meet the expected launch opportunities.") Mitchell called for statements that included technical and management plans, procurement arrangements, schedules, and resource requirements.

TWX, Jesse L. Mitchell to MSFC, LaRC, Goddard Space Flight Center, and MSC, 27 January 1966.

28

In a letter to MSC Director Robert R. Gilruth, George E. Mueller, Associate Administrator for Manned Space Flight, summarized his views of specific AAP objectives within the broader context of future manned space flight and national space goals. AAP, Mueller stated, would provide a foundation for the next



This concept, indicating extravehicular activity accommodations for either the Gemini spacecraft or Apollo command and service modules, was submitted to NASA in January 1966 by Douglas Aircraft Company, Inc. It was part of a report on the orbital S–IVB spent-stage experiment support module feasibility study.

major American space effort. Specifically, AAP would provide the experience of extended lunar explorations and long-duration manned operations in Earth orbit through resupply and in-orbit assembly. These objectives he saw as "logical extensions of the planned Gemini and Apollo accomplishments" that would contribute significantly to the broader goals of United States preeminence in space and of using space for the benefit of mankind. Mueller foresaw that AAP could be shaped to achieve a number of benefits and applications:

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- Improved weather forecasting with attendant benefits for agriculture and industry
- Improved communications satellites through periodic manned maintenance
- Improved Earth resources remote sensing and management
- Solution of air pollution problems
- Establishment of astronomical observatories in space and on the Moon to explore fundamental questions of the origins on the solar system and of life on Earth
- Research in the hard vacuum of space on specific materials technology and processes

And, finally, Mueller prophesied that AAP could support the international posture of the United States through advances in science and technology and would strengthen America's national security.

Letter, George E. Mueller to Robert R. Gilruth, 28 January 1966.

During the Month

Douglas Aircraft Company submitted a summary report to LaRC covering the activities of three phases of the MORL study. General objectives of the MORL

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study were to (1) establish the feasibility of a manned research laboratory; (2) determine the required level of technical, logistic, and economic support; and (3) define a realistic space station program responsive to the needs of NASA and other government agencies in particular and the scientific community in general.

The three phases of the study were

- Phase I (June–September 1963)—System Comparison and Selection Study of a MORL
- Phase IIa (December 1963–November 1964)—Optimization of the MORL System Concept
- Phase IIb (December 1964–February 1966)—Development of the MORL System Utilization Potential.

The feasibility of launching, operating, and maintaining a manned research laboratory was demonstrated in the Phase I study, and NASA selected one of the concepts investigated for further study.

During the Phase IIa effort, the MORL concept was optimized to satisfy the requirements of a single, low-altitude, low-inclination orbital mission. This part of the study resulted in definition of an MORL concept that became the "baseline" system for the Phase IIb study. The major system elements of the baseline included: (1) a 660-cm-diameter laboratory launched by the Saturn IB into a 370-km orbit inclined at 28.72 degrees to the equator; (2) a Saturn IB-launched Apollo logistics vehicle, consisting of a modified Apollo command module, a service pack for rendezvous and reentry propulsion, and a multimission module for cargo, experiments, laboratory facility modification, or a spacecraft excursion propulsion system; and (3) supporting ground systems.

The prime objective of the MORL Phase IIb study was to examine the utilization of the MORL system concept for accomplishing an expanded spectrum of space-related objectives typifying research programs of the 1970s. During this phase, Douglas was associated with several subcontractors whose areas of effort were as follows: Eclipse-Pioneer Division of Bendix, stabilization and control; Federal Systems Division of IBM, communications, data management, and ground support systems; Hamilton Standard Division of the United Aircraft Corporation, environmental control/life support; Stanford Research Institute, priority analysis of space-related objectives; Bissett-Berman, oceanography; Marine Advisors, oceanography; Aero Services, cartography and photogrammetry; Marquardt, propulsion; and TRW, propulsion.

A thorough review of the MORL system was conducted to identify potentially critical research and technology requirements. These requirements were contained in the NASA-defined research and technology categories:

- Research—An activity directed toward an increase in basic scientific or engineering knowledge.

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• Advance Technology—Those activities required to advance the state of the art in the field of methods and techniques through the application of science and engineering.

• Advance Development—The activity of developing subsystems or components recognized to have long development lead times.

• Supporting Development—Those activities leading to the development of backup or alternate systems, subsystems, components, and fabrication or testing techniques.

The activities were further divided into the following technological categories. (1) Astronautics dealt with the problems of space flight, including aerothermodynamics, flight mechanics, vehicle dynamics, and navigation, as well as design criteria of a general nature. (2) Biotechnology considered the relationship of man to the vehicle, the environment, and the mission, including the environmental control and life support subsystem, crew environment criteria, crew systems, and crew training. (3) Flight Technology included communications, telemetry, and data processing subsystems. (4) Control Systems consisted of the technologies associated with direction and orientation of the laboratory such as guidance, stabilization and control, and reaction control. (5) Structures dealt with items pertaining to the mechanical design of the spacecraft, including materials technology, mechanical systems, and manufacturing and assembly techniques. (6) Power included the production, conditioning, and distribution of electrical power.

The summary listed a number of tasks that had been identified within the aforementioned 10 categories, including some considered as applicable for the Apollo Applications Program. (For a list of these tasks, see Appendix 7.) Analysis of development problems in the program suggested that the critical functional subsystems were stabilization and control, environmental control and life support, and electric power.

Douglas Aircraft Co., Summary Report SM-48822, *Report on the Development of The Manned Orbital Research Laboratory (MORL) System Utilization Potential,* January 1966.

February

11

MSFC submitted its response to the call from Headquarters for project management proposals for the Apollo telescope mount (ATM). The plan summarized Marshall's developmental work on ATM-type systems so far and contained specific technical and managerial concepts for implementing the ATM project. Of all its inherent strengths and capabilities, the Center emphasized the talents concentrated in the Research Projects Laboratory under Ernst Stuhlinger, the scientific arm of the Center.

MSFC, "Apollo Telescope Mount Project Proposal," 11 February 1966.

17

Edgar M. Cortright, Deputy Associate Administrator for Space Science and Applications, testifying before the House Committee on Science and Astronautics' Subcommittee on Space Science and Applications, stressed selectivity in planning

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the space science program: "We have been looking at Apollo applications for some time to identify those areas of scientific activity where the man can be a real asset to the experiment, and the areas that interest us most are astronomy; natural resources, which is looking down at the earth with various detectors; biology, which is concerned with long-duration weightless flight, from both a fundamental biological point of view and in preparation for longer flights; and of course continued lunar exploration."

U.S. Congress, House, Subcommittee on Space Science and Applications of the Committee on Science and Astronautics, *1967 NASA Authorization: Hearings on H.R. 12718 (Superseded by H.R. 14324)*, 89th Cong., 2d sess., 1966, pp. 57–59.

18

Testifying before the House Committee on Science and Astronautics Subcommittee on Manned Space Flight, Deputy Administrator Robert C. Seamans, Jr., described three basic elements in NASA's AAP effort:

- Extension of orbital staytimes to 45 days or more through minor modifications to the present Apollo system.
- Procurement of additional spacecraft and launch vehicles for follow-on flights beyond the present Apollo schedule.
- Utilization of Apollo vehicles during the 1968–1970 time frame if the agency's most optimistic Apollo schedules were realized.

"We cannot today look toward a permanent manned space station, or a lunar base, or projects for manned planetary exploration," Seamans stated, "until our operational, scientific and technological experience with major manned systems already in hand has further matured."

Ibid., pp. 5–6.

25

Maurice J. Raffensperger, Director of Manned Earth Orbital Mission Studies at NASA Hq, summarized the outcome of discussions and agreements between Washington and the Centers regarding the S–IVB Workshop project:

- MSFC had overall responsibility for the Workshop system design and integration, with a design objective of a 30-day flight capability.
- The Gemini office at MSC had contractual and design responsibility for the airlock module, using basic Gemini components where feasible. (It was anticipated that McDonnell Aircraft Corporation would be the logical contractor.) Also, MSC would manage the CSM portion of the Workshop concept.
- MSFC was responsible for implementing the S–IVB Workshop experiment program and integrating experiments into the Workshop.

Raffensperger called for compilation of a Workshop planning document (something like a short version of a preliminary project development plan) so that NASA Hq could proceed with steps for authorization and definitive implementation of the project.

TWX, Raffensperger to MSFC and MSC, "Saturn S–IVB Workshop Experiment," 25 February 1966.

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In an informal note on AAP planning to James C. Elms, Deputy Associate Administrator for Manned Space Flight, AAP Deputy Director John H. Disher suggested a number of operational objectives that he believed should be essential elements within the program: manned operations in synchronous and high-inclination Earth orbit; manned orbital assembly and resupply; crew transfer in orbit; extended Earth-orbit mission duration capability; extended lunar exploration; and conduct of a broad range of operational, scientific, and technological experiments in space.

1

Memorandum, John H. Disher to James C. Elms, 1 March 1966.

Associate Administrator for Manned Space Flight George E. Mueller acknowledged receipt from Joseph F. Shea, the Apollo Spacecraft Program Manager at MSC, of a detailed technical description of MSC's plans and development progress toward developing a landing rocket system for Apollo. (MSC had undertaken this effort some months earlier at Mueller's specific request.) Mueller advised Shea that he had asked AAP Deputy Director John H. Disher to work closely with Shea's people to devise a land landing system for AAP built on Houston's effort for Apollo.

3

Letters, George E. Mueller to Joseph F. Shea, 3 March 1966; Joseph F. Shea to George E. Mueller, [late January or early February 1966].

A team of engineers from Douglas Aircraft Company, headed by Jack Bromberg, presented a technical briefing and cost proposal to Associate Administrator for Manned Space Flight George E. Mueller on the company's design on the airlock for the AAP. Mueller observed that Douglas' idea for a 30-day capability seemed technically sound. He expressed strong interest in the AAP spent-stage experiment because it would establish a solid basis for space station requirements and definition. However, he cautioned that he had not received definite approval from either the Administrator, James E. Webb, or his deputy, Robert C. Seamans, Jr., on the spent-stage concept and admitted that he had "some selling to do."

9

Memorandum for record, H. E. Pitcher, Douglas, "Airlock Presentation to Geo. Mueller," 11 March 1966.

MSC planners drew up and submitted to NASA Hq the Center's procurement plan for an S–IVB Workshop experiment support module. The components of such an experiment comprised an Apollo CSM, an S–IVB stage, and a support module interconnect, which MSC proposed to award to McDonnell for development. MSC Director Robert R. Gilruth urged speedy action on the proposal and by the contractor because of the necessity for early definition of hardware interfaces, as well as impending phaseout of the Gemini and subcontractor efforts.

11

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Letter, Robert R. Gilruth to S. A. Cariski, "Procurement Plan, S-IVB Workshop Experiment Support Module," 11 March 1966.

March

11

At Headquarters, the directors of the program offices presented to Deputy Administrator Robert C. Seamans, Jr., and members of the Administrator's top staff a joint briefing and summary of NASA's total agencywide AAP effort. In reviewing their presentation, Seamans emphasized three cardinal tenets regarding AAP planning:

(1) The Apollo lunar landing remained the top priority and must not be compromised by any AAP activity.

(2) All changes to any Apollo hardware for AAP missions had to be approved personally by either the Administrator or Seamans. Consequently, all mission planning had to be precise and definite and would be referred to Webb or Seamans for action or approval. All procurement actions would be handled in the same fashion.

(3) The directors were to devise "a clear and defensible rationale" for AAP missions.

Seamans reported to Administrator James E. Webb the basic findings of the 11 March review:

- Largely because of limited resources, the pacing item in AAP was selection and development of experiments and packages to meet the earliest possible flight dates. (Although many possible experiments were being studied, only two minor AAP experiments so far had actually been committed to development. Also, some alternatives, such as use of Gemini and Apollo experiments and in-house development of experiment packages, had been examined with an eye toward early experiment availability.)
- Three leading candidates existed for alternate AAP missions: (1) an extensive lunar mapping program (beyond the needs of Apollo); (2) adaptation of lunar mapping equipment for Earth survey (though "serious interagency problems" had to be resolved before such a mission could be planned in detail); and (3) the ATM which, because of its scientific value and compatibility with the basic Apollo system, had received top priority for definition and development by the Office of Space Science and Applications (however, serious fiscal problems remained in light of the ATM's estimated total cost of about $69 million).

Memorandum, Robert C. Seamans, Jr., to Dist., "Apollo Applications Program," 30 March 1966.

12

MSC submitted to NASA Hq for approval the procurement plan for a multimission fuel cell assembly for the Apollo spacecraft. Such an advanced electrical power plant was necessary, explained Center Director Robert R. Gilruth, in order to support long-duration missions. The Center proposed to negotiate with three known fuel cell contractors, General Electric Company, Pratt and Whitney Division of United Aircraft Corporation, and Allis-Chalmers Manufacturing

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Company, for the effort. Four days later, Gilruth wrote Associate Administrator for Manned Space Flight George E. Mueller setting forth in detail MSC's plans for fuel cell development and production, including the recent decision to furnish the fuel cells to AAP contractors as government furnished equipment.

Letters, Robert R. Gilruth to S. A. Cariski, NASA Hq, "Procurement Plan, NASA Multimission Fuel Cell Assembly (FCA)," 12 March 1966; Robert R. Gilruth to George E. Mueller, 16 March 1966.

14

Saturn/Apollo Applications Deputy Director John H. Disher requested that his staff study payload capabilities of the Saturn IB to place AAP spacecraft and modules into low-altitude orbits of various inclinations. This part of the AAP definition effort, Disher said, would be used for evaluating the operational trade-offs in the general goal of achieving a high-inclination orbit operational capability in AAP.

Letter, John H. Disher to G. M. Anderson, NASA Hq, "High-Inclination Orbit Performance Studies for SAA," 14 March 1966.

17

Homer E. Newell, Associate Administrator for Space Science and Applications, asked for approval of the ATM project from Deputy Administrator Robert C. Seamans, Jr. The ATM, Newell explained, was based on an engineering and definition study effort completed 1 April by Ball Brothers Research Corporation, as well as evaluation of the concept by four NASA Field Centers—LaRC, Goddard Space Flight Center (GSFC), MSFC, and MSC.

The Ball Brothers Research Corporation study had been let in September 1965, said Newell, to determine means of providing an accurate pointing capability for high-resolution solar-oriented telescopes aboard an Apollo spacecraft. Further impetus to ATM had come from the agency's cancellation of the Advanced Orbiting Solar Observatory at the end of 1965. The ATM, he said, provided the means to obtain high-resolution data about the Sun during periods of maximum solar activity and served as a basis for evaluating ability to operate as an essential element within a complete manned space science system.

The need for quick project approval and hardware development had been recognized by all participating parties, Newell explained, and Goddard Space Flight Center, MSFC, and MSC had all expressed "deep interest and desire" to manage the project. However, after review within his office, he had decided to select Goddard as the most suitable location for development of the ATM. Accordingly, he asked Seamans to approve the project development plan.

Letter, Homer E. Newell to Deputy Administrator, "Establishment of the Apollo Telescope Mount (ATM) Project," 17 March 1966, with enclosure, "ATM Project Approval Document" [n.d.].

18

Gemini Program Manager Charles W. Mathews urged upon Edward Z. Gray, Director of Advanced Manned Missions, the necessity of proceeding immediately

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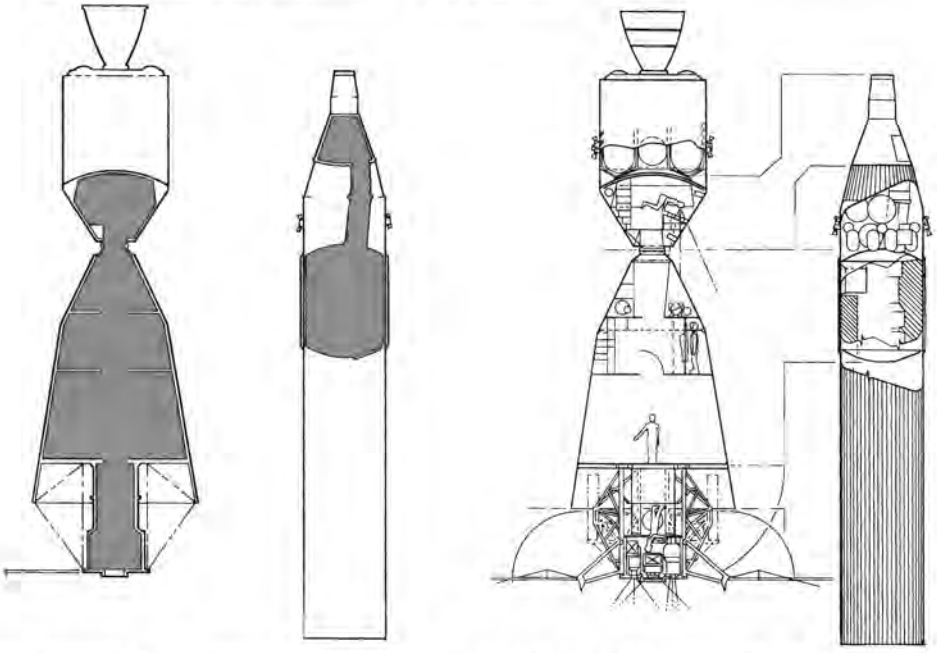
with certain phases of the S–IVB spent-stage experiment effort, particularly the McDonnell procurement for the spent-stage experiment support module and the North American study of modifications to the CSM. The situation at McDonnell was especially acute, said Mathews, because of impending phaseout of the Gemini program; also, certain information on the CSM was needed to define the efforts of both contractors on interfacing and spacecraft modifications. In view of these factors, Mathews asked Gray for approval to proceed with the definition and study efforts.

Memorandum, Charles W. Mathews to Edward Z. Gray, "Need for decision to proceed on S–IVB Spent-Stage Experiment," 18 March 1966.



The figures above present two comparisons of the total amount of space available for crewmen to work in the Apollo/SLA Workshop (to the left in each illustration) and the Air Force Manned Orbiting Laboratory. The MOL space could be expanded downward, using more of the empty propellant tank space in the launch vehicle.

21

A report by the Military Operations Subcommittee of the House Committee on Government Operations recommended combining NASA's Apollo Applications Program with the Air Force's Manned Orbiting Laboratory. "Inasmuch as both programs are still research and development projects without definitive operational missions," stated the Committee's report, "there is reason to expect that with earnest efforts both agencies could get together on a joint program incorporating both unique and similar experiments of each agency."

U.S. Congress, House, *Missile and Space Ground Support Operations: Twenty-third Report by the Committee on Government Operations,* 89th Cong., 2d sess., 21 March 1966, H. Rept. 1340, p. 46.

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21

By an agreement NASA and DOD created the Manned Space Flight Experiments Board as a means of coordinating experiment programs on NASA and DOD space flights. The MSFEB, headed by the NASA Associate Administrator for Manned Space Flight, had responsibility for recommending approval or disapproval of candidate experiments; assigning experiments to specific flight programs; recommending relative priorities to experiments to be implemented; and reviewing the status of approved experiments.

NASA Management Instruction NMI 1154.4A, "Manned Space Flight Experiments Board," 21 March 1966.

23

NASA released the first AAP schedule. It envisioned 26 Saturn IB and 19 Saturn V AAP launches. Among these would be three "S–IVB/Spent-Stage Experiment Support Modules" (i.e., "wet" Workshops), three Saturn V–boosted orbital laboratories, and four Apollo telescope mounts. The initial AAP launch was slated for April 1968. The schedule was predicated upon noninterference with the basic Apollo lunar landing program, minimum modifications to basic Apollo hardware, and compatibility with existing Apollo launch vehicles.

Apollo Applications Program Schedule ML–4, NASA Hq, 23 March 1966.

24

MSFC Director Wernher von Braun appointed Leland F. Belew as Manager of the MSFC Saturn/Apollo Applications Program Office and Stanley M. Reinartz as Deputy Manager. Establishment of the Saturn/AAP Office at MSFC was officially approved by the NASA Administrator on 27 June.

Letter, G. E. Mueller, NASA Hq, to Wernher von Braun, 1 July 1966.

25

In a lengthy letter to Associate Administrator for Manned Space Flight George E. Mueller, MSC Director Robert R. Gilruth expressed misgivings concerning certain aspects of AAP planning. Gilruth questioned whether the existing AAP represented the best approach to the future of manned space flight. Regarding AAP per se, he noted the desirability of continued use of Apollo hardware and facilities. Gilruth's areas of concern were the lack of a definite goal for the future of manned space flight; programming around a launch rate exceeding that for Apollo; and the use of Apollo hardware for purposes significantly different from the originally intended use, thus forcing unsound engineering changes. Also, the MSC Director expressed his concern over the many changes in AAP plans (caused largely by the steadily contracting AAP budget), which, he said, "have caused diversion of management attention and effort . . . from the mainline programs." Gilruth then mapped out what he believed presented a more realistic AAP structure and direction, emphasizing foremost the use of Apollo hardware with only minimal modifications (especially for the two Apollo spacecraft), and called for early definition of the next manned space flight program. Finally, he pointed again to what he believed was a mismatch between present AAP planning, the various opportunities for manned space flight, and resources available for the program.

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As presently structured, Gilruth stated, AAP would merely maintain the rate of production and flights of Apollo. "Merely doing this," he concluded, "without planning for a new major program, and without significant research and development as part of AAP, will not maintain the momentum we have achieved in the manned spaceflight program." (See 15 April 1966.)

Letter, Robert R. Gilruth to George E. Mueller, 25 March 1966.

April
5

Acting upon authority granted by Headquarters and approval of MSC's statement of work, Kenneth S. Kleinknecht, MSC Gemini Program Deputy Manager, informed officials in Washington and Huntsville that Houston had presented requests for proposals to Douglas, Grumman, and McDonnell to undertake definition studies on the Saturn S–IVB spent-stage experiment support module (SSESM). Study contracts were issued 18 April. The contractors were ordered to submit definitive statements of work within 60 days proposing a fixed price for one module (with an option for three additional modules). Under these initial study contracts, spacecraft hardware already flight-qualified would be used wherever practicable.

Letter, R. R. Gilruth, MSC, to G. E. Mueller, NASA Hq, "Saturn IVB spent stage experiment support module," 1 April 1966.

9

In response to a request from Deputy Administrator Robert C. Seamans, Jr., Saturn/Apollo Applications Deputy Director John H. Disher asked Jerry McCall, MSFC Deputy Director for Research and Development Operations, to prepare cost and schedule estimates for MSFC to integrate the ATM with the LEM. This request stemmed from a desire by the Office of Space Science and Applications (OSSA) to acquire ATM experiment data during upcoming periods of maximum solar activity. Disher listed guidelines for the MSFC estimates:

- OSSA-desired flight dates were April 1968, February 1969, and February 1970.
- Goddard Space Flight Center would be responsible for development of experiments aboard the ATM, as well as for the mounting structure and thermal provisions.
- MSFC would be responsible for development of modification kits to convert an Apollo lunar-landing-configured LEM to an AAP laboratory configuration (including provisions for reuse after three to six months storage in orbit); for development of interface modification kits needed to integrate the ATM and its experiments with the AAP LEM laboratory; and for installation of the modification kits and the ATM system in the LEM at KSC prior to checkout and launch.

In addition, Disher told McCall that MSFC should examine two approaches to ATM–LEM integration: (1) gimbal mounted and (2) hard mounted with provisions for momentum transfer for fine pointing control.

Letter, John H. Disher to Jerry McCall, 9 April 1966.

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13

MSC awarded a cost-plus-fixed-fee contract to the Allis-Chalmers Manufacturing Company to develop and test several fuel cell systems for possible use on AAP spacecraft. Allis-Chalmers completed the project at the end of September 1966, but MSC issued a request for proposal for continuing the research effort to adapt the fuel cell to changing AAP requirements.

Memorandum, D. W. Lang, MSC, to W. L. Hjornevik, MSC, 6 December 1966.

14

At a news conference in Colorado, NASA Administrator James E. Webb stated that the AAP would be hampered by a lack of payloads unless Congress granted additional funds in the Fiscal Year 1968 budget. Efforts to obtain appropriations for post-Apollo projects were hindered by rising costs of the Vietnamese conflict and congressional discontent with NASA's increasing administrative costs. Asked about the House Government Operations Committee's suggestion that NASA abandon AAP and participate in the Air Force's Manned Orbiting Laboratory program, Webb denied that "complete common use" of facilities was possible. He noted that many countries in which the United States had tracking facilities would not cooperate if those installations were used for military projects.

Denver Post, 15 April 1966.

15

MSC Director Robert R. Gilruth summarized Houston's position expressed during discussions with Associate Administrator for Manned Space Flight George E. Mueller two days earlier. Gilruth cited NASA's need for a manned space flight goal other than "using Apollo hardware" (and suggested a Mars flyby or landing mission as an in-house focus for planning.) Also, he repeated his concern over the imbalance between AAP goals and resources, as well as the extent of engineering redesign and hardware modification that had been forced upon the project. Though expressing his and MSC's desire to contribute to and be a part of AAP, Gilruth voiced concern that "the future of manned space flight . . . is in jeopardy because we do not have firm goals, and because the present approach appears to us to be technically unsound."

Letter, Robert R. Gilruth to George E. Mueller, 15 April 1966.

15

Associate Administrator for Manned Space Flight George E. Mueller informed Deputy Administrator Robert C. Seamans, Jr., of the Saturn/Apollo Applications Program Office's evaluation of a Lockheed proposal to launch space probes from orbit using Agena rockets launched from AAP stations in space. The proposal was feasible, Mueller advised, but did not seem a desirable mission for inclusion in the AAP. Lockheed's proposal estimated a 1800-kg payload to Mars, a performance capability not sufficient to justify the proposal solely on a mission basis. (In contrast, the Satura IB–Centaur offered a 4500-kg capability.) The other aspect of Lockheed's proposal concerned the development of techniques for launching vehicles from orbit. In this area, the chief contributions anticipated from AAP were assembly of large vehicles in orbit, fuel transfer, and preparation

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officials and representatives of the three manned spacecraft Centers. The more fundamental programmatic and design decisions included the concept of a "dependent" spent-stage experiment support module (SSESM) and S–IVB Workshop (i.e., fuel cells in the CSM would support the entire vehicle); a process by which expendables in the SSESM would be fed to the CSM via external umbilicals; and development of extended-duration fuel cell assemblies for long-duration synchronous and lunar orbit AAP missions. Also, Mueller reaffirmed an early 1968 schedule for availability of the first SSESM; that the first flight article would be a simple structure with no "follow-on goodies" (such as dual docking capabilities); an unmanned SSESM launch; CSM–SSESM orbital stay times of 14 days, with the capability to extend the flights to 28-day missions; and that the current SSESM definition studies at MSC must produce design specifications adequate for a fixed-price phase II contract to build the first flight article.

Memorandum for record, W. B. Taylor, "SAA Review with Dr. Mueller, May 18, 1966," 20 May 1966.

20

Associate Administrator for Manned Space Flight George E. Mueller officially named Kenneth S. Kleinknecht, Gemini Program Deputy Manager at MSC, to head the Source Evaluation Board (SEB) for the S–IVB spent-stage experiment support module (SSESM). Mueller personally charged Kleinknecht with undertaking this task, since the SEB had been created before formal approval of either the project or the procurement plans. Under these circumstances, Mueller cautioned Kleinknecht and the Board to avoid any commitment that NASA would pursue the phase II part of the effort or even that one of the phase I contractors would be selected if and when the project were approved. Also, Mueller reminded him of the compressed schedule requirements and limited resources immediately available for the SSESM project. Thus, said Mueller, emphasis should be placed upon costing and firm schedule commitments on the part of the contractor. The SSESM technical concept and design must be adequate to meet mission requirements, but no cost or schedule penalties should be accepted for "unnecessary design refinements."

Letter, George E. Mueller to Kenneth S. Kleinknecht, 20 May 1966, with enclosure, letter, George E. Mueller to Director, MSC, "Source Evaluation for an S–IVB Spent Stage Experiment Support Module (SSESM)," 20 May 1966.

20–21

Representatives of the Air Force and NASA met at Brooks AFB, Texas, to exchange information on medical experiments planned for the Air Force's MOL project and NASA's AAP. Stanley White, who headed the USAF group of aerospace medical experts, expressed strong interest in exploiting NASA's AAP project to study the effects of long-duration space flight on human life processes. White stated the Air Force's desire that MOL thus be relieved of this experiment burden so program planners could direct the program more closely toward evaluating man's utility for military space operations. The meeting furnished the basis for closer ties between the two organizations on their biomedical activities, observed NASA's Acting Director of Space Medicine, Jack Bollerud.

Letter, Jack Bollerud to Dist., "USAF (MOL)/NASA Biomedical Experiment Discussion," 1 August 1966, with enclosure, memorandum for record, "USAF (MOL)/NASA Biomedical Experiment Discussions, 20–21 May 1966," 16 June 1966.

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1

L. W. Vogel, Executive Secretary to the Administrator, notified Associate Administrator for Manned Space Flight George E. Mueller that Administrator James E. Webb and Deputy Administrator Robert C. Seamans, Jr., had selected Martin and Lockheed to perform the final definition studies (phase C) for the payload integration aspect of the Apollo Applications Program. (These selections were based upon presentation by the Source Evaluation Board and comments of senior project officials involved.) The fixed-price contracts, expected to be worth about $1.2 million, each, were to run for one year.

Letter, L. W. Vogel to Associate Administrator for Manned Space Flight, "Selection of Contractors to Accomplish Apollo Applications Program Payload Integration Definition," 1 June 1966.

Week Ending June 2

The newly created Source Evaluation Board for the SSESM held its first meeting, and members made tours of the three study contractors' plants. All three study contractors had completed preliminary design work and were currently examining design details critical to weight and costs. Program officials already had impressed upon the three firms the crucial importance of low cost. Further, they had been told to concentrate on the SSESM configuration and were requested to study use of cryogenics in the SSESM for reactivation of the SSESM/S–IVB Workshop during subsequent flights.

Memorandum, John H. Disher, NASA Hq, to Associate Administrator for Manned Space Flight, "SAA Weekly Status Report for Week Ending, Noon, June 2, 1966," 7 June 1966.

9

George M. Low advised Headquarters that MSC was reducing its funding request for Fiscal Year 1967 in support of research on a land-landing capability for the AAP. Specifically, this program reduction involved halting all work dealing with braking rockets and attenuation systems and concentrating all effort on prototype development of several types of lifting parachute and parawing designs. These program changes were mandatory, Low stated, because of limited AAP development funds and because a land-landing capability was still not a firm objective (even though MSC had previously presented such a program leading to a land-landing capability for AAP by the end of 1969).

Letter, George M. Low, MSC, to NASA Hq, Attn: John H. Disher, "Revision of 1966–67 funding request for AAP landing program," 9 June 1966.

9

George M. Low, in a letter to Associate Administrator for Manned Space Flight George E. Mueller, proposed a general test plan for evaluation of Apollo vehicles and subsystems to cover the requirements of AAP. Subsequently, the Engineering and Development Directorate at Houston drew up specific test plans covering individual items in the general plan. On 18 July, Low submitted to AAP Deputy

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Director John H. Disher for approval the first of these specific AAP test plans, covering extension of the Apollo Block II fuel cell from 400 to 1000 hours. Disher approved the plan several days later, and MSC officials began working out contractual details with the fuel cell contractor, Pratt and Whitney.

Letters, George M. Low, MSC, to NASA Hq, Attn: John H. Disher, "AAP Test Program—Block II Fuel Cell Test Plan Approval," 18 July 1966, with enclosure, letter, J. G. Thibodaux, Jr., to Director of Engineering and Development, "Combined Apollo/AAP testing—plans for implementation," 30 June 1966; John H. Disher to George M. Low, "Extended Block II Fuel Cell Testing for AAP," 21 July 1966.

9

Robert R. Gilruth advised George E. Mueller of Houston's work to define testing requirements on basic Apollo vehicles and subsystems to cover requirements for the AAP. (Mueller had requested such a study by MSC at the end of November 1965.) Objectives of the MSC study, said Gilruth, were to (1) specify a test program for defining the limitations of Apollo hardware for AAP missions; (2) explore the feasibility of combining Apollo and AAP testing to reduce costs and eliminate duplication; and (3) minimize impact on Apollo per se. Houston's study drew upon support of AAP groups at both North American and Grumman, and results of their work were screened by appropriate elements within MSC's Engineering and Development Directorate. Only a small number of tests would be required to assure extension of the command and service modules' capabilities to fulfill AAP's 45-day goal, Gilruth reported. Also, although some hardware problems existed, these appeared to be not solely AAP-related, but Apollo-related as well. And, although some testing objectives already were evident, most had to await better definition of mission objectives, as well as configuration of the overall vehicle (especially for the lunar excursion module). Moreover, through better definition of the overall AAP test program and requirements vis-à-vis Apollo, Gilruth estimated that the program might be carried out at a cost several million dollars less than previously estimated.

Letter, Robert R. Gilruth, MSC, to George E. Mueller, NASA Hq, 9 June 1966.

10

Associate Administrator for Space Science and Applications Homer E. Newell renewed his request for approval of ATM development to Deputy Administrator Robert C. Seamans, Jr. (See 17 March 1966). Newell repeated that detailed studies in house and under contract had established the feasibility of an ATM for conducting high-resolution observations of the Sun. He pointed out that a formal ATM organization had been created at Goddard Space Flight Center with over 30 people working full time on the project, and that they had prepared detailed scientific, technical, and management plans and were ready to begin the project immediately.

Newell emphasized the importance of the ATM to the overall NASA solar physics program. Cancellation of the Advanced Orbiting Solar Observatory project, he said, left the Orbiting Solar Observatory as the only approved program devoted to solar physics and that spacecraft did not have the technical capability to carry

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out the high-resolution studies so urgently needed. Newell pleaded for project approval and assignment of necessary funds to his office so that the ATM could be completed in time for a planned launch in 1969, the next period of maximum solar activity.

Letter, Homer E. Newell to Deputy Administrator, "Apollo Telescope Mount (ATM)," 10 June 1966.

10

In preparation for upcoming evaluation of spent-stage experiment support module proposals, Kenneth S. Kleinknecht, Chairman of the SEB, established Technical and Business Management Committees to conduct actual evaluations. Kleinknecht expected that evaluation of the proposals due 17 June would begin as soon as they were received from the initial study contractors, Douglas, McDonnell, and Grumman.

Letter, Kenneth S. Kleinknecht, MSC, to Dist., "Appointment of Source Evaluation Committees for Saturn IVB Spent-Stage Experiment Support Module Part II Proposals," 10 June 1966.

16

Reflecting MSC's concern over several crew-safety factors regarding the suitability of the S–IVB hydrogen tank as a habitable structure to support the SSESM program, Gemini Program Manager Charles W. Mathews requested that officials at MSFC determine the compatibility of pressurization oxygen with possible out-gassing hydrogen and the possible effects on electrical cabling. Mathews desired such information as soon as possible, since results of this investigation would affect contractor efforts on the SSESM project. (See entry, 6 May 1966.)

TWX, Charles W. Mathews to MSFC, Attn: W. A. Ferguson, 16 June 1966.

20

E. E. Christensen, Mission Operations Director in NASA Hq, recommended to Associate Administrator for Manned Space Flight George E. Mueller that the Office of Manned Space Flight change its flight crew organizational setup from a decentralized, program-oriented type to a consolidated responsibility in one office (within mission operations). Previously, when emphasis was on hardware design and development, Christensen said, such a fragmentation of responsibility had helped preserve the integrity of a given program. Centralized authority now seemed more appropriate, with major hardware systems largely defined and OMSF rapidly changing to an operations-oriented phase. Mueller approved Christensen's suggestion on 2 July.

Memorandum, E. E. Christensen to George E. Mueller, "Proposal to Consolidate OMSF Flight Crew Operations Functions in Mission Operations (MO)," 20 June 1966.

22

Gerald M. Truszynski, Deputy Associate Administrator for Tracking and Data Acquisition, advised Mission Operations Director E. E. Christensen that a central problem foreseen for upcoming multiple-launch AAP missions was the limited

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capability of the Manned Space Flight Network (MSFN) unified S-band stations simultaneously to support two separate spacecraft. Unlike the facilities that had permitted support of the dual Gemini-Titan VI and VII missions, the Apollo network had only one antenna at each station. Performance limitations of the system might prove unacceptable, Truszynski said, particularly when considering abort possibilities and other contingencies. He suggested two possible solutions: (1) support one of the spacecraft via the S-band system and the second by C-band radar, VHF telemetry, UHF command, and VHF voice when necessary (although this approach would require modifications to the block II CSM; (2) add a second 9-m antenna system at each MSFN station to provide full S-band to both spacecraft at the same time. (This latter approach, he noted, might cost some $2 million per station and take about two years to complete.) Truszynski requested that Christensen include these MSFN support limitations in all mission planning for multiple-launch flights prior to mid-1969 and keep him advised as to what approach he wanted to pursue to support such multiple-launch missions.

Memorandum, Gerald M. Truszynski to Director, Mission Operations, "MSFN Support of Apollo and SAA Multiple Launch Missions," 22 June 1966.

28

Edward Z. Gray, Advanced Manned Missions Program Director in NASA Hq, criticized both MSFC and MSC for failing to present a realistic and viable experiment program for the AAP S–IVB Workshop. From the outset, Gray said, all recognized that AAP experiments had to be relatively simple and economical because of the requirement for early delivery of flight-qualified hardware (i.e., the fall of 1967) and fiscal limitations during Fiscal Years 1966 and 1967. The responses from MSFC and MSC so far, he stated, "do not constitute a reasonable program." Gray noted that experiments to assess the habitability of a spent stage (and also to develop design criteria for space stations) were almost totally absent. Several experiments were wholly unrelated to the Workshop and required little or no participation of the crewmen. "In my estimation we have not faced up to the problem of defining a useful set of experiments," Gray concluded. Unless great effort and imagination were brought to bear on this problem, he warned, "we will be hard pressed to defend the phase D effort on the Workshop which should constitute a key element of our Saturn Apollo Applications Program."

TWX, Edward Z. Gray to MSFC and MSC, "S–IVB Workshop Experiments Program," 28 June 1966.

July

3

MSFC announced a number of appointments to fill out the Saturn/Apollo Program Office staff: Stanley R. Reinartz, Deputy Manager; Hilmar W. Haenisch, Assistant Manager; Jack C. Swearingen, Manager, Program Control Office; Rein Ise, Manager, Apollo Telescope Mount Project; and Jack H. Waite, Manager, Mission Planning and Experiments Project (later redesignated Experiment Development and Payload Evaluation Project).

MSFC, *Skylab Illustrated Chronology 1962–1973,* 1 May 1973, p. 8.

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6

At Houston, MSC Deputy Director George M. Low was appointed Acting Manager of the newly established Apollo Applications Program Office. Robert F. Thompson was named Assistant Manager. At MSFC, Leland F. Belew was designated Manager of the new office. The two new offices were made responsible for all "activities concerned with projects using Apollo hardware for purposes in addition to the manned lunar landing." A new Experiments Office headed by William G. Johnson was also established at MSFC.

MSC Announcement 66-92, "Establishment of the *Apollo Applications* Program Office and Designation of the Acting Manager and the Assistant Manager," 6 July 1966.

7

In a memorandum to Headquarters staff members, Advanced Manned Missions Program Director Edward Z. Gray summarized the three separate study efforts underway within NASA directed toward evaluating the S-IVB stage as a manned laboratory:

(1) The spent-stage experiment support module (SSESM) study, a joint effort by MSC and MSFC.
(2) A spent S-IVB-stage utilization study at MSFC.
(3) A Saturn V single-launch space station.

Gray noted that the SSESM study had as its chief objective an airlock and attendant subsystems to support an early spent-stage laboratory to conduct 30-day, three-man flights. The second study, to be initiated following competition, sought to examine concepts for an advanced spent-stage laboratory dependent upon regular resupply. The last approach, approval for which had yet to be gained, Gray called the "brute force" approach to a space station. In this concept, to achieve a one-year space station, the S-IVB stage was to be launched by a Saturn V and would not be required to perform as a propulsive stage. No resupply would be necessary except for experiments and crew rotation, and existing subsystems could be employed. Gray emphasized how crucial it was that ongoing and planned study efforts compare the advantages and disadvantages of simple spent-stage concepts, more sophisticated spent stages, and brute-force stations to accomplish the experiments under development. In this manner, when budgetary decisions must be made during forthcoming years, the agency would not be faced with, as Gray said, "a succession of pallet/LEM-lab/workshop-type problems with insufficient information to make sound choices."

Memorandum, Edward Z. Gray to Director, Program Review Division, "S-IVB Stage Space Station Concepts," 7 July 1966.

9

George M. Low expressed his reservations about the validity of planning a synchronous-orbit mission for AAP. In a note to Maxime A. Faget, Low commented on the recent interest in such a mission and voiced his own doubt concerning either the need for or the desirability of such a flight. Low stated that such things as synoptic views of terrain or weather phenomena could be done just

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as well from low Earth orbit using mosaic techniques. Moreover, low orbits afforded simpler operations, much greater payload capabilities, and minimal radiation hazards. Low asked Faget to have his organization prepare an analysis of low Earth-orbit versus synchronous-orbit operations in preparation for upcoming AAP planning discussions in Washington at the end of the month.

Memorandum, George M. Low, MSC, to Maxime A. Faget, MSC, "Synchronous orbit missions for AAP," 9 July 1966.

11

Meeting at Headquarters, Deputy Administrator Robert C. Seamans, Jr., Associate Administrator for Manned Space Flight George E. Mueller, and Associate Administrator for Space Science and Applications Homer E. Newell made several significant program decisions affecting AAP and post-Apollo development planning in general:

- MSFC would be the lead Center for developing the ATM and would be responsible for all astronomy experiments.
- MSFC would be the lead Center for "lunar engineering"—i.e., design and development of lunar exploration vehicles (including surface modules, supply trucks, and roving vehicles).
- MSC would have responsibility for Earth resources and lunar scientific experiments.

Memorandum for record, E. J. Brazill, NASA Hq, "Meeting Held on Monday, July 11, 1966 by Dr. Seamans, Dr. Mueller and Dr. Newell," 15 July 1966.

12

During informal discussions in Washington, Associate Administrator for Space Science and Applications Homer E. Newell was asked his views regarding the agency's options for post-Apollo space projects. Newell's reply, reflecting to a great extent the thinking of scientists within the agency, cited three chief factors: Earth-orbit missions, solar exploration, and orbiting astronomical observatories. Also, Newell played down the importance of the search for extraterrestrial life in connection with solar exploration in the post-Apollo period.

Memorandum for record, J. C. Satterthwaite, NASA Hq, "Post-Apollo," 12 July 1966.

13

Apollo Applications Program Deputy Director John H. Disher created the Saturn/Apollo Applications Mission Planning Task Force to oversee and coordinate mission definition for proposed AAP missions. The group, headed by William D. Green, Jr., of the AAP office in Washington, included members from the three manned Centers as well as Headquarters. Disher charged the group with a number of specific responsibilities:

- Determine the feasibility of accomplishing the proposed AAP missions, including objectives, experiment compatibility, spacecraft and launch vehicle characteristics, crew capabilities, facilities requirements, mission contingencies, and off-nominal operation.

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• Conduct analyses on allocation of experiments to different spacecraft modules, as well as alternate modes of mission and experiment operation.

• Recommend resolutions whenever conflicts arise over hardware or mission issues.

In all of these areas, the task force acted as an advisory body to the program director.

Letter, John H. Disher to Dist., "Saturn/Apollo Applications Mission Planning Task Force," 13 July 1966, with enclosure, Saturn/AAP Program Directive No. 1, "Saturn/Apollo Applications Mission Planning Task Force," 13 July 1966.

13

NASA announced that project management responsibility for the ATM had been assigned to MSFC. Under the agency's "phased project planning," any decision to begin ATM hardware development must await preliminary design study and evaluation at Marshall. But as conceived at this stage, the ATM would comprise several high-resolution solar telescopes attached to the Apollo spacecraft, to be operated by scientist-astronauts. Subsequently, ATM experiments contracts also were transferred from Goddard Space Flight Center to Huntsville.

NASA News Release 66–185, "Telescope Mount for Apollo Flight Assigned by NASA," 13 July 1966; letter, Homer E. Newell, NASA Hq, to George E. Mueller, NASA Hq, 1 September 1966.

14

Through a formal memorandum of understanding between NASA and the Department of Defense, the two agencies established the Joint Manned Space Flight Policy Committee to coordinate, at the policy level, manned space flight programs of the respective organizations. The committee was presided over by Cochairmen John C. Foster, Jr., Director, Defense Research and Engineering, and Robert C. Seamans, Jr., NASA Deputy Administrator. Functions of the committee were to resolve matters of mutual interest between the two agencies; to agree on decisions involving top policy determinations; and to facilitate exchange of information and views regarding coordinated planning of manned space flight programs within NASA and the Defense Department. (This agreement superseded a similar earlier coordination group established in mid-January 1963, the Gemini Program Planning Board.)

NASA Management Instruction NMI 1154.2, "Manned Space Flight Policy Committee," 14 January 1966; memorandum, John C. Foster, Jr., and Robert C. Seamans, Jr., to Secretary of Defense and NASA Administrator, "Manned Space Flight Policy Committee," 9–13 January 1966, with enclosure, "Memorandum of Understanding Between The Department Of Defense And The National Aeronautics And Space Administration Concerning The Manned Space Flight Programs Of The Two Agencies," 11–14 January 1966.

18

George E. Mueller, Associate Director for Manned Space Flight, officially assigned Headquarters management responsibility for development of the S–IVB Orbital Workshop and SSESM to David M. Jones, Acting Saturn/Apollo Applications Program (S/AAP) Director. Experiments as a part of the SSESM and Workshop

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programs, Mueller said, would still be processed through the Manned Space Flight Experiments Board for approval.

Memorandum, George E. Mueller to Acting Director, S/AAP, "S-IVB Workshop and SSESM Development," 18 July 1966.

19

NASA Deputy Administrator Robert C. Seamans, Jr., ordered the heads of program offices at Headquarters to conduct a 60-day study to update planning for a permanent manned space station in light of current thinking and recent program developments. The study, a joint Headquarters-Field Center undertaking, was conducted under the auspices of the Planning Coordination Steering Group and comprised two separate subject areas: (1) a study of requirements and constraints for a permanent station to meet a broad range of scientific objectives; and (2) a similar study of hardware configurations, mission operations, costs and schedules, and development plans. (The two separate study groups were headed by Charles J. Donlan and Edward Z. Gray, respectively.) Also, as Seamans phrased it, since it was "still a question whether a permanent space station is the best approach to achieving the envisioned mission objectives," the study group's report should assess its advantages and disadvantages. He emphasized that the study in no way implied that NASA had, in fact, decided to develop or even propose such a permanent manned station in space. It would, however, "help us to decide if such a course is desirable and when."

Seamans also described the interrelationship between the space station and NASA's current manned programs, particularly the AAP. The studies, he said, should recognize AAP planning already underway and should assist in defining AAP activities that should form precursors to an actual space station (including experiments and operational capabilities, as well as supporting research and development). The study must, above all, "consider the logical growth pattern which should evolve from the AAP program to a space station."

Memorandum, Robert C. Seamans, Jr., to Dist., "Preliminary Study of a NASA Manned Space Station," 19 July 1966.

19

Following the decision of Deputy Administrator Robert C. Seamans, Jr., to assign development responsibility for the ATM project to MSFC (see 11 July 1966), the manned space flight organization had concentrated its efforts on selecting the best location for the ATM within the Apollo spacecraft. Associate Administrator for Manned Space Flight George E. Mueller informed Seamans of their recommendation—and requested his approval—that the ATM be mounted within the LM. Mueller cited the design tradeoffs that led to this recommendation, the foremost being that the LM-mounted ATM, modified for storage and reuse in orbit, offered the greatest potential for meeting ATM performance requirements and experiment objectives, including the possibility of manned operation while detached from the CSM and thus free from external disturbances during fine pointing operations. (Other possible installation locations considered but rejected were an empty bay of the service module; a specially built rack for the ATM that

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would be launched inside the adapter section where the LM normally rested; and inside the spent-stage experiment support module.) Mueller stated that the LM-mounted ATM could be accomplished with programmed funds using MSFC in-house effort. Also, the system would include use of the LaRC-developed control moment gyro system for fine pointing control.

Memorandum, George E. Mueller to Deputy Administrator, "Apollo Telescope Mount Installation," 19 July 1966.

19

Harold Glaser, Deputy Chief of Solar Physics at Headquarters, presented to Advanced Manned Missions Director Edward Z. Gray detailed arguments justifying sole-source award of a contract to North American to study engineering problems associated with incorporating large telescopes and other scientific equipment into the Apollo spacecraft. (Glaser also argued for a similar contract to Harvard University for technical and scientific assistance to North American.) This effort, a coordinated effort between the Advanced Mission Planning Groups in the OMSF and the Physics and Astronomy Programs in the OSSA, he told Gray, was essential to make maximum use of the Apollo Extension System as an orbital platform for a variety of scientific experiments.

Letter, Harold Glaser to Edward Z. Gray, "Sole Source Justification for Noncompetitive Procurement. . .," 19 July 1966.

21

KSC announced creation of an Advanced Programs Office within the Apollo Program Office. The new group, headed by Robert C. Hock, was given responsibility for overall Center planning in the advanced programs area, including Saturn/Apollo Applications.

Spaceport News, 21 July 1966, p. 5.

22

George M. Low summarized MSC's thinking regarding proper location of the ATM with the AAP payload configuration. Low affirmed Houston's approval of the recent assignment of total responsibility for the ATM to MSFC (an assignment that MSC had supported from the outset). The most important task now was to "get on with the ATM in a most expeditious manner so that we can demonstrate once and for all that there is a major place for science and applications in manned space flight." Further, Low said, getting on with the job meant "making Marshall's job as simple and as straightforward as possible." Because of extremely complex technical and managerial interfaces, the benefits of total systems responsibility at MSFC would be lost if the ATM were mounted on an Apollo LM. "We frankly don't believe that the job can be done in this manner in any reasonable length of time," he said. For much the same reasons, MSC also withdrew earlier recommendations that the ATM could be located in a sector of the service module or in the spent-stage experiment support module. Rather, he urged that the ATM be integrated into a self-contained rack fitted into the adapter area and launched aboard a single vehicle along with the CSM. Low cited a number of specific objections to Headquarters' recommendation that the

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ATM be in the LM, even though the approach was technically feasible and offered several important advantages. Nonetheless, he repeated his view that operational factors, technical and managerial interfaces, and cost and schedule considerations all favored a rack-mounted approach. Crew safety factors alone were ample justification for such an approach, and he urged that Headquarters and MSFC proceed with such a design at the earliest possible date.

Letter, George M. Low, MSC, to John H. Disher, NASA Hq, 22 July 1966.

25 William A. Ferguson, MSFC Orbital Workshop Project Manager, made a presentation on the OWS as an experiment to the Manned Space Flight Experiments Board (MSFEB). Associate Administrator George E. Mueller approved the experiment for flight on AS–209.

Manned Space Flight Experiments Board, "Minutes," 25 July 1966.

25 John H. Disher, Saturn/Apollo Applications Deputy Director, advised his Systems Engineering Director that, on the basis of studies and review within both the OMSF and the OSSA, the choice of location for the ATM had been narrowed down either to the LM ascent stage (with a "half rack" in place of the descent stage) or to a specially designed rack structure completely supplanting the LM. Disher requested additional information on both of these approaches to help in making final recommendations:

(1) A comparison of command and service modules interfaces for the two concepts.
(2) An analysis of interfaces between the LM rack and the ascent stage.
(3) Descriptions of the subsystem installations for both the LM ATM and the rack ATM.

Memorandum, John H. Disher to Director, Systems Engineering, "ATM LM vs. Rack Installation," 25 July 1966.

26 Deputy Administrator Robert C. Seamans, Jr., formally notified Associate Administrators Mac C. Adams, Edmond C. Buckley, George E. Mueller, and Homer E. Newell that he had assigned full responsibility for Apollo and AAP missions to Mueller's Office of Manned Space Flight. This decision, he said, was in line with the "fundamental policy of NASA that projects and programs are best planned and executed when these responsibilities are clearly assigned to a single management group." Thus, OMSF had full responsibility for AAP hardware systems, integration of experiments, and conduct of the missions. At the same time, Newell's Office of Space Science and Applications, the office with overall responsibility for the scientific content of NASA's space flight programs, had the task of selecting experiments to be flown aboard AAP missions, as well as for analysis and dissemination of data collected. Likewise, Adams' Office of Advanced Research and Technology was responsible for technology experiments aboard

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manned space flights, while Buckley's Office of Tracking and Data Acquisition was charged with satisfying the communications requirements for experiments as specified by the other offices involved.

Memorandum, Robert C. Seamans, Jr., to Dist., "Management Responsibilities for Future Manned Flight Activities," 26 July 1966.

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2

George E. Mueller, Associate Administrator for Manned Space Flight, advised Robert C. Seamans, Jr., of progress toward selecting the proper location of the ATM with the AAP payload cluster and requested his approval of the preliminary project development plan. Mueller. urged proceeding immediately with the project based upon mounting the ATM on a rack structure that would (1) either supplant the descent stage of the LM (thus using the LM ascent stage for mounting experiment consoles and for supporting the crew during periods of observation) or (2) attach directly to the Apollo CSM. Mueller recommended beginning development work on the ATM project immediately, rather than deferring such action until the end of the year, in order to ensure flight readiness during the 1968–1969 period of maximum solar activity. Also, Mueller strongly supported Seamans' suggestion that much in-house effort and manpower at MSFC could be brought to bear on the ATM development program. Indeed, Mueller stated that such a course was essential to successful prosecution of the ATM project within available resources, even though several important industrial contracts for ATM components were still necessary.

Memorandum, George E. Mueller to Deputy Administrator, "Apollo Telescope Mount Project," 2 August 1966.

2

George E. Mueller, Associate Administrator for Manned Space Flight, recommended to Deputy Administrator Robert C. Seamans, Jr., that NASA proceed with its procurement effort on an S–IVB airlock module (AM) experiment as part of the dual-launch Apollo-Saturn 209–210 mission. The AM, to replace a LM aboard one of the vehicles, was to serve as the module affording a docking adapter at one end to permit CSM docking and at the other end a sealed connection to a hatch in the spent S–IVB stage of the rocket. The AM, a tubular structure about 4.5 m long and 3 m in diameter, would thus provide a pressurized passageway for the crew from the spacecraft to the empty interior of the S–IVB hydrogen tank. Oxygen tanks in the module would pressurize the AM and interior of the S–IVB to create a "shirt-sleeve" environment for the crew. Objectives of the AM, Mueller explained, were to investigate the feasibility of using a spent rocket stage as a large habitable structure in space and to develop the capability for long-duration manned missions. If successful, he told Seamans, the AM would give NASA an early capability for manned experimentations and operations in space. Definition and design of the AM had already been completed, and the experiment already had approval of the Manned Space Flight Experiments Board. Moreover, procurement bids had been received from industrial firms and results of the competition presented to Administrator James E. Webb in mid-July. Thus, because the AM presented "a unique opportunity to

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investigate a major new manned space flight capability at a reasonable cost," Mueller urged Seamans to approve its early procurement.

On 2 August, Seamans presented Mueller's arguments to Webb, recommending approval of the AM experiment. Seamans reasoned that the experiment, if feasible, would provide the United States with a major new capability for long-duration manned space operations without interfering with the basic Saturn IB launch vehicle program or the mainline Apollo lunar landing goal. Webb approved Seamans' arguments the following day, with an added comment: "particularly as it [the AM] would open up additional areas of knowledge we might need if Russian programs accelerate to the degree that we wish to add to our manned operations with least lead time and maximum use of Apollo equipment."

Memoranda, George E. Mueller to Deputy Administrator, "SIVB Airlock Experiment," 2 August 1966; Robert C. Seamans, Jr., to James E. Webb, same subject and date, with Webb's hand-written comments, 3 August 1966.

2

In a letter to Robert R. Gilruth, George E. Mueller acknowledged MSC's expeditious completion of the phase C definition phase of the Apollo experiments pallet effort. However, he noted several fundamental changes since the pallet effort was started. With experiment funding severely limited, NASA had now placed greater emphasis on a few major experiments (such as the Apollo telescope mount) in contrast to the wide variety of experiments originally envisioned for AAP missions. Also, Mueller observed that because of recent reshaping of AAP objectives toward long-duration missions program planners now believed that, in general, experiments should be carried in the adapter area of the launch vehicle rather than in the vacant bay of the service module (which thus could be used for expendables to support the longer duration flights). In light of these program changes, Mueller concluded it was no longer wise to proceed with phase D of the pallet program—actual hardware development.

Letter, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, 2 August 1966.

9

Based on confirmation during discussion with Melvin Savage of NASA Hq, MSC Gemini Program Deputy Manager Kenneth S. Kleinknecht advised of changes in hardware nomenclature for the Apollo Applications Program:

- The S–IVB spent-stage experiment was now the Orbital Workshop.
- The spent-stage experiment support module was now the airlock module.
- The spent S–IVB was now the Orbital S–IVB.

Memorandum, Kenneth S. Kleinknecht to Dist., "Change in nomenclature from 'S–IVB Spent Stage Experiment' to 'Orbital Workshop,'" 9 August 1966.

10

MSC Flight Operations Director Christopher C. Kraft, Jr., expressed to George M. Low, Acting MSC Apollo Applications Program Manager, grave doubts

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regarding the wisdom and validity of present AAP planning for program integration. Citing specifically the Saturn/AAP Development Plan of 20 June 1966 and MSFC's Phase C AAP Integration Contract dated 12 June 1966, Kraft pointed out the absence of any specific method of providing "integration" of the complete AAP vehicle and identified several potential problem areas.

Kraft expressed concern about the necessity for clear assignment of responsibility for vehicle integration (i.e., comprehensively covering configuration, payload, trajectories, data acquisition, operations, and objectives). Existing plans, he said, made MSC responsible for integration of the command and service modules; MSFC the S–IVB, instrument unit, and lunar module; and, by implication, Headquarters the job of total payload integration. Kraft called illogical any scheme of having two independent and parallel efforts for the spacecraft payload integration. Also, it was inconceivable that Headquarters could take on such a detailed and complex role. In short, Kraft made out a case for MSC ensuring to itself its traditional responsibilities in the areas of spacecraft design and integration in the face of assignment of some measure of overall payload responsibility to MSFC. Above all, he called for clearly defined roles and responsibilities.

Memorandum, Christopher C. Kraft to Acting Manager, AAP Office, "Payload Integration and AAP," 10 August 1966.

13–15

At a meeting of the Manned Space Flight Management Council at Lake Logan, North Carolina, Headquarters and Center representatives worked out a general agreement regarding the respective roles of MSC and MSFC in the development and operations of future manned space flight hardware. The conceptual basis for this agreement, a space station, reflected an intermediate step between early AAP missions and later more complex planetary missions. In fact, much the same jurisdictional arrangement characterized AAP's OWS and the ATM. The underlying rationale and capability for this division of program roles and responsibilities lay in the idea—one dating from the early planning stages of Apollo—of modularization. Thus, provided interfaces were not extremely complex, parts of a total space vehicle could be farmed out to separate field centers for development. In line with the traditional roles of MSC and MSFC, Huntsville would oversee launch vehicles, a "mission module" of the living quarters, and the laboratory part of a large space station. MSC would be responsible for a "command post" or flight deck, where all piloting functions were located, as well as logistics vehicles, rescue craft, other specialized vehicles, and crew training and mission operations. This, in effect, similarly portrayed the division of responsibilities between the two Centers for AAP.

The combination of CSM and AM comprised the "command post" of AAP, and therefore was MSC's responsibility. The OWS similarly belonged to MSFC. Experiments were divided between the two organizations. These working premises represented perhaps the most fundamental statement of intra-NASA jurisdictional

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responsibilities since MSFC first became a part of the agency and MSC emerged as a separate field element.

Letter, Robert R. Gilruth, MSC, and Wernher von Braun, MSFC, to George E. Mueller, NASA Hq, 24 August 1966, with enclosure, "Post Apollo Manned Spacecraft Center and Marshall Space Flight Center Roles and Missions in Manned Space Flight," 24 August 1966.

19

NASA announced selection of McDonnell to manufacture an AM for AAP to permit astronauts to enter the empty hydrogen tank of a spent S-IVB Saturn stage. The AM would form an interstage between the spent rocket stage and the Apollo CSM and would contain environmental and life support systems to make the structure habitable in space. Though MSFC had project responsibility for the complete Orbital Workshop, technical and management responsibility for the AM rested with the AAP office at MSC. Contract negotiations with McDonnell were completed in mid-September. Because design of the AM would employ existing Gemini technology and hardware where feasible, MSC Gemini Deputy Manager Kenneth S. Kleinknecht detailed a number of people from his office to support the AM project.

NASA News Release 66-223, "Select Contractor for Spent Saturn Airlock Experiment," 19 August 1966; memorandum, Kenneth S. Kleinknecht to Deputy Director, "Changes to Contract NAS 9-6555, Airlock," 23 September 1966.

29

NASA Deputy Administrator Robert C. Seamans, Jr., notified George E. Mueller of approval to proceed with development and procurement actions to conduct one AAP ATM flight on missions 211/212 (as an alternate to the basic Apollo mission assigned to those two vehicles). Since only one ATM flight was thus far approved, Seamans emphasized the importance of focusing all project effort on meeting the existing SA 211/212 schedule.

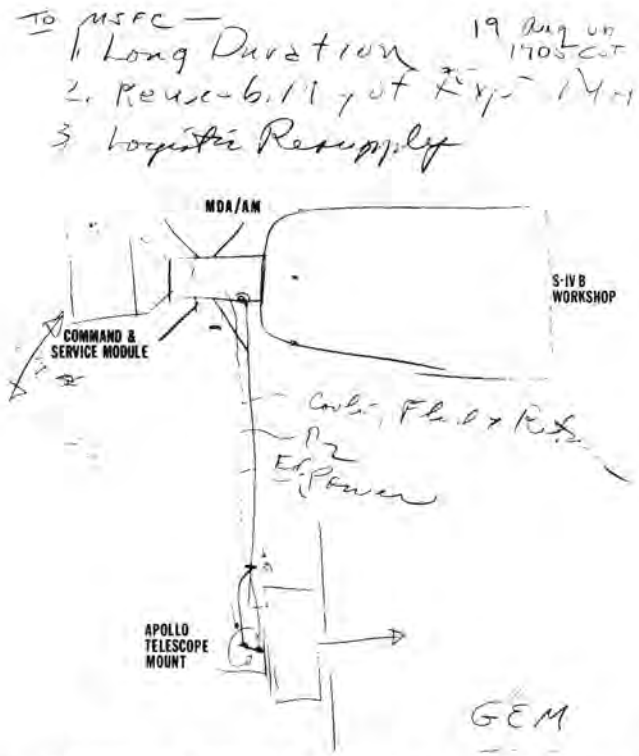
Seamans asked that he be kept fully informed of all major decisions during the system definition phase of the ATM project. He cited a number of points of particular interest: the design concept for the ATM and its rationale; experiments planned for the mission (especially on the assumption of a single ATM flight); operational concepts; procurement phasing with the option for a follow-on ATM if resources permitted; organizational, procurement, and management approaches for the mission; and schedule options available if SA 211 and 212 became available for an alternate ATM mission.

Memorandum, Robert C. Seamans, Jr., to Associate Administrator for Manned Space Flight, "Apollo Telescope Mount (ATM)," 29 August 1966, with attachment, "Project Approval Document, Research and Development [AAP ATM]," 25 August 1966.

September

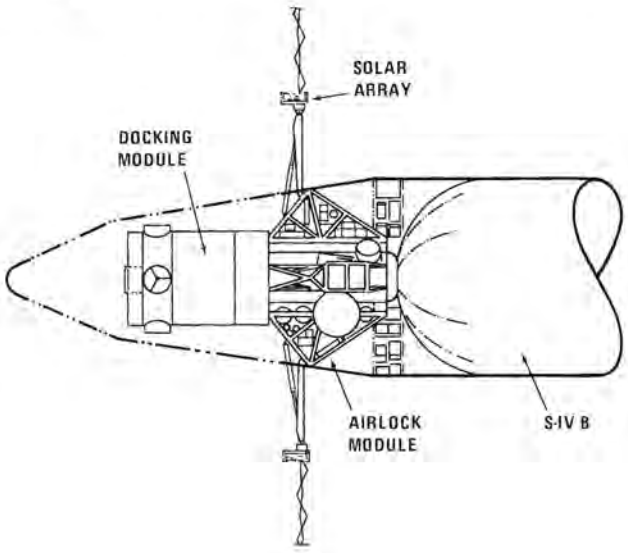
13

NASA Hq Saturn/Apollo Applications Program Office defined mission requirements and Center responsibilities to successfully carry out a Saturn/Apollo Applications 209 mission, a 28-day, manned, Earth-orbital flight. Candidate



A reproduction of a rough sketch by NASA's Associate Administrator for Manned Space Flight, George E. Mueller, which indicates his thinking on the configuration of the S–IVB Workshop as of August 1966.

An advanced airlock concept prepared by P. M. Chapman, Douglas Aircraft Company, on 20 August 1966. The 9705-kilogram weight included 5675 kilograms for the airlock and 4030 kilograms for government-furnished equipment, experiments, and margin.



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experiments for the mission included 13 engineering, 7 medical, and 6 technology-related experiments.

S/AAP Directive No. 3, "Flight Mission Directive for SAA 209 Mission," 13 September 1966.

21

Prompted by recent operational difficulties involving extravehicular activity during Gemini flights IX–A, X, and XI, Deputy Project Manager Kenneth S. Kleinknecht recommended to Saturn/Apollo Applications Program officials in Washington a redesigned forward dome hatch in the S–IVB hydrogen tank; i.e., one that could be more readily removed. He urged installing a flexible type of airlock seal prior to launch of the stage. These changes, Kleinknecht said, would go far toward minimizing astronaut workload for activating the spent stage once in orbit.

Memorandum, Kenneth S. Kleinknecht to John H. Disher, NASA Hq, "Recommendation for reduction in Orbital Workshop activation workload," 21 September 1966.

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7

In light of agreements on Center roles and responsibilities reached during the Lake Logan Management Council meeting (see 13–15 August 1966), recent Gemini flight experience, and review of assigned advanced study activities related to extravehicular activity (EVA), Advanced Manned Missions Director Edward Z. Gray revised the division of effort between MSFC and MSC on EVA studies and responsibilities. (Gemini had proved the need for careful assessment of EVA requirements dictated by mission objectives, the laying down of specific EVA hardware and procedures, and the verifying of astronaut capability to perform various EVA tasks.) Gray stipulated that MSC would be responsible for study, test, and development of EVA equipment and procedures (including astronaut participation); MSFC had responsibility for development and test of large structures in space that might require astronaut EVA for assembly, activation, maintenance, or repair. As a whole, these study efforts at the Centers, said Gray, were aimed at formulating a thorough analysis of EVA potential and astronaut capabilities and at devising a long-range program for developing and using EVA hardware and procedures to further man's usefulness in space.

Letter, Edward Z. Gray to Robert R. Gilruth, MSC, 7 October 1966.

7

Saturn/Apollo Applications Program Deputy Director John H. Disher, in response to a letter from MSC AAP Assistant Manager Robert F. Thompson regarding the difficult workload imposed on the crewmen during the SAA–209 mission (i.e., opening the S–IVB tank dome cover and installing the airlock boot might be enough to jeopardize the mission), asked both Thompson and Leland F. Belew, S/AAP Manager at MSFC, to explore various alternatives to this method of activating the Workshop. Also, Disher asked that Belew undertake a simulation effort to evaluate definitively the workload involved in activating the present Workshop configuration.

Letter, John H. Disher to Leland F. Belew and Robert F. Thompson, "Reduction in Orbital Workshop Activation Workload," 7 October 1966.

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MSFC Director Wernher von Braun described to his MSC counterpart Robert R. Gilruth his ideas for transferring to Houston the bulk of MSFC's lunar exploration studies and development contracts. (As a result of the 13–15 August Lake Logan meeting, Deputy Administrator Robert C. Seamans, Jr., had designated MSC the lead Center for lunar science.) von Braun proposed that planning for AAP-type lunar traverses and a wide variety of lunar scientific experiments (including a scientific package of experiments to be emplaced near landing sites) be transferred to Houston. On the other hand, he believed that lunar roving and flying devices, the AAP lunar drill, and the lunar surveying system should be retained at Huntsville, saying that these projects were of an engineering rather than a scientific nature and that, with MSFC's in-house capability for engineering work of this type, his Center could make substantial—and cost-effective—contributions to lunar exploration. 19

Letter, Wernher von Braun to Robert R. Gilruth, 19 October 1966.

Robert F. Thompson, Assistant Apollo Applications Program Manager at MSC, wrote AAP Deputy Director John H. Disher criticizing reductions by Headquarters in Houston's AAP Project Operating Plan for Fiscal Year 1967 for both experiments and the Orbital Workshop mission ($8.6 million for each). Thompson claimed that the current requirement for the Workshop mission was $17 million ($14 million for hardware and mission support and $3 million for currently assigned experiments). He then broke down specific funding requirements for the airlock module, command and service modules modifications, guidance and navigation hardware and software, crew systems, and training requirements. Houston was going ahead with the Workshop mission as speedily as possible, Thompson said. However, "prompt and adequate funding . . . is required if current schedules are to be met." 19

Letter, Robert F. Thompson to John H. Disher, "FY 1967 funding requirements for the Orbital Workshop Mission," 19 October 1966.

MSC officials conducted a preliminary design review on the AM at the McDonnell plant in St. Louis. Participants found two major problem areas that could severely affect the probability of mission success. The most critical was the design concept of total reliance on passive thermal control for the S–IVB. The second was the lack of definition on extravehicular and intravehicular equipment (which affected AM systems and hardware design). In addition, NASA reviewers made a number of specific suggestions for improved system design, notably provisions for revisitation and rehabitation of the AM on successive flights. 21

Memorandum, Donald K. Slayton, MSC, to Airlock Manager, Gemini Program Office, and Assistant Manager, Apollo Applications Program, "Comments Concerning the Air Lock Preliminary Design Review," 25 October 1966.

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25

Kenneth S. Kleinknecht, Gemini Program Deputy Manager at MSC, requested from W. A. Ferguson at MSFC that Huntsville furnish MSC two S–IVB trainers for use in crew training and crew evaluation of hardware for the airlock program. MSC wanted a full-scale S–IVB neutral buoyancy trainer for evaluation of extravehicular operations, crew transfer, and equipment retrieval and stowage. Kleinknecht also asked for a full-scale, high-fidelity, one-g trainer for similar application. He requested that these trainers be updated as changes were made to the design of the S–IVB flight article.

Letter, Kenneth S. Kleinknecht to W. A. Ferguson, "S–IVB Trainers for Manned Spacecraft Center," 25 October 1966.

25

MSFC distributed its research and development plan for the OWS. The development plan defined objectives and basic criteria for the project and established a plan for its technical management (chiefly through MSFC's Propulsion and Vehicle Engineering Division). Officially, the Workshop had won approval for the Saturn/Apollo Applications 209 mission, which was a backup for Apollo-Saturn 209. Primary purpose of SAA–209 was activation of the spent S–IVB stage into a habitable space structure for extended Earth-orbit missions. In addition, a number of objectives for the OWS were considered essential to man's abilities in space:

- Evaluation of man's capability to inhabit and exploit large space structures
- Development of supporting technology for the AAP and advanced space vehicles
- Evaluation of man's ability to accomplish complex tasks in space
- Evaluation of biomedical and systems aspects of extended duration missions
- Deactivation of the Workshop so that it could be revisited and reactivated on subsequent missions.

Most importantly, the OWS would advance space science and technology and thus "sustain the tempo of the national space program, and aid in assuring U.S. primacy in space."

MSFC, "Orbital Workshop Research and Development Plan," 25 October 1966.

Week Ending October 27

Saturn/Apollo Applications officials at Headquarters sounded out Houston officials on the status of MSC's land-landing development plan. MSC technicians had "reevaluated" their original cloverleaf-retrorocket configuration and now were pushing for development of a sailwing as the reentry descent system, believing that the sailwing had greater potential for Apollo-class vehicles (especially in range and maneuverability). Also, MSC spokesmen proposed that Houston take over testing of the "parawing" (a limp paraglider) being developed by Langley. They stated that the research and testing effort required to develop the sailwing and parawing would delay until 1971 or 1972 NASA's achieving a

land-landing capability. (Previous work on the cloverleaf-retrorocket concept had promised such a capability by about mid-1970.)

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Memorandum, John H. Disher, NASA Hq, to Associate Administrator for Manned Space Flight, "Weekly Status Report for Week Ending October 27, 1966," 3 November 1966, with attachment, "Saturn/Apollo Applications Program Summary."

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2

After intensive effort by AAP groups at MSFC and MSC on the ATM and AAP mission planning for Flights 209 through 212, George E. Mueller told the two Center Directors that he now had ample information for a "reasonable plan" to proceed with AAP. First, Mueller stated that the Orbital Workshop mission could best achieve AAP objectives by launching the complete airlock, Workshop, and multiple docking adapter unmanned into a one-year orbit, with activation to be accomplished by a separately launched crew. The first two AAP missions, said Mueller, would thus provide a three-man, 28-day flight and, at the same time, would establish a large clustered space configuration for use during subsequent missions. Secondly, Mueller posited that the ATM to be developed by MSFC could readily be integrated into an LM ascent stage and could reasonably be scheduled for launch during 1968. He cited the possibility that, by eliminating some equipment from the LM, the complete CSM–LM–ATM vehicle could be launched by a single booster. However, Mueller stated his belief that the correct approach should retain those LM subsystems required to operate the vehicle in a tethered mode, even though normal operation might call for the LM/ATM to be docked to either the Workshop or the CSM. Further, Mueller expressed real concern regarding the likelihood of significant weight growths in the ATM systems. For this reason he favored separate launch of the LM/ATM combination. Mueller planned to present AAP planning along these lines during discussions over the next several days with Administrator James E. Webb and the Director of the Budget regarding NASA's planning for manned space flight in the post-Apollo era.

Letters, George E. Mueller, NASA Hq, to Wernher von Braun, MSFC, and Robert R. Gilruth, MSC, 2 November 1966.

5

George E. Mueller, Associate Administrator for Manned Space Flight, recommended to Robert C. Seamans, Jr., the lunar module ascent stage/half-rack Apollo telescope mount (LM/ATM) as the baseline configuration for development of the ATM. Mueller explained that a number of "desirable characteristics" had been examined in comparing the LM ATM with its chief rival, a CSM rack/ATM: (1) achievement of maximum solar data (through ease of operation, ability to repair, maintain, and reuse, and the capability of adding new instruments on subsequent missions); (2) maximum employment of man's capabilities for orbital astronomy (including pointing, film retrieval, repair and maintenance, and inflight analysis of solar data); (3) modes of manned operations (docked with the Orbital Workshop and separated from the cluster via a tether); (4) minimum cost consistent with accomplishing mission objectives; and (5) highest assurance of achieving program schedules.

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Comparison studies had shown that both the rack ATM and the LM/ATM should use the Langley-developed control moment gyro system for fine pointing control and that both configurations required a sizable volume to allow crew access to instruments and controls. The rack/ATM concept, Mueller told Seamans, was attractive primarily because of its simplicity. However, the vehicle could not be operated at a distance from the CSM to minimize contamination or motion disturbances (items of particular concern to ATM experimenters). On the other hand, the LM/ATM offered the greatest flexibility for meeting ATM requirements without any impact on the CSM. It could normally be operated while docked to either the CSM or the Workshop or, if experiment requirements so dictated, be either tethered or in free flight. This latter capability was especially valuable, Mueller explained, because it afforded a method of evaluating the range of modes for operating future manned orbiting telescopes and would permit early determination of the most desirable approach. (Mueller had recommended to Seamans approval of the ATM project some three months earlier [see 2 August 1966] and Seamans had given his okay shortly thereafter [see 29 August 1966].)

Memorandum, George E. Mueller to Deputy Administrator, "Apollo Telescope Mount (ATM)—Spacecraft Configurations and Operating Modes," 5 November 1966.

8

In accordance with decisions made by Associate Administrator George E. Mueller (see 2 November 1966), Saturn/Apollo Applications Deputy Director John H. Disher notified Robert F. Thompson, Robert C. Hock, and Leland F. Belew, Apollo Applications Program Managers at MSC, KSC, and MSFC, respectively, of the approved mission sequence for missions 209 through 212.

- SAA–209: manned block II CSM flight of 28-day duration, with the CSM fuel cells providing primary electrical power.
- SAA–210: launch of the unmanned airlock–Orbital Workshop–multiple docking adapter combination, with solar cells as the chief source of power.
- SAA–211: manned CSM flight of 56-day duration.
- SAA–212: unmanned lunar module-Apollo telescope mount flight.

Disher said that mission planning directives were being expedited to implement this mission sequence.

TWX, John H. Disher to MSC, KSC, and MSFC, 8 November 1966.

16

In a major AAP mission planning session at Houston, Texas, George M. Low and Eberhard F. M. Rees, Deputy Center Directors at MSC and MSFC, respectively, and Robert F. Thompson and Leland F. Belew, the respective AAP Managers at those Centers, established a joint approach for implementing missions identified with the first four AAP flights. (Although tentative, current plans called for using Saturn IB vehicles 209 through 212.) In effect, their planning saw two separate AAP missions, each comprising two Saturn IB dual launches: (1) S/AA 209–210, primarily a manned Workshop operation; (2) S/AA 211–

212, a flight consisting of solar astronomy and orbital assembly operations and lasting up to 56 days. 1966 November

Clearly, during their talks, the manned 56-day mission stood as the more difficult. The four men agreed to the creation of a small MSC–MSFC team to establish a baseline by which each Center could focus its effort more effectively. The team, under MSFC's lead, examined the 211–212 mission in several specific areas: mission objectives, ground rules, spacecraft configurations, and hardware systems. Also, the team drew assistance from the principal AAP contractors.

In summarizing their talks, Belew noted that the meeting produced "a basis on which to proceed," with no apparent divisive issues and with affirmations by both Centers "to proceed in getting the job done together."

Memorandum for record, Leland F. Belew, "Notes on Meeting at MSC November 16, 1966, Apollo Applications Program," 17 November 1966.

Maurice J. Raffensperger, Earth Orbital Mission Studies Director in NASA Hq, spelled out revised criteria for design of a one-year Workshop in space (criteria to be incorporated by MSFC and MSC planners into their proposed configurations): 16

- This "interim space station" should be ready for launch in January 1971. The design had to be a minimum-cost structure capable of a two-year survival in low Earth orbit. (Raffensperger speculated that a "dry-launched" S–IVB stage could be employed without major structural changes.)
- Initial vehicle subsystems were to consist of flight-qualified Apollo and Manned Orbiting Laboratory hardware capable of one-year operation.
- Operation of the station during the second year was to be accomplished by means of a long-duration "developmental systems" module that would be attached to the original space station structure (and would be developed separately as part of the long-duration space station program).
- Initial launch of the station would be with a Saturn V (and include CSM).
- This interim space station must be suited for operation in either zero-g or with artificial gravity (using the "simplest, least expensive" approach).
- Cost of the hardware must not exceed $200 million (excluding launch vehicle and the long-duration subsystems module).
- Cargo resupply and crew changes were to be carried out using Apollo-Applications-modified CSMs (limited to three Saturn IBs per year).

TWX, Maurice J. Raffensperger to MSFC, 16 November 1966.

As requested by Robert C. Seamans, Jr., at the monthly program meeting during October, Associate Administrator for Manned Space Flight George E. Mueller summarized the agency's present plans for including the DOD's astronaut maneuvering unit "back pack" aboard AAP flights. The unit was first flown aboard the *Gemini IX* mission, but EVA problems forced an early termination of the 18

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experiment. At the end of September 1966, NASA had eliminated the unit from the Gemini XII mision in order to concentrate efforts on investigating the basic fundamentals of EVA.

Mueller told Seamans that the astronaut maneuvering unit could be incorporated into AAP flights without compromising primary objectives of the Orbital Workshop mission. At the request of the Air Force, Ling-Temco-Vought, Inc., the unit contractor, was working with both North American and McDonnell to identify modifications needed to integrate the back pack into the Apollo CSM and AM. Although the Air Force had not yet asked that the astronaut maneuvering unit be assigned to AAP, officials were studying the desirability of committing the estimated cost of $2.5 million to $3 million to do so. If indeed the military service made this commitment, Mueller told Seamans, NASA planned to carry one unit aboard the SAA–210 and the SAA–211 and 212 missions.

Memorandum, George E. Mueller to Deputy Administrator, "DOD Back Pack (AMU) Experiment for Orbital Workshop Mission," 18 November 1966.

18 J. Pemble Field, Jr., Director, Saturn/Apollo Applications Control, notified program officials in Headquarters of Acting Director David M. Jones' decision to designate AAP missions in numerical sequence, starting with AAP–1 (rather than the former designation of S/AA–209). However, program planning documents would still include tentative hardware assignments pending firm vehicle allocations.

Memorandum, J. Pemble Field to Dist., "AAP Mission Designation," 18 November 1966.

21 A LM/ATM review team led by John M. Eggleston (MSC) met at MSC to determine the nature and state of design of the LM/ATM; to evaluate the feasibility of approach in each system area; and to identify interface areas between MSC and determine areas needing MSC support. The review group recommended tasks that MSC should or must do to assist MSFC; to fulfill MSC responsibility in ensuring that the LM remained a safe and useful manned spacecraft; and to provide MSC management sufficient data to negotiate with MSFC on roles and mission.

ATM presentation, 21 November 1966.

28 AAP Deputy Director John H. Disher advised the AAP Managers at MSC and MSFC (Robert F. Thompson and Leland F. Belew, respectively) of a number of requirements that were to be included in a program-level interim specification on the AAP cluster. These requirements included solar cells with rechargeable batteries, a two-gas environmental control system, the capability for multiple dockings, windows, and the capability for long-term storage and reuse of the basic hardware cluster. Disher emphasized that the AAP OWS assembly must be produced at a minimum cost and that no element of the system should incur

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additional costs to provide capabilities beyond those of the basic program requirements. Also, he pointed out, he did not demand that the OWS system be guaranteed to last a year in space without some maintenance by successive crews. The 28- and 56-day flights were goals rather than guaranteed requirements.

Letter, John H. Disher to Leland F. Belew and Robert F. Thompson, "Orbital Workshop Configuration for 1968–1969 AAP Missions," 28 November 1966.

28

NASA announced selection of Bendix Corporation's Eclipse Pioneer Division to negotiate a contract for development and production of a pointing control system for the ATM. The work, covering three flight units at an estimated cost of $6.9 million, was directed by MSFC. The pointing system, one of several flight systems to be developed for the ATM program, was based on design of a control moment gyro that Bendix was already developing for Langley.

NASA News Release 66–309, "Aiming System Contract Let for Scope Mount," 28 November 1966.

30

NASA Hq announced the appointment of Charles W. Mathews, Gemini Program Manager at MSC, to the post of Director of Saturn/Apollo Applications. (Mathews replaced David M. Jones, who had been Acting Director in addition to his regular job as Deputy Associate Administrator for Manned Space Flight [Programs].) Mathews assumed direction of the agency's effort to use Apollo vehicles to extend scientific and technical exploration of space.

NASA News Release 66–310, "Mathews Named to Headquarters Post-Apollo Job," 30 November 1966.

December

1

John H. Disher released the report by a study group at Headquarters on various modified lunar modules suitable for a lunar exploration program as part of AAP. These modified craft took the form of a LM taxi, ferry and logistics craft, a LM shelter, and an "augmented" LM. Disher authorized MSC to extend its engineering studies contract with Grumman to further define such modified LM configurations. He also asked MSFC to try to increase the Saturn V's translunar injection capability to 46 720 kg. These actions, he explained, afforded an opportunity to pursue any of several alternatives once future landing levels were known.

Memorandum, John H. Disher, NASA Hq, to Dist., "SAA Lunar Surface Exploration Program," 1 December 1966.

5

NASA Hq issued a schedule which introduced the cluster concept into the AAP design. The cluster concept consisted of a Workshop launch following a manned CSM launch. Six months later, a LM/ATM launch would follow a second manned flight. The LM/ATM would rendezvous and dock to the cluster. The first Workshop launch was scheduled for June 1968. As opposed to the habitable OWS and cluster concept which projected a much more complex program,

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the S–IVB SSESM had been a comparatively simple mission requiring no rendezvous and docking and no habitation equipment.

A major similarity between the old S–IVB/SSESM concept and the cluster concept was use of the S–IVB stage to put the payload into orbit before passivation and pressurization of the stage's hydrogen tanks. The new cluster concept embodied the major step of making the Saturn–IVB habitable in orbit, incorporating a two-gas atmosphere (oxygen and nitrogen) and a "shirt-sleeve" environment.

The OWS would contain crew quarters in the S–IVB hydrogen tank (two floors and walls installed on the ground), which would be modified by Douglas Aircraft Company under MSFC management; an airlock module (previously called the SSESM) attached to the OWS, which would be built by McDonnell Aircraft Corporation under MSC management; and a multiple docking adapter (MDA), which would contain five docking ports permitting up to five modules to be docked to the Workshop at any one time. The MDA would also house most OWS astronaut habitability equipment and many experiments.

The schedule called for 22 Saturn IB and 15 Saturn V launches. Two of the Saturn IBs would be launched a day apart—one manned, the other unmanned. Flights utilizing two Saturn V Workshops and four LM–ATM missions were also scheduled.

NASA Hq Schedule, 5 December 1966.

5 John H. Disher distributed to elements of his Headquarters organization and to the Apollo Applications Managers at the field centers a list of action items and required completion dates that resulted from a major AAP management and planning review meeting at KSC on 9–10 November 1966. Disher listed 27 specific priority items, encompassing cost and schedule impacts of configuration changes, reusable Workshop designs, solar panels versus fuel cells, two-gas atmospheric selection, emergency procedures, extravehicular activity requirements, experiment definition, Apollo-vehicle design modifications required for AAP, a definite plan for follow-on hardware procurement, testing requirements, reliability and quality assurance, and organizational and manpower requirements. These sundry actions, he said, constituted a roll call of the fundamental items that had to be accomplished to establish a viable and ongoing AAP.

Memorandum, John H. Disher to Dist., "Action Items from Apollo Applications Meeting at KSC, November 9–10, 1966," 5 December 1966, with attachment, "Apollo Applications Program Meeting, November 9–10, 1966, KSC: Action Items."

6 NASA Hq approved MSC's contract with McDonnell for the airlock portion of the OWS experiment. The contract provided for delivery of one flight unit, with options for three additional modules if the agency so desired.

TWX, Kenneth S. Kleinknecht, MSC to John H. Disher, NASA Hq, 16 December 1966.

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MSFC awarded a contract to Bendix Corporation to design and develop control moment gyros to stabilize the attitude of the ATM in orbit.

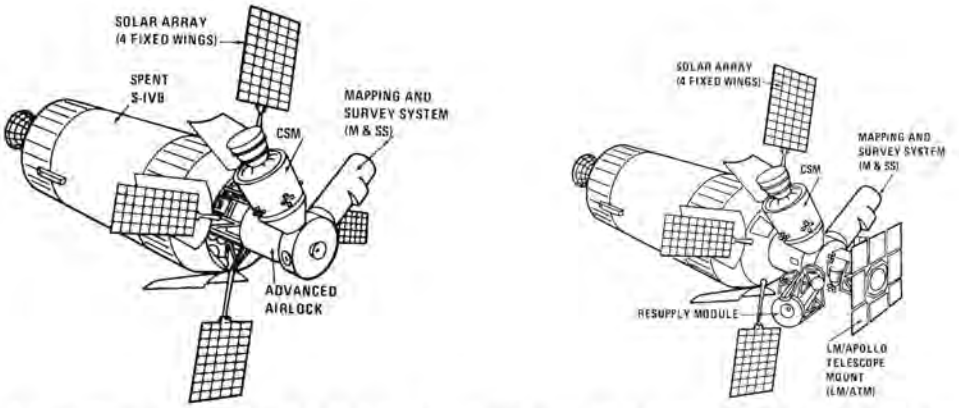
16

NASA Contract NAS 8-20661, 16 December 1966.

19

During presentations on manned space station studies to Deputy Administrator Robert C. Seamans, Jr., and Associate Deputy Administrator Willis H. Shapley, discussions turned to the contributory role of the AAP to any NASA future space station. Much had to be learned from AAP before agency officials and program planners could lay down any firm program objectives for such a station (including in the area of astronomy, which Associate Administrator for Manned Space Flight George E. Mueller had said was a major justification for AAP). Seamans affirmed that the agency would probably ultimately need such a large Earth-oriented capability, but that AAP would provide sufficient information on which to base future policy decisions. Much would depend upon man's capabilities for long-duration missions (another element that AAP was to prove out). Despite some criticism from scientific elements both within the agency and in the country at large, Seamans contended a great deal of interest existed in manned astronomical work and that future space astronomy missions had a real need for man in space, especially to perform inflight maintenance.

Memorandum for record, T. E. Jenkins, NASA Hq, "Action Items and Significant Discussion, *Manned Space Station Study Presentation* to Dr. Seamans and Mr. Shapley on December 19, 1966," 22 December 1966.



Two proposed advanced airlock mission configuration design sketches prepared by Wade W. Wilkerson of McDonnell Aircraft Corporation on 22 December 1966.

22

George E. Mueller wrote MSC Director Robert R. Gilruth and MSFC Director Wernher von Braun advising them of a joint MSC–Hq medical position regarding selection of a gaseous atmosphere for the Apollo Applications S–IVB Workshop. This medical position, based upon retention of the existing 100-percent oxygen environment in the command module, called for a "shirt-sleeve" atmosphere in the Workshop of 69-percent oxygen and 31-percent nitrogen at 35 kilonewtons per sq m (5 psia). (One-hundred-percent oxygen was still required for

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spacesuited emergency operation and during extravehicular activities.) Mueller solicited from the Center Directors comments on the engineering design and operational techniques of the Workshop Mission.

Letter, George E. Mueller, NASA Hq, to Robert R. Gilruth and Wernher von Braun, 22 December 1966.

22

MSC announced a reorganization of the Apollo Applications Program Office at Houston. Key assignments were R. F. Thompson, Assistant Manager; K. F. Hecht, Orbital Workshop Project Office Manager; H. E. Gartrell, Future Missions Project Office Manager; W. D. Wolhart, Program Control Office Deputy Manager; H. W. Dotts, Systems Engineering Office Manager; W. H. Douglas, Test Operations Office Manager; and W. B. Evans, Mission Operations Office Manager.

MSC Announcement 66–184, "Organization and Personnel Assignments of the Apollo Applications Program Office," 22 December 1966.

23

In a memorandum to the Associate Administrator for Manned Space Flight, George E. Mueller, Saturn/Apollo Applications Deputy Director John H. Disher posed a number of AAP issues needing resolution:

(1) Should AAP be portrayed as an "open-ended" program or should the agency identify a certain goal or activity as marking its completion?

(2) Should AAP include space rescue activities?

(3) The Office of Manned Space Flight (i.e., Mueller) must agree upon the feasibility of including in AAP's objectives retrieval of panels from one of the Pegasus-series of meteoroid detection satellites (an experiment given high priority by the Office of Advanced Research and Technology).

(4) Regarding the Mission Planning Task Force's effort to define the AAP Earth-orbital missions for 1969, a fundamental conflict in objectives existed between reuse of modules from previous missions (in a 28½-degree-inclination orbit) versus the goal of conducting "AAP–A" meteorology experiments at their required higher orbital inclination (at least 50 degrees). The priorities of orbital inclination versus reuse of modules must be determined, Disher told Mueller.

(5) In light of evident program funding constraints, what should really be done about the lunar exploration part of AAP (shelter-taxi vs. augmented lunar module, etc.)?

A few days later, Disher posed some additional questions for Mueller to consider:

(1) Should Headquarters urge the Centers to make stronger efforts in the area of competitive procurement of follow-on hardware?

(2) What should the long-term policy be regarding the systems engineering role of Bellcomm, Inc., in AAP and advanced missions?

Memorandum, John H. Disher to George E. Mueller, "AAP Problems," 23 December 1966; note, John H. Disher to George E. Mueller, "Additional AAP Questions for Dr. Mueller's Consideration," 28 December 1966.

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NASA Hq officially promulgated mission objectives of the AAP–1 and AAP–2 flights. They were to conduct a low-altitude, low-inclination Earth-orbital mission with a three-man crew for a maximum of 28 days using a spent S–IVB stage as an OWS; to provide for reactivation and reuse of the OWS for subsequent missions within one year from initial launch; and to perform test operations with the lunar mapping and survey system in Earth orbit.

NASA Hq, SAA Directive No. 3A, 30 December 1966.

1967 January 4

John H. Disher, Deputy Director of Saturn Apollo Applications, established specific design criteria for the OWS mission. These criteria required MSFC to proceed with the design of the MDA and the integration of experiments into it for launch stowage. It also required MSFC to perform systems engineering analyses on the OWS ensuring its compatibility with the baseline configuration of the MDA. MSC was required to take action necessary for integration of government-furnished solar cells into the MDA and to examine the rechargeable battery capacity required for independent operation from the CSM.

Letter, John H. Disher to R. F. Thompson, MSC, and L. F. Belew, MSFC, "Orbital Workshop Configuration for 1968–1969 AAP Missions," 4 January 1967.

10

A Science and Applications Directorate was established at MSC to plan and implement MSC programs in space science and applications, act as the MSC focal point in these programs, and provide the Center's point of contact with the scientific community. Establishment of the Science and Application Directorate reflected the growing significance and responsibilities of MSC in these areas. The position of Director for the new organization was not filled at this time. Wilmot N. Hess was later named Director; Robert O. Piland, Deputy Director.

MSC Announcement 67–7, 10 January 1967; MSC Announcement 67–27, 17 February 1967.

16

MSC requested assistance from LaRC through use of the Langley full-scale rendezvous docking simulator to provide data for AAP docking requirements. It was anticipated that the docking of the lunar mapping and survey system to the OWS would partially obstruct the pilots' view, and that the CSM payload configuration would have sluggish handling qualities in both translation and rotation. A study using the Langley full-scale rendezvous docking simulator would provide useful data for the AAP docking requirements.

Letter, George M. Low, MSC, for Robert R. Gilruth, MSC, to F. L. Thompson, LaRC, "Simulation of Apollo Applications Program docking," 16 January 1967.

26

At a NASA Hq briefing, Associate Administrator for Manned Space Flight George E. Mueller stated that NASA planned to form an "embryonic space station" in 1968–69 by clustering four AAP payloads launched at different times. The first mission would be the launch of a manned spacecraft followed several days later

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by a spent S–IVB stage converted into an OWS. After the two spacecraft had docked, the crew would enter the Workshop through an airlock. Twenty-eight days later they would passivate the OWS and return to Earth in their spacecraft. In three to six months, a second manned spacecraft would be launched on a 56-day mission to deliver a resupply module to the OWS and to rendezvous with an unmanned ATM, the fourth and last launch of the series. The cluster would be joined together using the multiple docking adapter. Emphasizing the importance of manning the ATM, Mueller said that "if there is one thing the scientific community is agreed on it is that when you want to have a major telescope instrument in space it needs to be manned."

NASA Apollo Applications Briefing, 26 January 1967.

27

Apollo Spacecraft Program Manager Joseph F. Shea sent a flash report to NASA Hq: "During a simulated countdown for mission AS–204 on January 27, 1967, an accident occurred in CM 012. This was a manned test with the prime astronaut crew onboard. A fire occurred inside the command module resulting in the death of the three astronauts [Virgil I. Grissom, Roger B. Chaffee, and Edward H. White, II] and as yet undetermined damage to the command and service modules." (See also 24 May 1967 entry.)

TWX, Joseph F. Shea to NASA Hq, Attn: Apollo Program Director, 28 January 1967.

February

1

Despite the fact that crew assignments for the ATM flight had not yet been made, Saturn/Apollo Applications Program Director Charles W. Mathews recommended to MSC AAP Manager Robert F. Thompson that scientist astronauts who had been participating in the ATM program at Huntsville be given an opportunity to visit a number of leading astronomical observatories in the country. In this manner, Mathews said, potential crew members could derive a better understanding of the equipment being employed, operation techniques being used, and the nature and types of observations being made.

Letter, Charles W. Mathews to Robert F. Thompson, "Apollo Telescope Mount (ATM) Scientist/Astronauts' Familiarization with Ground-Based Observatories," 1 February 1967.

2

The AAP experiments program was divided into two primary phases of activity—definition and development. During the definition phase, one of the major problems was the selection and definition of high-quality experiments from which a well-rounded experiments program could be identified in time to effectively support the planning of future missions and flight programs. Once the experiments were defined and approved for flight, the experiment passed into the development phase with somewhat different problems. During this second phase, such facets as program direction, resource requirements, program status, and problems encountered in experiment implementation were of primary concern.

Letters, George E. Mueller, NASA Hq, to Wernher von Braun, MSFC, 2 February 1967; Wernher von Braun to George E. Mueller, 2 March 1967.

1967

February

21

NASA awarded Allis-Chalmers Manufacturing Company a contract to continue AAP fuel cell work. Under the new agreement, the contractor was to improve system performance leading to a 2500-hour operational lifetime.

NASA News Release 67-33, "Contract Set for Fuel Cell Power System," 21 February 1967.

23-25

A meeting at NASA Hq reviewed the status of mission configurations for the AAP-1/AAP-2, AAP-3, and AAP-4. Agreement was reached on a baseline description for the first four flights.

Letter, Charles W. Mathews, NASA Hq, to Robert F. Thompson, MSC, 9 March 1967.

28

A fundamental principle of AAP planning and implementation was the use of Apollo-developed components, subsystems, and operating procedures with no modifications wherever possible. By rigorous application of this principle, the cost of doing business in manned space exploration would be reduced, thus helping to ensure a continuing program leading to the next generation of manned space systems.

Letters, Charles W. Mathews, NASA Hq, to Robert F. Thompson, MSC, "CSM Earth Orbital Mission Capabilities," 28 February 1967; Maurice J. Raffensperger, NASA Hq, to W. E. Stoney, MSC, 22 February 1967.

March

6

George S. Trimble, Jr., joined NASA as Director of the Advanced Manned Missions Program, Office of Manned Space Flight, succeeding Edward Z. Gray, who resigned. Before joining NASA, Trimble had served as Vice President–Advanced Programs, The Martin Company, Baltimore, since 1960.

NASA News Release 67-44, "Trimble Appointed in Manned Flight Future Missions," 6 March 1967.

9

To facilitate program management operations involving inter-Center activities, Saturn/AAP Director Charles W. Mathews created an AAP Inter-Center Interface Panel structure. Panels included mechanical, electrical, instrumentation and communications, and mission evaluation. Two weeks later, Mathews added three more panels to the structure: mission requirements, systems integration, and systems safety.

Letters, Charles W. Mathews, NASA Hq, to MSC, Attn: AAP Program Manager, "Establishment of AAP Inter-Center Interface Panel Structure," 9 March 1967, and 24 March 1967; Apollo Applications Program Directive No. 7, "Establishment of AAP Inter-Center Interface Panel Organization," 21 September 1967.

1967

March

15 The Naval Research Laboratory awarded a subcontract to Ball Brothers Research Corporation for the production of the Apollo telescope mount NRL experiments. Prior subcontracts had been let with Ball for production of the High Altitude Observatory experiment on 11 January 1965, and for the Harvard College Observatory experiment on 27 December 1966. Development responsibility was transferred from Goddard Space Flight Center to MSFC.

NRL Contract N00014–67–C–0470, 1 June 1967.

17 Donald K. Slayton, MSC Director of Flight Crew Operations, expressed concern over the excessive number of experiments assigned to the first AAP mission. Experimenters had requested 672 man-hours for inflight accomplishment of experiments, where only 429 man-hours were available, creating a deficit of 243 inflight man-hours. The same problem was applicable to premission experiment training. Experimenters were requesting 485 hours per man for premission experiment training, where only 200 hours per man were available, creating a deficit of 285 hours per man.

Memorandum, Donald K. Slayton to Assistant Manager AAP, "Apollo Applications Mission 'A' experiments," 17 March 1967.

20 MSFC awarded Bendix Corporation a contract for development and production of the ATM pointing control system. The control system would enable astronauts to point a telescope at selected regions of the Sun during periods of maximum solar flare activity. MSFC had earlier awarded American Optical Company a contract to build a dynamic simulator for use in developing the pointing control system.

NASA News Release 67–66, "Bendix Awarded ATM Point-Control System Contract," 20 March 1967.

24 In response to AAP Assistant Manager Robert F. Thompson's request for technical support for AAP from existing Apollo contractors, Robert G. Chilton of the Guidance and Control Division recommended that the Massachusetts Institute of Technology Instrument Laboratory (MIT/IL), designer of the Apollo guidance and navigation system, be given the task of determining the suitability of the Apollo guidance and navigation system to perform the AAP missions. Since this task was of "prime importance at this stage of AAP planning," Chilton recommended that it have "immediate priority."

Memorandum, Robert G. Chilton, MSC, to Assistant Manager, AAP Office, "Apollo Applications Program (AAP) design analysis task for MIT/IL," 24 March 1967.

24 In accordance with design discussions and decisions reached during discussions several days earlier, AAP Director Charles W. Mathews directed Center AAP Managers to implement a modified OWS electrical power system. Because of increased electrical power requirements resulting from making the OWS a habit-

1967
March

able laboratory, solar cell arrays were added to each side of the S-IVB stage to provide most of the electrical power used during AAP cluster operation. (Before this design shift, the CSM's fuel cells had been considered the primary source of power.) In addition, the ATM would still have its own solar array panels and power system.

Letter, Charles W. Mathews to R. F. Thompson, MSC, L. F. Belew, MSFC, and R. C. Hock, KSC, "Electrical Power Supply for S-IVB Workshop," 24 March 1967.

27

NASA stated that the purposes of Apollo Applications missions 3 and 4 were to

- Increase man's knowledge of the characteristics of the Sun by conducting solar astronomy observations in space during a time of maximum solar activity.
- Conduct an operational evaluation of the performance characteristics of a manned solar astronomy system to provide engineering and scientific data essential to the development of advanced orbital solar and stellar observation systems.
- Demonstrate feasibility of

(1) Reactivating an OWS that has been left unattended in Earth orbit for several months.

(2) Reusing the OWS as a base of operations for the conduct of experiments in solar astronomy, science, applications, technology, engineering, and medicine.

- Qualify man, evaluate his support requirements, and determine human task performance capabilities on long-duration manned space flight missions.

AAP Directive No. 5, 27 March 1967.

April
3–12

Technicians from MSC's Landing and Recovery Division conducted demonstrations of land-landing at Ft. Hood, Texas, on 6, 11, and 12 April. The demonstrations were part of MSC's effort to develop an advanced system to provide a land-landing capability for the Apollo Applications Program, an improved launch abort situation, and reduced horizontal velocities for water landings.

Memorandum, C. C. Kraft, Jr., MSC, to Dist., "Advanced Landing System Operational Demonstration," 3 April 1967.

6

Donald K. Slayton, MSC Director of Flight Crew Operations, requested that the proposed T-020 "Jet Shoes" experiment be removed from all AAP flights. The "Jet Shoes" experiment was an astronaut maneuvering system consisting of two small thrusters mounted one beneath each foot and oriented so that the thrust vectors passed close to the center of body mass with legs and feet in a comfortable position.

During January, an engineering development model of the "Jet Shoes" was tested by several astronauts on the MSC air bearing facility in cooperation with the Principal Investigator. Although the tests by the astronauts were shirt-sleeve runs,

1967
April

an LaRC test pilot made several runs in an inflated pressure suit. The results were unsatisfactory. In his objections to the experiment, Slayton suggested that its attempted use by an astronaut wearing a life support unit would provide extremely poor visibility.

Memorandum, Donald K. Slayton to Assistant Manager, MSC AAP, "Request for removing the T–020 'Jet Shoes' Experiment from all AAP flights," 6 April 1967.

11 An AAP schedules meeting attended by the Center AAP Managers and the Headquarters' Directors was held on 31 March 1967 at NASA Hq. Consensus was that the airlock-multiple docking adapter tasks were well detailed and that the projected schedule for AAP–2 (Orbital Workshop operations) was realistic.

Memorandum, C. W. Mathews, NASA Hq, to M/Associate Administrator for Manned Space Flight, "Schedule Assessment of AAP 1–4," 11 April 1967.

13 An informal presentation was made to NASA-KSC by Grumman Aircraft Engineering Corporation proposing Grumman as the integrating contractor for the hardware and facility modification phase at Launch Complex 37 (LC–37) for all phases of AAP activities on LC–37. The presentation defined the work and schedules confronting NASA at LC–37 for the AAP.

Memorandum, L. P. Lopresti and E. T. Barron, Grumman, to G. M. Skurla, KSC, "Proposal to make GAEC the integrating contractor on LC–37 for post LM–1 launch," 13 April 1967.

18–19 A meeting was held at MSFC to review the S–IVB stage for acceptability as a habitable vehicle. Personnel from MSC and MSFC attended. A presentation on the flammability testing of the liquid hydrogen tank insulation with an aluminum foil flame retardative liner was made by MSFC personnel. During the course of the meeting, various actions were established relating to habitability requirements of the S–IVB.

Minutes of MSC/MSFC Saturn S–IVB Habitability Review, 18–19 April 1967.

27 NASA awarded contracts to General Electric and Lockheed to conduct four-month parallel studies of a medical laboratory to support AAP missions. Designated the integrated medical and behavioral laboratory measurement system, the laboratory would permit detailed evaluation of body systems and crew functions during flight. It could be flown as a complete laboratory or as selected groups of measurement instruments on specific missions.

NASA News Release 67–102, "Apollo Application Studies Set," 27 April 1967.

28 The McDonnell Company and Douglas Aircraft Company merged to form McDonnell Douglas Corporation.

Telecon, R. Newkirk, HSCC, with F. Morgan, McDonnell Douglas, 15 October 1974.

1967

Both MSFC and MSC recognized the existence of a potential interference of contaminant materials in the vicinity of manned spacecraft with the optical equipment on the ATM. It was also recognized that certain building materials that might create contaminate problems needed to be avoided in the ATM structure. A considerable activity concerning this contamination problem had already developed at MSFC, MSC, NASA OSSA, some contractor plants, and the ATM Principal Investigators.

May 1

Letters, Wernher von Braun, MSFC, to Robert R. Gilruth, MSC, 8 March 1967; Robert R. Gilruth to Wernher von Braun, 1 May 1967.

A preliminary design review was conducted at MSFC during 2–10 May 1967 to evaluate the basic design approach of the MSFC/MSC/McDonnell Douglas team relative to the spent-stage aspects of the Orbital Workshop project. Purpose of the review was to define a baseline design on as many subsystems as possible and to define steps leading to a baseline on the remaining subsystems.

2–10

Letter, Chairman, Orbital Workshop Preliminary Design Review to Dist., "Minutes of Orbital Workshop (OWS) Preliminary Design Review (PDR) During May 2–10, 1967, at MSFC," 24 May 1967.

Confidence in any selected course of action in committing man to the space vehicle environment had grown slowly, based on actual experience. In this respect NASA had followed the philosophy of incremental exposure, generally doubling the duration of successive manned missions as long as no unforeseen medical problems were encountered in crews returning from space flight. This enabled NASA to acquire biomedical information from which to begin formulation of general statements about the effects of the space flight environment on human physiology.

4

Memoranda, J. Bollerud, NASA Hq, to C. W. Mathews, NASA Hq, "Preliminary Ideas Regarding Rotation of Crews in AAP Missions," 10 January 1967; C. W. Mathews to J. Bollerud, "Crew Rotation in AAP Missions," 2 March 1967; A. D. Catterson, MSC, to Julian West, MSC, "Crew Rotation for Long Duration Manned Space Flight," 4 May 1967.

Some significant features of a revised Apollo and AAP-integrated program plan were: CSM would be available to support the first four AAP launches; AAP–1/AAP–2 in early 1969 were to accomplish OWS objectives; AAP–3/AAP–4 in mid-1969 were to accomplish the 56-day ATM objectives in conjunction with reuse of the OWS. Two additional AAP flights were planned for 1969 to revisit the OWS and the ATM using refurbished command modules flown initially on Earth-orbit Apollo flights in 1968. AAP missions planned for low Earth orbit during 1970 would utilize two dual launches (one manned CSM and one unmanned experiment module per dual launch) and two single-launch, long-duration CSM to establish and maintain near-continuous operation of the OWS cluster and a second ATM.

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1967

Memorandum, George E. Mueller, NASA Hq, to Deputy Administrator, "Revised Apollo and AAP Integrated Program Plan," 5 May 1967.

May

5 Grumman Aircraft Engineering Corporation presented to the MSC AAP Office a preliminary statement of work and cost proposal for developing the LM as an ATM for the AAP–4 mission. The AAP staff then began reviewing the proposal which described the work necessary to develop the final LM–ATM spacecraft configuration.

MSC, "AAPO Weekly Activity Report," 10 May 1967.

8 Required changes in the Apollo Applications Program flight schedules resulted in plans for the Earth-orbital test of the lunar mapping and scientific survey (LM&SS) as part of a single launch mission unrelated to the Orbital Workshop. The mission would have the primary objective of conducting manned experiments in space sciences and advanced technology and engineering, including the Earth-orbital simulation of LM&SS lunar operations. The LM&SS would be jettisoned after completing its Earth-orbital test. Planned launch date for the mission was 15 September 1968.

Letter, C. W. Mathews, NASA Hq, to R. F. Thompson, MSC, "Earth Orbital Test of LM&SS," 8 May 1967.

11 The AAP Office (NASA Hq) was preparing a draft task definition for a proposed command module modification contract. It would include primary and alternate locations for work; proposed interface of the modification contractor with North American; timing of the work effort; and definition of the work to be performed. Purpose of the proposed contract was to modify and refurbish Apollo hardware for AAP.

Memorandum for record, J. R. Biggs, NASA Hq, "Apollo Procurement, Program, and Organization Action Items," 11 May 1967.

12 Release of a staff paper by J. Bollerud and C. Berry recommending a 35-kilonewtons-per-sq-m 69-percent-oxygen, 31-percent-nitrogen, shirt-sleeve atmosphere in the OWS initiated a discussion as to its impact on engineering design and operational plans, as well as the physiological response of test subjects to a one-gas (pure oxygen) system over extended periods of time. The consensus was that the 35-kilonewton (5 psia) oxygen-nitrogen for the OWS would best serve the needs of the OWS Earth-orbiting program.

Letters, George E. Mueller, NASA Hq, to Wernher von Braun, MSFC, 22 December 1966; Robert R. Gilruth, MSC, to George E. Mueller, 12 May 1967; memoranda, D. R. Hagner, Bellcomm, to John H. Disher, NASA Hq, "Comments on Draft ltr. from W. von Braun to G. E. Mueller re two-gas atmosphere in the S–IVB Workshop," 24 January 1967; E. Z. Gray, NASA Hq, to Deputy Associate Administrator (Programs), "Two-Gas Systems," 2 February 1967; J. Bollerud, NASA Hq, and C. Berry, MSC, staff paper, "Two-Gas Atmospheres for Prolonged Manned Space Missions in the S–IVB Workshop," December 1966.

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15

Guidelines and a set of minimum requirements to be met by each Center in establishing their configuration management systems for AAP were prescribed by NASA Hq. Configuration management systems would be progressively applied as individual projects matured. Once documentation such as a program or project baseline description had been officially issued, or documentation approved at formal design reviews such as a preliminary design review or critical design review, changes to such documentation would require formal approval through configuration management procedures, thereby establishing full configuration control at the critical design review.

Letters, C. W. Mathews, NASA Hq, to R. F. Thompson, MSC, L. F. Belew, MSFC, and R. C. Hock, KSC, "Documentation of Configuration of Hardware at Time of Turnover to AAP from Apollo," 13 March 1967; C. W. Mathews to R. F. Thompson, L. F. Belew, and R. C. Hock, "Configuration Management," 15 May 1967.

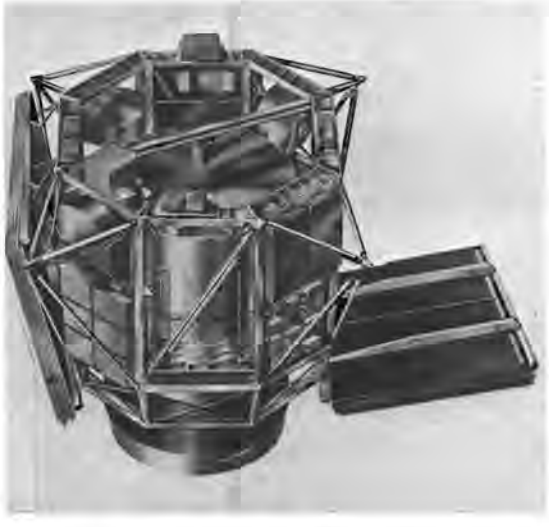
23

Flight training hardware, identical in configuration to the flight hardware except that it need not be flight qualified, was required for training purposes. The training hardware consisted of those components of experiment hardware that required manipulation, handling, observation, or other usage by astronauts during flight. Neutral buoyancy training hardware was also required for underwater zero-g simulation training.

Letter, R. F. Thompson, MSC, to L. F. Belew, MSFC, et al., "Experiment training hardware requirements," 23 May 1967.

24

The ATM would offer a unique combination of several important advantages over previous manned orbital astronomical experiments, ground-based observatories, and unmanned orbital observatories. It would be the first U.S. manned mission with a primary goal of recovering scientific data. The ability to observe the Sun in previously inaccessible but important regions of the electromagnetic spectrum, to observe the details on the solar disk and in the corona for nearly two solar rotations, and to react rapidly to unpredictable and unexpected occur-



An early version of the Apollo telescope mount.

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May

rences with instruments of high data acquisition capabilities would be an unprecedented combination of opportunities available only to the crewman operating the ATM. However, it was essential to recognize that the crewman's ability to observe, exercise judgment, and efficiently conduct the routine experiment tasks, as well as to rapidly respond to unpredictable phenomena would be contingent upon the existence of displays in the proper wavelength regions with sufficient resolution to observe the important features on the solar disk. Also necessary would be controls which would combine simplicity and versatility to facilitate equipment setup for data acquisition.

Letter, D. K. Slayton, MSC, to R. F. Thompson, MSC, "Flight Crew Operations Directorate Requirements and Philosophy on ATM Displays and Controls," 24 May 1967.

24

Because of the Apollo 204 accident in January and the resulting program delays, NASA realigned its Apollo and AAP launch schedules. The new AAP schedule called for 25 Saturn IB and 14 Saturn V launches. Major hardware for these launches would be two Workshops flown on Saturn IB vehicles, two Saturn V Workshops, and three ATMs. Under this new schedule, the first Workshop launch would come in January 1969.

NASA Hq Schedule, 24 May 1967.

29

NASA announced that LaRC had selected Northrop Ventura Company to negotiate a contract to conduct a research program (including flight tests) of a flexible parawing for potential use in manned spacecraft landing systems. Northrop Ventura would evaluate the suitability of using a parawing (instead of conventional parachutes) to allow controlled descent in a shallow glide and thus offer wide flexibility in choosing a touchdown point, as well as provide a soft landing impact. The parawing would be evaluated for possible use on the Apollo Applications Program during the early 1970s to achieve a true land-landing mission capability.

NASA News Release 67-134, "NASA Contracts for Parawing Test Program," 29 May 1967.

31

A status review of the studies being conducted by North American Aviation on the AAP command and service modules' electrical power system was held at MSC. It was agreed that North American Aviation should pursue a two-regulator power control and regulation configuration and redundant battery changer configuration. The baseline fuel cell for AAP-1 would use 31-cell, ceria-coated, cobalt-activated fuel cells.

MSC, "AAPO Weekly Activity Report," 31 May 1967.

June

1

The Apollo Applications missions were designed to build upon the base of flight experience, ground facilities, and trained manpower developed in past programs.

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Each mission was designed to take full advantage of the Apollo Saturn system to make significant contributions to a wide range of objectives. Missions were planned to gain experience, test theory, perform experiments, and collect data.

Key elements of the planning included the decision to use, modify, and expand Apollo systems capabilities and to reuse basic hardware for multiple missions. Principal objectives of the AAP were the development of an extended flight capability to determine the usefulness of man in space; the conduct of manned astronomical observations from space; and the development of economical space flight through hardware reuse and long-duration flight.

OMSF-NASA, Apollo Applications Program Technical Summary, 1 June 1967.

1

During an informal discussion held in the Office of the Deputy Administrator, the AAP Office recommended that steps be taken to select a modification and refurbishment contractor to engage in a study of modification and refurbishment task requirements. The study would enable NASA to determine the feasibility of following a modification and refurbishment route for AAP.

Memorandum for record, R. C. Seamans, Jr., NASA Hq, "June 1, 1967, meeting to discuss AAP payloads," 1 June 1967.

5–13

An Apollo Applications Program test review group, consisting of personnel from MSC, MSFC, and McDonnell, met in St. Louis on 5 June. The purpose of the meeting was a further definition of the ground rules governing the proposed integrated structural testing of the MDA/AM and to review the test requirements for compatibility. A second meeting of the group was held 13 June to review MSC, MSFC, and McDonnell facilities schedules to select a test site.

MSC, "AAPO Weekly Activity Report," 14 June 1967.

6

Kurt H. Debus, KSC Director, expressed concern that a proposal, if adopted, for a separate command and service modules launch contractor for AAP would create a very difficult operational environment. Debus said it was difficult to see how KSC could have two separate contractor teams responsible for checking out substantially the same kind of stage hardware on the same test equipment, when the schedule would require simultaneous operations or at least intermittent sequential activity by both contractors in the same facilities. KSC was already coping with the challenge of integrating, within common facilities, the work of six Apollo contractors preparing separate stages with separately assigned checkout equipment. A most serious problem would be the interference with ongoing mainline Apollo operations created by the activity of a new contractor attempting to familiarize himself with facilities, equipment, and procedures in the same timeframe as the most critical Apollo missions.

Letter, Kurt H. Debus to George E. Mueller, NASA Hq, 6 June 1967.

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6 At an American Institute of Aeronautics and Astronautics meeting in Washington, Associate Administrator for Manned Space Flight George E. Mueller outlined a number of innovations in AAP to achieve reductions in the unit cost of future space missions: (1) reuse of command modules; (2) land landing, which would greatly facilitate such spacecraft reuse; (3) "double use" of the S–IVB as both a propulsive stage and an OWS once in orbit; (4) repeated use of the OWS during a series of missions; (5) flights of increasingly longer duration (approaching perhaps a year or more); and employment of existing Apollo flight hardware, physical facilities, management expertise, and industrial organizations once they became available. Thus, said Mueller, AAP would evaluate man's usefulness in space at a relatively low cost, and that measurement would be "obtained by doing useful things—astronomical observation, extended exploration of the moon and experiments with sensing equipment that can lead to benefits of enormous significance to all mankind."

Astronautics and Aeronautics, 1967, p. 178.

19 The purposes of the AAP–1/AAP–2 mission were (1) to conduct a low-altitude, low-inclination, Earth-orbital mission with a crew of three men, open ended to 28 days' duration, using a spent S–IVB stage as an OWS; (2) to provide for reactivation and reuse of the OWS during subsequent missions occurring up to 1 year later; (3) to conduct inflight experiments in the areas of science, applications, technology, engineering, and medicine; and (4) to qualify man, evaluate his support requirements, and determine human task performance capability on long-duration manned space flight missions.

Objectives of the mission were to (1) demonstrate rendezvous and hard docking of the command and service modules to the multiple docking adapter; (2) determine the feasibility of operating the OWS as a habitable space structure for an extended period; and (3) obtain data to evaluate space flight environmental effects on the crew of a mission duration of 28 days.

AAP Directive No. 3B, "Flight Mission Directive for Mission AAP–1/AAP–2," 19 June 1967.

19–21 MSFC and MSC representatives met with Principal Investigators at MSC where detailed briefings on the ATM were held. This was the final briefing of a series on ATM systems and experiments.

MSC, "AAPO Weekly Activity Report," 28 June 1967.

21 Both North American and Grumman were out of funds on Apollo Applications Program contracts. Procurement plans for follow-on effort with both contractors were in Headquarters for approval. North American was limiting its effort to AAP–1 and AAP–2. No work peculiar to AAP–3 and AAP–4 was being accomplished. Grumman was continuing operations using its own funds.

MSC, "AAPO Weekly Activity Report," 21 June 1967.

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28

Donald K. Slayton and Christopher C. Kraft, Jr., of MSC stated that it was mandatory, in their opinion, to launch the unmanned vehicle first in the AAP–1/AAP–2 mission. Reasons cited were the following:

- If the unmanned vehicle failed to achieve orbit or could not be made to function once in orbit, the CSM would not be launched as planned. This would eliminate subjecting the flight crew to the potentially hazardous conditions of booster-powered flight, service propulsion system circularization burn, retrofire, reentry, landing, and recovery. It would also save costs, since the CSM could be used for another mission.
- Operationally, it would be more feasible to ascertain that an unknown configuration could withstand a launch phase than to commit a proven space vehicle without this knowledge.

Memorandum, C. C. Kraft, Jr., and D. K. Slayton to R. F. Thompson, MSC, "Unmanned versus manned launch sequence for AAP mission 1/2," 28 June 1967.

30

Prenegotiation factfinding sessions with Grumman were completed at MSC. Agreement was reached on the statement of work for the final definition (phase C) of the LM for the first LM/ATM mission and continued definition study (phase B) for utilization of the LM. Grumman cost proposals were discussed from the manning aspect only. Dollar figure discussion was delayed pending verification of bid rates.

MSC, "AAPO Weekly Activity Report," 5 July 1967.

July
3

MSC established an Apollo Applications Program Mission Design Information Group within the Mission Planning and Analysis Division. Function of the new group was to establish mission planning information requirements, acquire the necessary information, and integrate and publish the information in support of mission planning milestones. Data categories included such items as configuration, propulsion, aerodynamics, sequences of events inherent in spacecraft design, consumables, electrical power, environmental control, communications, thrust vector control, guidance and navigation, and mass properties.

MSC Announcement 67–101, "Apollo Applications Program Mission Design Information Group," 3 July 1967.

5

MSFC and MSC personnel met at MSC to resolve action items from a Headquarters test meeting held on 30 March. The action items involved the LM/ATM thermal vacuum test program. General agreement was reached on test configuration, with MSC supporting the MSFC position that a thermal vacuum test was necessary on the ATM flight unit. MSC agreed to conduct a chamber contamination test with jointly agreed upon procedures.

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MSC, "AAPO Weekly Activity Report," 5 July 1967.

July

11

Increased activity and interest in the ATM project created the necessity for conducting ATM monthly project reviews in the Office of Manned Space Flight. MSFC provided the principal inputs on such aspects as schedules, funding, and technical performance. Material covered progress achieved during the month, current problems, and actions taken.

Letter, C. W. Mathews, NASA Hq, to R. F. Thompson, MSC, "Apollo Telescope Mount Monthly Project Review," 11 July 1967.

12

Detailed discussions by MSC representatives with Lockheed and Martin were completed on the planned AAP–A and AAP–B carrier definition studies which were to be accomplished during the next 60 days. Discussions had begun on 27 June. A common work statement was prepared and forwarded to MSFC for release to the contractors. Additional meetings were planned with both contractors to familiarize them with MSC engineering and operations organizations.

MSC, "AAPO Weekly Activity Report," 12 July 1967.

24

A factfinding tour of NASA's major manned space flight facilities at the end of June by Deputy Administrator Robert C. Seamans, Jr., and top members of the Administrator's immediate staff produced a broad evaluation of the program roles and workloads of the various Centers in light of coming Apollo accomplishments and transition to other manned space flight programs. In regard to AAP, staff members recommended to Seamans that flight schedules be stretched out to reduce costs, and that the agency investigate the feasibility of including Earth-sensing payloads aboard the basic Apollo AAP spacecraft. In part, study of Earth-sensing payloads should include definition of those payloads per se; launch vehicle requirements to achieve high-inclination Earth orbits; development status of the AAP cluster hardware for the Orbital Workshop; definition of biomedical technology; and experiment requirements at MSC.

Letter, C. R. Praktish, NASA Hq, to R. C. Seamans, Jr., NASA Hq, "Report Covering Visits to KSC, MSFC, MTF, Michoud, and MSC—June 26–June 28, 1967," 24 July 1967.

25–26

An ad hoc committee formed to establish the criteria for combined AM/MDA manned altitude chamber testing met at MSC. Agreement was reached on ground rules for the detailed planning of the mated vehicle test program and for the proposed test flow of the combined vehicle.

MSC, "AAPO Weekly Activity Report," 2 August 1967.

26

NASA selected the Martin Marietta Corporation, Denver Division, for negotiation of a 27-month contract for payload integration of experiments and experiments support equipment in space vehicles for the AAP. Initial work of the contractor

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involved the OWS and ATM at MSFC; meteorological and Earth resources payloads at MSC; and test integration planning and support for launch operations at KSC.

NASA News Release 67–199, "Contract Set With Martin Co. for AAP," 26 July 1967; memoranda, L. W. Vogel, NASA Hq, to Associate Administrator for Manned Space Flight, "Selection of Contractor to Accomplish Apollo Applications Program Payload Integration (Phase D)," 27 July 1967; G. E. Mueller, NASA Hq, to Deputy Administrator, "AAP Payload Integration Contractor Selection," 18 July 1967.

26

NASA Administrator James E. Webb testified on the NASA FY 1968 authorization bill before the Senate Committee on Appropriations' Subcommittee on Independent Offices. Asked by Sen. Spessard Holland (D–Fla.) to make a choice between a substantial cut in funding for the Apollo Applications Program and the Voyager program, Webb replied that both were vital to the U.S. space effort. "The Apollo Application is a small investment to expend on something you have already spent $15 billion to get and it seems to me that this is important.

"On the other hand, the United States, if it retires from the exploration of the planetary field, in my view, . . . [will face] the most serious consequences because the Russians are going to be moving out there and our knowledge of the forces that exist in the Solar System can affect the Earth and can be used for many purposes to serve mankind or for military power . . . ." Criticized by Sen. Holland for refusing to make a choice, Webb said he did not want "to give aid and comfort to anyone to cut out a program. I think it is essential that we do them both."

U.S. Congress, Senate, Subcommittee of the Committee on Appropriations, *National Aeronautics and Space Administration Appropriations for Fiscal Year 1968: Hearings on H.R. 12474*, 90th Cong., 1st sess., 1967, pp. 76–77.

26

NASA awarded The Boeing Company a contract for long-lead-time materials (such as propellant ducts and fuel tank components) for two additional Saturn V's. This contract marked the first Saturn V procurement in support of Apollo Applications Program.

NASA News Release 67–200, "NASA Orders 2 Saturn V's for Post-Apollo," 26 July 1967.

27

MSFC effected a reorganization to meet the needs of systems engineering and integration for AAP. A Systems Engineering Office was established as an integral part of the AAP Office, with responsibility for all AAP systems engineering. In addition, the central Research and Development Systems Engineering Office was strengthened to provide a focal point for the concentration of systems engineering in support of all assigned programs.

Letters, George E. Mueller, NASA Hq, to Wernher von Braun, MSFC, 30 June 1967; Wernher von Braun to George E. Mueller, 27 July 1967.

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July

27 NASA extended its Science and Technology Advisory Committee for Manned Space Flight for two more years. Purpose of the committee was to advise the Associate Administrator for Manned Space Flight on the scientific and technical content of manned space flight programs and on methods for obtaining maximum use of the scientific and engineering talents and knowledge required for the success of the manned space flight program.

NASA News Release 67–202, "Manned Science Group to Serve Two More Years," 27 July 1967.

28 At a design meeting in Huntsville, designers decided to incorporate the Orbital Workshop's two floors into one common grated floor in the crew quarters to save weight. This concept called for the crew quarters to be on one side of the floor and a large open area on the opposite side permitting intravehicular activity in the hydrogen tank dome.

MSFC, Orbital Workshop Status Meeting minutes, 28 July 1967.

August

1 NASA's Office of Manned Space Flight and Office of Advanced Research and Technology were engaged in a cooperative program to develop the technology of flexible wings for spacecraft recovery. The technology was expected to have broad applicability in the Apollo Applications Program, as well as follow-on manned space flight programs. The principal technology effort would concentrate on parawing and sailwing configurations. LaRC would manage the parawing technology program with support from MSC. The sailwing technology effort would be managed by MSC with LaRC providing wind tunnel support.

Memorandum of understanding, Charles W. Mathews, NASA Hq, and M. B. Ames, Jr., NASA Hq, "OMSF/OART Cooperative Parawing/Sailwing Technology Program," 28 July and 1 August 1967.

1 Representatives of McDonnell Douglas and Grumman met with MSC personnel to discuss the feasibility of installing lunar module radar transponders on the airlock module. Several problems were identified, but the concept appeared feasible. Problems involved the thermal and electrical power interface electronic package with the AM and the electromagnetic radiation pattern of the antenna. McDonnell Douglas and Grumman were to work on the interface problems and MSC was to conduct pattern tests to identify and determine magnitude of the radar null zones.

MSC, "AAPO Weekly Activity Report," 9 August 1967.

2 NASA decided to terminate all activity associated with the hardware and software procurement, development, and testing for the lunar mapping and survey system. The purpose of the system was to provide site certification capability to the most scientifically interesting areas on the lunar surface for the AAP.

TWX, Charles W. Mathews, NASA Hq, to Robert F. Thompson, MSC, R. O. Piland, MSC, Leland F. Belew, MSFC, and R. C. Hock, KSC, 2 August 1967.

1967
August

2

NASA defined requirements and responsibilities to initiate the actions necessary for the execution of the AAP–IA mission. It defined the mission purpose, mission objectives, and Center responsibilities for implementation of the mission, as well as the general flight plan, configuration, and supporting ground test constraints.

AAP Directive No. 6, "Flight Mission Directive For AAP–1A," 2 August 1967.

10

Justifying the validity of the Apollo Applications Program (AAP), George E. Mueller discussed the development of AAP. In outlining some of the significant decisions and changes, Mueller showed that the evolution of the program plan had taken place in an orderly fashion, with the Centers participating in the planning process. He stated that the program had progressed in spite of complicating factors such as the impact of the Apollo 204 accident and the adjustments required by congressional funding.

Memorandum, George E. Mueller, NASA Hq, to NASA Deputy Administrator Robert C. Seamans, Jr., 10 August 1967.

23

The ATM required a closely controlled environment during manufacture, quality checkout, and flight checkout activities. To ensure the required control of cleanliness, temperature, and humidity, two buildings were required at MSFC—one for the manufacturing process, the other for quality checkout. An environmentally controlled area was also required at KSC for flight checkout of the ATM.

Memoranda, E. H. Cagle, MSFC, to C. L. Dykes, MSFC, "Environmentally Controlled Rooms for the ATM," 23 August 1967; E. H. Cagle to Dist., "Minutes of MSFC/MSC ATM Thermal Vacuum Meeting," 22 August 1967.

29

In a letter to Saturn Apollo Applications Director Charles W. Mathews, MSC's AAP Assistant Manager Robert F. Thompson presented Houston's philosophy regarding major AAP reprogramming. Two factors, Thompson said, underlay the necessity for planning alterations: (1) the likelihood of funding cutbacks during 1968 and 1969 and (2) a clearer picture of how much Apollo hardware AAP might inherit, as Apollo reprogramming matured after the 204 accident. Thompson then set forth MSC's recommendations for the next phase of AAP planning: a manned Earth-orbital mission during 1969; two manned flights of 28 and 56 days using the OWS during 1970; a manned AAP/ATM flight during 1971; long-duration (two months to one year) manned flights during late 1971 and 1972; and manned lunar missions (including surface operations) in the post-Apollo period. In defining the AAP missions, however, Thompson stressed that until the Apollo goal of landing on the Moon had been achieved, AAP must be looked on as an "alternate to" rather than an "addition to" the main thrust of Apollo. It must be clear throughout the NASA manned space flight establishment

1967

August

that Apollo and AAP would not be overlapping programs and that AAP must not compete with or detract from the main Apollo design.

Letter, Robert F. Thompson to Charles W. Mathews, "Apollo Applications Program Planning," 29 August 1967.

During the Month

The first NASA/North American management meeting was held at Downey, California. At the time, North American was placing major effort on the processing of kit data packages. It was envisioned that a sufficient number of the kits would be processed to cover all AAP requirements. From these, selected ones would be utilized for a specific mission.

History of the Apollo Applications Program, 1966 to September 1, 1968, pp. 2–12.

September

1

MSFC returned a McDonnell Douglas-built S-IVB Orbital Workshop mockup to the contractor's Space Systems Center in Huntington Beach, California, for incorporation of a number of design changes. Following modification, the mockup would represent the S-IVB stage as a manned space laboratory designed for use in the AAP. The design changes included relocation of a floor separating two sections of the stage's liquid hydrogen tank, addition of a ceiling and other fixtures, and relocation of some of the experiment stations.

MSFC, *Skylab Chronology, 1 January–31 December 1967*, p. 71.

5

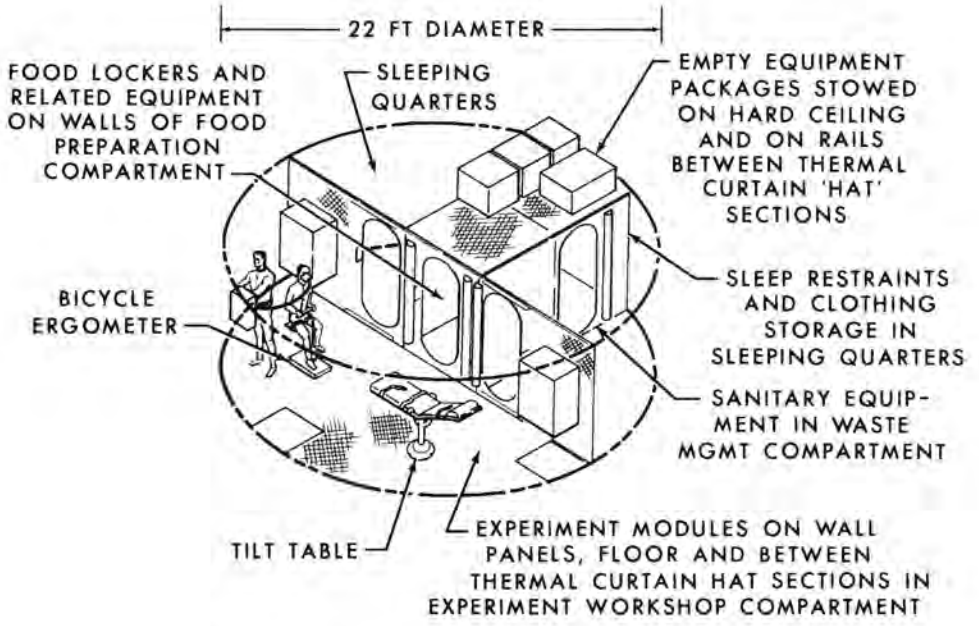
During a manned space flight program review, AAP contractual actions were discussed. It was pointed out that since June there had been no contractual coverage of the North American activity on AAP. It was also pointed out that the Grumman activity on AAP had never been covered by contract and was being funded by Grumman in anticipation of contractual coverage.

Memorandum, F. Magliato, NASA Hq, to Robert C. Seamans, Jr., NASA Hq, "Manned Space Flight Program Review," 13 September 1967.

20

Martin Marietta's Denver Division completed a 60-day study on AAP Mission 1A. The study defined hardware configuration and developed an approach for integrating NASA-designated experiments into AAP-1A. Objectives of the experiments and mission operations were to (1) perform an early evaluation of the operational feasibility of selected Earth resources, bioscientific, meteorology, and astronomy experiments; (2) verify the enhancement of experiments by the presence of man for monitoring, controlling, and interpreting data obtained on orbit; (3) obtain operating experience with available hardware; and (4) extend experiment and mission coverage to 50° latitude. The study showed how the mission objectives could be met.

Martin Marietta Corp., Final Report, *AAP Mission 1A, 60-Day Study*, 20 September 1967.



AAP cluster experiments for S–IVB Orbital Workshop.

1967

September

21

An interface panel organization was established within the NASA Skylab Program for defining, controlling, and resolving inter-Center problems. Among the panels established were mechanical, electrical, instrumentation and communication, mission requirements, launch operation, test planning, and mission evaluation. Panels were responsible for identifying, resolving, and documenting technical problems in coordination of more than one Center. Panels would take necessary action regarding design, analysis, studies, and test and operations within the scope of their charters, to ensure technical compatibility for physical, environmental, functional, and procedural interfaces.

Skylab Program Directive No. 7, 21 September 1967.

22

North American Aviation, Inc., and Rockwell-Standard Corporation merged as North American Rockwell Corporation.

Telecon, R. Newkirk, HSCC, to Lyle Burt, Rockwell International, 15 October 1974.

29

Thomas W. Morgan, USAF, was designated Apollo Applications Program Manager at KSC. Robert C. Hock, who had been Acting Manager since 10 January, became Deputy Manager in addition to his duties as Chief, Advanced Programs Office.

Announcement, KSC to Dist., "Morgan Named Apollo Applications Program Manager," 29 September 1967.

1967
October
2 NASA Deputy Administrator Robert C. Seamans, Jr., resigned. He had joined NASA in September 1960 as an Associate Administrator. In December 1965 he had been appointed Deputy Administrator of NASA by President Lyndon B. Johnson. His resignation would become effective 1 January 1968.

NASA News Release 67-257, "Dr. Seamans' Resignation Announced," 2 October 1967.

3 NASA Hq issued a revised AAP schedule incorporating recent budgetary cutbacks. The schedule reflected the reduction of AAP lunar activity to four missions and of Saturn V Workshop activity to 17 Saturn IB and 7 Saturn V launches. There would be two Workshops launched on Saturn IBs, one Saturn V Workshop, and three ATMs. Launch of the first Workshop was scheduled for March 1970.

NASA Hq Schedule, 3 October 1967.

20 NASA selected Bendix Corporation for negotiation of a contract for design and development of long-duration cryogenic gas storage tanks for use in the first 56-day AAP flight. The contract was expected to require 18 months for completion.

MSC News Release 67-64, 20 October 1967.

20 NASA requested that a joint MSFC/MSC document be prepared identifying each potential crew safety hazard, the successful resolution of these hazards, and test result documentation supporting the resolutions. The effort would include the crew safety/health hazards associated with flammability, micrometeoroid penetration, outgassing, and passivation, and would consider propellant, insulation liner, crew quarters thermal curtain, and other nonmetallic material implications. Since crew safety was fundamental to the design of the OWS, the document would be required prior to the OWS preliminary design review.

Letter, Charles W. Mathews, NASA Hq, to Leland F. Belew, MSFC, and Robert F. Thompson, MSC, "Orbital Workshop—Crew Safety Aspects Request for Joint Actions," 20 October 1967.

23 Minuteman strap-ons for the Saturn IB were canceled as part of the AAP. The studies for AAP on the feasibility of the Minuteman strap-ons were terminated.

TWX, Charles W. Mathews, NASA Hq, to Leland F. Belew, MSFC, Thomas W. Morgan, KSC, and Robert F. Thompson, MSC, "Minuteman Strap-ons For the Saturn IB," 23 October 1967.

26 An active cooling system (fluid circulation) was incorporated into the ATM thermal system to meet temperature control requirements.

Memorandum for record, R. Ise, MSFC, 3 November 1967.

1967

October

31

At KSC, Apollo Applications Program Manager Thomas W. Morgan requested that key personnel in each KSC Directorate participate in design reviews to ensure operational suitability of AAP hardware in the KSC environment, to plan for prelaunch testing of AAP-peculiar hardware and experiments, and to provide general KSC support to AAP.

Memorandum, Thomas W. Morgan to Dist., 31 October 1967.

November

15

A NASA Resident Management Office was established as an extension of both MSFC and MSC at Martin Marietta, Denver Division, to serve as a central point of contact to both Martin Marietta and the Air Force Plant Representative on matters involving the Apollo Applications Program, with immediate emphasis on payload integrations. In addition, it would serve as a focal point for visitor coordination exchange of information and matters of mutual interest to NASA and Martin Marietta.

Letters, Wernher von Braun, MSFC, and Robert R. Gilruth, MSC, to J. D. Rauth, Martin Marietta, 15 November 1967; H. H. Gorman, MSFC, and W. L. Hjornevik, MSC, to F. F. Swan, USAF, 13 November 1967.

15

Representatives from MSC, MSFC, and Grumman met at Huntsville to discuss the LM/ATM testing to be performed at KSC. Purpose of the meeting was to resolve any differences in the testing procedures for the LM/ATM prior to presenting the requirements to KSC.

Letter, Leland F. Belew, MSFC, to Thomas W. Morgan, KSC, "Preliminary test requirements LM/ATM," 17 November 1967.

18–19

During meetings held in Washington and Huntsville, an alternative configurational approach (basis for dry Workshop) for meeting AAP objectives was proposed by MSC as one method of overcoming certain problems that had been identified during the past several months. Following the discussions, it was decided to proceed as programmed. (See 21 May 1968 entry.)

Memorandum for record, John H. Disher, NASA Hq, "Pros and Cons of an Alternate Configurational Approach to Meeting AAP Objectives," 27 November 1967, and "AAP Program Discussion at MSFC on November 19, 1967," 27 November 1967; letters, G. S. Trimble, MSC, for Robert R. Gilruth, MSC, to George E. Mueller, NASA Hq, 14 December 1967.

27–29

NASA's AAP Director Charles W. Mathews stated: "The activities involved in the AAP represent major steps in the utilization of our space capability. The results of this program can serve to establish the direction of future space exploration and applications. In particular, increased knowledge on the effective integration of men into the total system should accomplish much in determining the character, system configurations and operational approach in future programs. The ability to capitalize on the large investments already made in the Apollo program affords the opportunity to carry on this work in Apollo applications in an efficient and economical manner."

1967

November

Charles W. Mathews, "Apollo Applications—A Progress Report" paper presented at the Astronautics International Symposium sponsored by the American Astronautical Society, New York, 27–29 November 1967.

30

The NASA Directors of the Apollo and Apollo Applications Programs Samuel C. Phillips and Charles W. Mathews, in a letter to their MSC counterparts, George M. Low and Robert F. Thompson, said: "Within the scope of the AAP program, it is desirable that an in-depth evaluation of a recovered CM be made as early as possible to fully determine the technical feasibility and economy of refurbishment and reuse of recovered Apollo Command Modules . . . ."

They added that as a prerequisite to test and evaluation for refurbishment potential, salt water corrosive effects must be minimized on recovered spacecraft. This would involve some postflight operations to be performed aboard the recovery ship: dropping the aft heat shield, flushing the pressure shell, and drying and packaging for subsequent test and evaluation.

Low and Thompson were requested to coordinate and jointly establish postflight handling and test requirements for spacecraft 020 in a manner ensuring no impact on the Apollo 6 schedule or the postflight evaluation of the recovered spacecraft.

Letter, Samuel C. Phillips and Charles W. Mathews to George M. Low and Robert F. Thompson, "Post Flight Operations and Tests of S/C 020 for Refurbishment Evaluation," 30 November 1967.

December

1

NASA presented the ATM program to the Astronomy Missions Board at Cambridge, Massachusetts. Considerable interest was shown by the Board regarding crew participation in the ATM mission. The Board recommended an early crew assignment for ATM, so that adequate training in solar physics could be provided, and also recommended that scientist astronauts be assigned as members of the ATM flight crew.

NASA, "Manned Space Flight Weekly Report," 11 December 1967.

4

Robert F. Thompson, Assistant Manager of MSC's Apollo Applications Program Office since its establishment in July 1966, was appointed Manager of that office. The position had been vacant since April 1967 when MSC Deputy Director George M. Low, who had been Acting Manager, became Manager of the Apollo Spacecraft Program Office.

MSC Announcement 67–173, "Manager, Apollo Applications Program Office," 4 December 1967.

7–8

Representatives of MSFC, MSC, Grumman, Martin Marietta, North American, and McDonnell Douglas met at MSC to explore flight vibration levels for application to hardware mounted internal to the spacecraft lunar module adapter (SLA) on an S–IB. All agencies were in agreement that acoustic vibration testing

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December

was the most appropriate for design verification of hardware mounted within the SLA in the moderate- to high-frequency region. It was also agreed that the MSC Acoustic Facility was the most desirable for this testing.

NASA, "Apollo Applications Weekly Status Report," 22 December 1967.

11–14

Representatives of NASA and the aerospace industry participated in a four-day meeting on the Orbital Workshop design requirements at MSFC. During the first day, discussions covered structures, mechanical systems, and propulsion. On the second day, instrumentation and communications documentation was reviewed. The third day focused on crew station reviews. On the final day, results were summarized.

NASA, "Manned Space Flight Weekly Report," 18 December 1967.

27

Apollo Applications Program Director Charles W. Mathews directed the AAP Managers at the three manned space Centers to halt all activity pertaining to the AAP–IA missions. The purpose of the AAP–1A mission would be to perform experiments in space sciences and advanced applications in a low-altitude Earth orbit for up to 14 days.

TWX, Charles W. Mathews to Leland F. Belew, MSFC, Robert F. Thompson, MSC, and Thomas W. Morgan, KSC, "Mission 1A Termination," 27 December 1967.

1968

January

5

A lunar exploration program had been developed which would cover the period from the first lunar landing to the mid-1970s. The program would be divided into four phases:

(1) An Apollo phase employing Apollo hardware.

(2) A lunar exploration phase untilizing an extended LM with increased landed payload weight and staytime capability.

(3) A lunar orbital survey and exploration phase using the AAP–1A carrier or the LM/ATM to mount remote sensors and photographic equipment on a manned polar orbit mission.

(4) A lunar surface rendezvous and exploration phase which would use a modified LM in an unmanned landing to provide increased scientific payload and expendables necessary to extend an accompanying manned LM mission to two weeks duration.

Bellcomm, Inc., Technical Memo, "Lunar Exploration," 5 January 1968.

8

NASA Administrator James E. Webb recommended a cautious, step-by-step, wait-and-see approach to selection of a contractor for adapting the Apollo CSM to AAP requirements.

Memorandum, James E. Webb to Associate Administrator for Manned Space Flight, "Adapting the Apollo CSM for AAP," 8 January 1968.

1968

January

9 NASA budgetary restraints required an additional cut in AAP launches. The reduced program called for three Saturn IB and three Saturn V launches, including one Workshop launched on a Saturn IB, one Saturn V Workshop, and one ATM. Two lunar missions were planned. Launch of the first Workshop would be in April 1970.

NASA Hq Schedule, 9 January 1968.

9 MSFC awarded Perkin-Elmer Corporation a contract to develop the telescopes for the ATM.

Contract NAS 8–22623, 8 January 1968.

12 NASA Hq authorized MSC to extend through 15 May 1968 the existing contract with Grumman. Purpose of the contract was a study leading to a preliminary design review of LM modifications for AAP.

TWX, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, "Extension of Present AAP LM Modification Contract," 12 January 1968.

16 NASA awarded a letter contract to Martin Marietta for the payload integration effort on AAP. (See 26 July 1967 entry.)

Letter, contract NAS 8–24000, 16 January 1968.

22 A directive to specifically identify responsibilities for planning, conducting, and reporting on audits of reliability, quality, and system safety program activities at all AAP organizational levels was issued by NASA.

AAP Directive No. 9, "Reliability, Quality, and System Safety Auditing," 22 January 1968.

23 As originally conceived, the AM consisted of a simple tunnel and truss structure that provided access to the S–IVB OWS from the CSM. The AM subsystems provided distribution of power from the CSM to the OWS, a temperature regulated, clean atmosphere for the Workshop, and limited instrumentation.

After a year of program evolution, the AM, although similar in appearance and utilizing more than 60 percent of the effort expended on the original AM, had become physically different, with a considerably more complex role to play. The AM had become the hub and central "engine room" of the cluster by incorporating the electric power conditioning, storage, and distribution system. It was designed to receive and store power from the solar arrays, the CSM, and LM and to make distribution of power to the OWS, AM, MDA, CSM, and, in emergencies, the LM. The AM was designed to provide the central environmental control system for distributing a dehumidified, cleansed, odor free, temperature

The airlock tunnel assembly was fabricated at the McDonnell Douglas facility in St. Louis. This photo shows the hatch still being tackwelded.

conditioned, oxygen/nitrogen atmosphere to the OWS, AM, MDA, CSM, and LM and to provide coolant loops for its equipment and that in the MDA. In addition, it contained the central command and instrumentation center for the OWS, as well as an overall caution and warning system. The AM was being developed by McDonnell Douglas, St. Louis.

Memorandum for record, T. E. Hanes, "Comparison of the originally contracted Airlock with the scope of present Airlock contract requirements," 23 January 1968.

25 A study of the LM/ATM was initiated to conduct a critical and constructive review of all aspects of the LM/ATM mission to include cost, scheduling, and complexity. The three-man study team consisted of George E. Mueller (NASA Hq), Ludie G. Richards (MSFC), and George S. Trimble (MSC).

Letter, George S. Trimble to George E. Mueller, 25 January 1968; memoranda, Robert F. Thompson to Dist., "LM/ATM Study," 23 January 1968, and "Ad Hoc Studies of Alternate Apollo Applications Program Plans," 17 January 1968.

27 A Bellcomm review which summarized the system configuration aspects of operating the LM/ATM independently of the OWS was presented at the AAP review NASA Hq. The review concluded that decoupling was feasible within the framework of the mission objectives.

Memorandum for file, R. K. McFarland, Bellcomm, "Coupled vs. Decoupled LM/ATM Mission Concepts: System Configuration Aspects," 14 February 1968.

29 Nomenclature for the OWS included in the AAP presented in the FY 1969 budget was confirmed by NASA. The ground-outfitted OWS to be launched with Saturn V would be designated the "Saturn V Workshop." (This had sometimes been called the "dry Workshop.") The OWS that would be launched by a Saturn IB would be referred to as the "Saturn I Workshop." (Colloquially it had been referred to as the "wet workshop.") Terminology "Uprated Saturn I" would not be used officially. This launch vehicle would be referred to as the "Saturn IB."

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Memorandum, W. H. Shapley, NASA Hq, to Heads of Program and Staff Offices, "Nomenclature for AAP Orbital Workshops," 29 January 1968.

January

29

An S–IVB residual-propellant dump test was conducted in orbit during the Apollo 5 mission. Test results were applicable to the AAP OWS passivation requirements. The test was performed on the S–IVB after separation of the lunar module. First the liquid oxygen was dumped, then the liquid hydrogen. This was followed by the release of helium in the stage pneumatic system. Preliminary indications were that propellant settling was satisfactory.

NASA, "AAP Weekly Progress and Problem Summary," 29 January 1968.

31

An MDA preliminary design review was held at MSFC on 16–17 January and resulted in action to integrate the resupply and reuse requirements for AAP–3A and AAP–3/4 experiments. On 26 January an AAP (Mission 2) MDA preliminary design review, Phase II, Technical Review Board convened at MSFC. As a result of discussions of this Board meeting, a joint MSFC MSC study group was proposed to define AAP cluster attitude control pointing capabilities. The study group would define the capabilities of the presently baselined S–IVB attitude control system, the Apollo service module reaction control system, and the Apollo telescope mount control moment gyro system to determine if incompatibilities existed with the operations requirements and the proposed experiments and sensors.

NASA, *OMSF History of the Apollo Applications Program, 1966–1 September 1968;* NASA, "AAP Weekly Progress and Problem Summary," 29 January 1968; memoranda, Robert F. Thompson, MSC, to Dist., "Multiple Docking Adapter Preliminary Design Review," 4 January 1968; Robert F. Thompson to Dist., "Joint MSFC–MSC AAP Cluster Attitude Control Capabilities Study Group," 31 January 1968.

February

5

Saturn V OWS study teams were examining a range of concepts in two distinct categories, OWS–B and OWS–C. OWS–B would be a relatively simple, generic evolution from the Saturn I OWS being developed for the first AAP missions. It would retain the basic elements of the Saturn I OWS but would incorporate the ATM solar astronomy payload as an integral part of the OWS. Other modifications to improve overall effectiveness would be incorporated where this could be achieved with small increments of funds or time. OWS–C would be a more advanced concept in the evolution toward a flexible operational system for sustained operations in Earth orbit. It would provide living and working quarters for a crew of nine and would be operable for two or more years.

Memorandum, Charles W. Mathews, NASA Hq, to F. L. Thompson, LaRC, "Saturn V Workshop Studies," 5 February 1968.

12

Objectives of the AAP–3/AAP–4 mission were to

- Obtain scientific data on the physical characteristics of the Sun through observations of various portions of the electromagnetic spectrum made with ATM experiments.

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February

• Obtain engineering data from the operation of the ATM attached to a LM ascent stage to support development of an advanced manned orbital observatory.

• Demonstrate hard dock of the LM/ATM to the MDA of the Saturn I OWS left in orbit from the AAP–1/AAP–2 mission.

• Determine feasibility of reactivating and operating a Saturn I OWS as a habitable space structure for a period of up to 56 days from the AAP–3 launch date through evaluation of the CSM/S–IVB/AM/MDA.

AAP Directive No. 5A, "Flight Mission Directive for AAP–3/AAP–4," 12 February 1968.

26

A management review of the pointing system for the ATM was held with Perkin-Elmer Corporation. Conceptual design was completed and approved by MSFC. In addition, the preliminary requirements review for the H-Alpha telescope and pointing system was satisfactorily completed by MSC.

NASA, "Manned Space Flight Weekly Report," 26 February 1968.

Astronauts and spacecraft designers used this engineering mockup of the Saturn I Workshop during a five-day crew station review at MSFC. The space-suited technician is shown operating a control panel while being held in place by "Dutch Shoes" attached to the mesh floor.

1968 February 26 — Harold T. Luskin, Chief Advanced Design Engineer at Lockheed-California Company, and former American Institute of Aeronautics and Astronautics President, was named NASA Deputy Associate Administrator for Manned Space Flight (Technical) effective 18 March.

NASA News Release 68–39, "Luskin Appointed at NASA," 26 February 1968.

26 — To ensure that at appropriate and progressive points in the AAP life cycle sufficient management visibility was obtained of the status of design, manufacturing, and testing to determine the integrity of the system before a mission, seven key checkpoints were established:

(1) PRR—preliminary requirements review.
(2) PDR—preliminary design review.
(3) CDR—critical design review.
(4) CI—configuration inspection.
(5) COFW—certification of flight worthiness.
(6) DCR—design certification review.
(7) FRR—flight readiness review.

AAP Directive No. 11, "Sequence and Flow of Hardware Development and Key Inspection, Review and Certification Checkpoints," 26 February 1968.

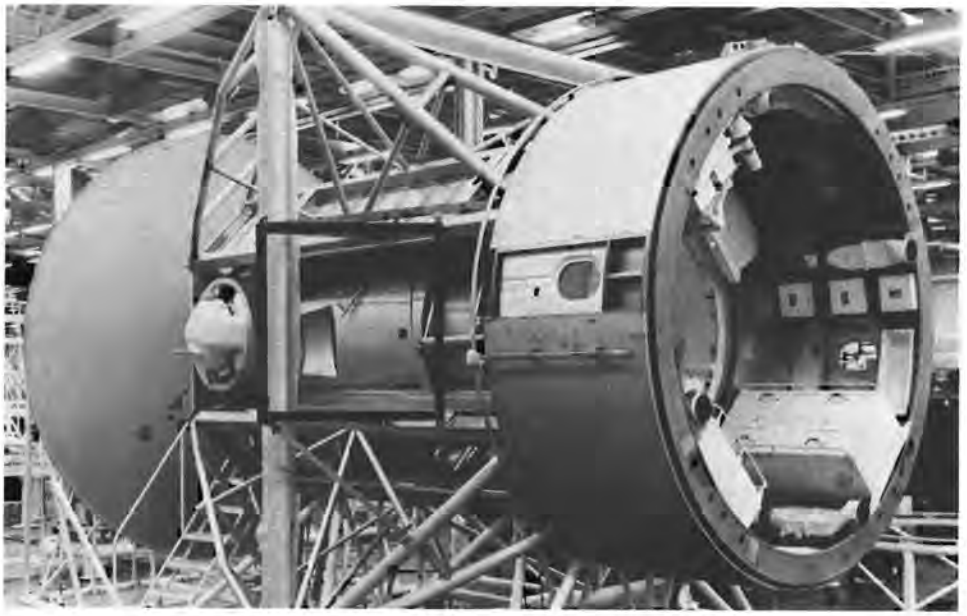
29 — AAP was first presented as a separate Research and Development program in NASA's FY 1968 budget request, which was submitted to Congress in January 1967. As originally conceived, AAP was designed to take full advantage of the Nation's investment in Apollo-developed hardware, facilities, and manpower. However, in making adjustments to considerably lower funding, the program was pared down to the minimum level for maintaining a reasonable manned space flight program in the early part of the next decade and preserving any basic capability for future U.S. manned operations in space.

Memorandum, J. Pemble Field, Jr., to Dist., "History of AAP, Prepared for Congressman Teague," 29 February 1968.

29 — LaRC Director Floyd L. Thompson was appointed Special Assistant to NASA Administrator James E. Webb and Chairman of a Post-Apollo Advisory Committee to evaluate future manned space flight projects. These assignments were in addition to his duties as LaRC Director. Since these additional responsibilities would require Thompson to spend a portion of his time away from Langley, LaRC Deputy Director Charles J. Donlan would serve as Acting Director.

NASA News Release 68–41, 29 February 1968; letter, James E. Webb to Floyd L. Thompson, 15 February 1968.

29 — An evaluation and selection committee was formed to review the suitability of candidate chambers for ATM thermal vacuum testing. The committee, composed



Manned Spacecraft Center Airlock Module Trainer.

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of members from the OMSF Apollo Applications Program Office, MSFC, MSC, Goddard Space Flight Center, and the Jet Propulsion Laboratory, would evaluate chambers located at MSC, Arnold Engineering Development Center, The Boeing Company, and General Electric Company, in terms of availability, schedules, capability, modification requirements, contamination control, cost, and logistics.

NASA, "Manned Space Flight Weekly Report," 4 March 1968.

March

4

Funds were released to MSC for support of the Environmental Science Services Administration for the design and fabrication of a preprototype model of the infrared temperature profile radiometer. Recent ESSA reviews indicated that the fabrication of a preprototype instrument at this stage of AAP would be a major advance in the ESSA goal of operational temperature soundings of the atmosphere in the mid 1970s.

Letter, L. Jaffe, NASA Hq, to Robert R. Gilruth, MSC, "Release of Fiscal Year 1968 Program Authority," 4 March 1968.

8

Fairchild-Hiller Corporation presented a mockup demonstration and technical discussion of proposed OWS solar arrays at their Germantown, Pennsylvania, plant. MSFC was planning to develop the OWS solar arrays and favored the Fairchild-Hiller design approach, but experience and the details of their patented design would require the establishment of a working arrangement.

NASA, "Manned Space Flight Weekly Report," 18 March 1968.

1968 March 9 — The ATM Principal Investigators presented the status of their experiments at Ball Brothers Research Corporation in Boulder, Colorado. They reported good progress in the development of their instruments and presented material to support their assessment that delivery would be on schedule. They also stressed the importance of flying a mission as early as possible during a period of high solar activity.

NASA, "Manned Space Flight Weekly Report," 18 March 1968.

11 — The first design verification thermal test of the cryogenic gas storage system for AAP was completed at Bendix Corporation. Following the tests, the unit was shipped to MSC for additional thermal vacuum testing to determine actual hydrogen and oxygen performance.

NASA, "Manned Space Flight Weekly Report," 11 March 1968.

12 — NASA established a Test Definition and Planning Group to assist the respective AAP Managers in the identification and resolution of problems concerned with inter-Center ground testing of space vehicles and associated ground support equipment. The group would perform a technical definition function for ground test activities. Primary emphasis would be on planning associated with coordination of integrated systems test activities where inter-Center functional responsibilities were involved. The group would work with the AAP panels, as required, to develop recommendations for test activity integration.

AAP Directive No. 8, "Establishment of the Apollo Applications Test Definition and Planning Group," 12 March 1968.

15 — MSC and MSFC were responsible, as development Centers, for design, development, fabrication, qualification, acceptance test, and delivery of AAP spacecraft and experiment carriers, assigned experiments, and associated ground support equipment.

KSC was responsible for the development and operation of launch and industrial facilities and associated ground support equipment required to support AAP, and the assembly, test, inspection, checkout, and launch of AAP space vehicles at KSC.

AAP Directive No. 12, "Prelaunch Checkout and Launch of Center Developed (In-House) Flight Hardware for the Apollo Applications Program," 15 March 1968.

15 — No central archives were planned for the experiment data from AAP. The experiment records would be kept by the Centers having responsibility for the experiments. However, MSC would establish and maintain a Central Index for AAP experimental data.

Letter, Charles W. Mathews, NASA Hq, to Robert F. Thompson, MSC, Leland F. Belew, MSFC, and Thomas W. Morgan, KSC, "Data Flow Plan for AAP Missions 1–4," 15 March 1968.

1968

March

18

A task team was established to review the requirements and establish a new baseline for the LM and the ATM with the objective of reducing costs and operational complexity. The team was composed of senior members from the OMSF, MSC, MSFC, The Martin Company, and Grumman.

Note, George E. Mueller, NASA Hq, to Charles W. Mathews, NASA Hq, 18 March 1968.

19

During the OWS preliminary design review, it was suggested that the AAP vehicles contain a library of material of an operational, technical, and recreational nature for use by the flight crews. Loewy and Snaith, Inc., had made a similar suggestion. A survey of AAP crew members was being conducted to determine the type and quantity of such materials the crews might desire so that design engineers could arrive at a preliminary systems approach to an inflight library and evaluate the impact.

Letter, Robert F. Thompson, MSC, to Donald K. Slayton, MSC, "In-flight library for AAP missions," 19 March 1968.

19–20

A preliminary design review board met at MSFC to discuss OWS major test items. These included plans for a dynamics test program to determine the dynamics of the cluster and the requirements for flammability, toxicity, and crew hazards analyses and tests. Individual subsystem flammability tests were planned. MSC specifications for crew compartment nonmetallic material selection and testing would be used.

NASA, "Manned Space Flight Weekly Report," 25 March 1968.

28

MSC adopted the position that only mixed gas atmospheres should be considered for missions longer than 30 days in duration. Conceding that studies of the physiologic effects of mixed gas atmospheres, other than air, were new in number and controversial in nature, MSC suggested that such evidence as did exist indicated that nitrogen was a superior choice as a second atmospheric constituent from an overall medical standpoint.

Letter, Robert R. Gilruth, MSC, to J. S. Bleymaier, USAF, 28 March 1968.

April

3–15

Following discussions at the Manned Space Flight Management Council meeting at KSC on 21–24 March, Associate Administrator for Manned Space Flight George E. Mueller and MSC Director Robert R. Gilruth concluded that, with the stringent funding restraints facing the AAP, the most practical near-term program was a Saturn IB OWS designed to simplify operational modes and

1968 April

techniques in Earth orbit. It was agreed that a special task force would be set up to define and implement any changes necessary to the MDA, incorporate new experiments into the program, and plan and program the critical series of medical experiments required for AAP in order to collect vital data regarding crew performance during the early phases of AAP long-duration flights.

The MDA task force held an initial meeting at MSC on 10–11 April. Requirements for the critical medical experiments were identified, and potential Earth Applications experiments were reviewed. MSFC was requested to make a preliminary design analysis of the impact of incorporating critical medical experiments and to determine which Earth applications experiments could be accommodated.

Letters. George E. Mueller to Robert R. Gilruth, 3 April 1968; Robert R. Gilruth to George E. Mueller, 15 April 1968; Charles W. Mathews, NASA Hq, to Leland F. Belew, MSFC, Robert F. Thompson, MSC, and Thomas W. Morgan, KSC, 2 April 1968 and 4 April 1968; "Manned Space Flight Weekly Reports," 8 April 1968 and 15 April 1968.

4 NASA announced the selection of General Electric Company's Apollo Systems Division to negotiate a one-year, cost-plus-fixed-fee contract to provide engineering support for AAP. Responsible to the AAP Office in NASA Hq, General Electric would perform such engineering support in the areas of reliability and quality control, configuration management, testing, and checkout. (General Electric was already fulfilling the same task in support of Apollo.)

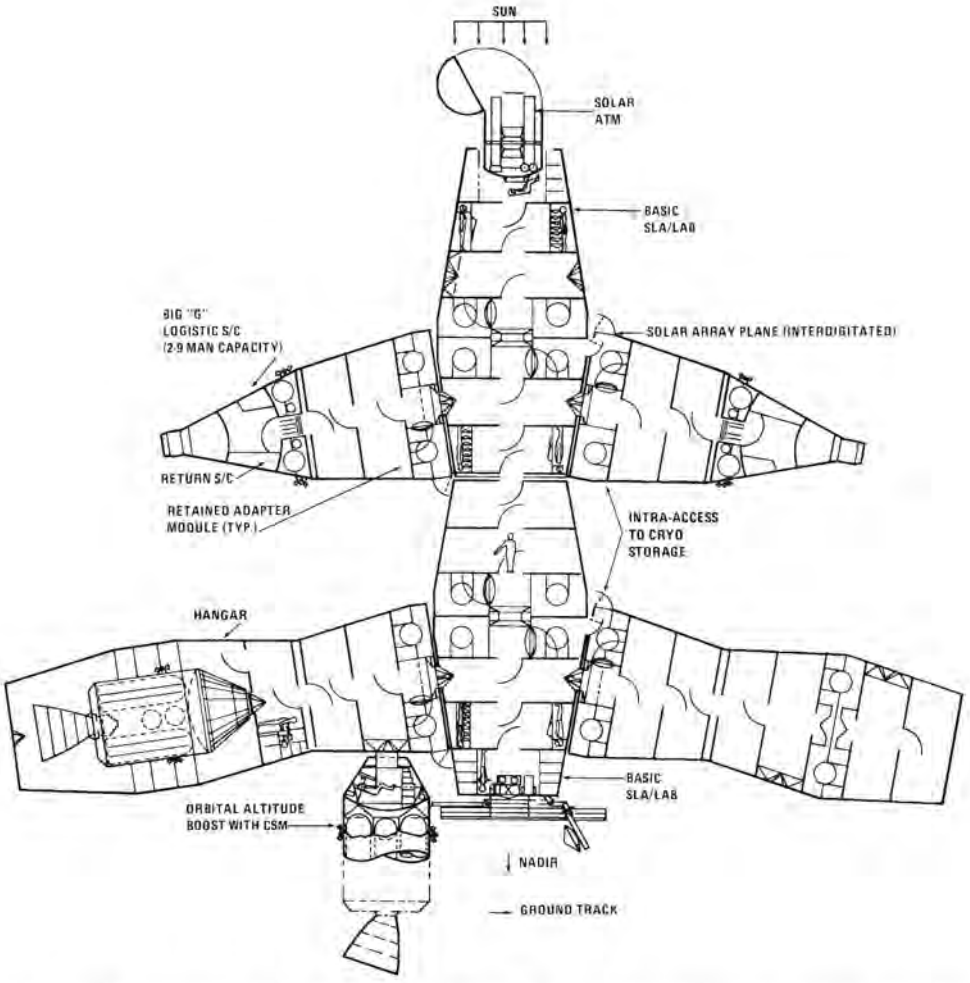
NASA News Release 68–61, 4 April 1968.

16 In a speech before the National Space Club in Washington, AAP Director Charles W. Mathews stated that, beyond the goal of landing on the Moon, NASA's overall plan for manned space exploration comprised "a balanced activity of lunar exploration and extension of man's capabilities in Earth orbit." The AAP, Mathews declared, contained sufficient flexibility so that it could be conducted in harmony with available resources: "We are also prepared to move forward at an increased pace when it is desirable and possible to do so." He said contingency planning left room for both budgetary and mission goal changes, thus answering congressional criticism that NASA had not provided sufficient flexibility regarding long-term goals.

Baltimore *Sun*, 18 April 1968, p. A–11.

19 The OWS passivation sequence was described at a flight operations plan meeting held at MSC. Solar arrays would be deployed on the first stateside pass, since the liquid portion of the passivation would have been completed. Gaseous passivation was expected to require approximately 24 hours. The meteoroid bumper would not be deployed until crew arrival because it would interfere thermally with the passivation.

NASA, "AAP Weekly Progress and Problem Summary," 26 April 1968.



One of 18 conceptual designs for the Earth-orbital spacecraft lunar module adapter laboratory prepared by spacecraft design experts of the MSC Advanced Spacecraft Technology Division. This configuration was developed to illustrate the extent to which the building block philosophy could be carried. It would utilize both Gemini and Apollo spacecraft and would require 2 unmanned launches and 10 manned logistic launches. The report was published 25 April 1968.

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25

NASA Hq requested MSFC, LaRC, and MSC to perform independent studies to identify the most desirable agency program for the Saturn V Workshop and to provide a project plan.

Letters, Charles W. Mathews, NASA Hq, to Robert R. Gilruth, MSC, Wernher von Braun, MSFC, and C. J. Donlan, LaRC, 25 April 1968.

26

A briefing was held at Andrews Air Force Base, Maryland, on a recovery support study conducted by the Department of Defense Manager for Manned Space Flight Operations. NASA requirements provided for the study were based on two concepts of support. The "current concept" implied support requirements similar to those required for the Gemini program. The other was the "future

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April

concept" which would be employed when sufficient reliability of spacecraft systems had been demonstrated. The "future concept" would employ two recovery zones (primary and secondary) as opposed to the four zones designated in the "current concept." Defense forces allocated to meet NASA requirements would be significantly reduced under the "future concept."

NASA, "AAP Weekly Progress and Problem Summary," 26 April 1968.

30

A primary objective of the Apollo Applications reliability program would be to identify all significant single failure point potentials of equipment for various modes of operation. Single failure point potentials would be examined for each mission, and a summary of single failure points would be prepared and kept current. Supporting information from the Apollo program would be used to the maximum extent possible.

AAP Directive No. 13, "AAP Failure Mode and Effect Analysis; Single Failure Point Identification and Control," 30 April 1968..

May

3

An AAP holding plan was implemented for the remainder of Fiscal Year 1968. The plan was activated in order to maintain a reasonable balance in program content while avoiding major cuts to work in progress. This action became necessary because of funding restraints imposed on AAP.

Letters, Charles W. Mathews, NASA Hq, to Leland F. Belew, MSFC, Thomas W. Morgan, KSC, and Robert F. Thompson, MSC, 3 May 1968.

10

A major goal of the AAP—to accelerate the evolution of the utility of space flights—required certain steps to achieve more effective and economical manned space operations, while enhancing the value of information obtained during orbital flights. Some of the more important steps required would be obtaining data on the physiological qualification of man for extended duration in space; providing adequate support systems which would allow man to maintain a high degree of effectiveness; and determining efficient man-machine relationships.

Speech, Charles W. Mathews, NASA Hq, to Society of Automotive Engineers, Inc., Space Technology Conference, "Apollo Applications—The Next Step in Man's Investigation of Space," 8–10 May 1968.

20

Designers at MSFC increased the capability of the MDA to provide for crew habitation and to perform certain biomedical experiments in the event the OWS could not be made habitable after reaching orbit.

MSFC, "AAPO Weekly Activity Report," 22 May 1968.

22

NASA Hq described the purposes of the AAP–3A mission: (1) qualify man, evaluate his support requirements, and determine human task performance capabilities on long-duration manned space flight missions; (2) demonstrate the

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May

feasibility of reactivating a Saturn I OWS that has been left unattended in Earth orbit for several months and reusing a Saturn I OWS as a base of operations for the conduct of experiments in astronomy, science, applications, technology, engineering, and medicine.

AAP Directive No. 14, "Flight Mission Directive for AAP–3A," 22 May 1968.

23

NASA Hq issued management procedures to be followed for AAP experiments. The procedures were divided into two phases: planning and implementation. In the planning phase, paperwork reflecting the plans of the development, integration, mission operations, and launch operations centers for an experiment would be submitted to the AAPO for compatibility assessment and implementation planning. The implementation phase would encompass all the activity involved in the acquisition of experiment hardware, preparation of hardware for flight use, performance of flight operations, and disposition of experiment data.

AAP Directive No. 15, "Management Procedures for the Planning and Implementation of AAP Experiments," 23 May 1968.

25

A LM/ATM Evaluation Board, established to make an in-depth review of the planned LM/ATM module configuration and mission, issued its final report. The Board review concentrated on the operational and programmatic aspects related to use of the LM with the ATM. At a meeting held on 9 March, the ATM experiment status was the subject of discussion. Principal Investigators and the MSFC ATM Program Office representatives summarized progress on each experiment and on the total ATM package.

At meetings held on 15–16 March, presentations were made by MSC and MSFC. MSC stressed the operational complexities of the dual-rendezvous, dual-docking capability of the LM, extravehicular activity, crew training, and mission critical sequencing. MSFC stressed the desirability of the cluster mission and, while recognizing the problems of dual rendezvous, suggested that the system and mission as configured was the best possible choice.

Final Report, LM/ATM Evaluation Board, 25 May 1968.

27

Center Directors Robert R. Gilruth (MSC) and Kurt H. Debus (KSC) approved a joint memorandum of understanding on MSC–KSC relations that laid down guidelines and procedures for execution of Center responsibilities within areas of mutual interest. The document thus sought to ensure an effective programmatic interface between the two Centers and also provided for subsequent agreement, spelling out in detail specific inter-Center policies and procedures.

MSCM 8010, "Program Management Guide," 27 May 1968.

28

A review of the AM test program was held at MSC to examine the existing baseline AM testing plan in terms of programwide AAP test requirements and

1968 May — guidelines. Participants included representatives from Headquarters, MSFC, MSC, and the AM contractor, McDonnell Douglas. Spokesmen for McDonnell Douglas recommended additional subsystem development testing, as well as thermal-vacuum testing of airlock flight hardware (a recommendation being evaluated by experts at both MSFC and MSC).

NASA, "Manned Space Flight Weekly Report," 3 June 1968.

June 4 — NASA released a new AAP launch readiness and delivery schedule. The schedule decreased the number of Saturn flights to 11 Saturn IB flights and one Saturn V flight. It called for three Workshops. One of the Workshops would be launched by a Saturn IB, and another would serve as a backup. The third Workshop would be launched by a Saturn V. The schedule also included one ATM. Launch of the first Workshop would be in November 1970. Lunar missions were no longer planned in the AAP.

NASA Hq Schedule, 14 January 1968.

8 — NASA launched two Aerobee 150 sounding rockets from White Sands Missile Range, New Mexico. The first rocket carried a Naval Research Laboratory and University of Maryland payload to a 179-km altitude to flight test a design verification unit of the high-resolution spectroheliograph planned for use on the ATM. The second rocket carried an American Science and Engineering, Inc., payload to a 150-km altitude to obtain high-resolution x-ray pictures of active regions of the Sun during solar flare and general x-ray emission of solar corona. The rocket and instrumentation performed satisfactorily, but the payload of the first rocket failed to separate, thus preventing functioning of the parachute recovery system.

NASA, "Reports on Sounding Rocket Launchings"; "Manned Space Flight Weekly Report," 10 June 1968.

24 — An MDA task force, established in March to examine the ability of the MDA to support the operation of critical medical experiments within 24 hours of rendezvous and docking and to examine the feasibility of conducting selected Earth resources and meteorological experiments, made recommendations which resulted in baseline configuration changes to the MDA.

Docking ports 2 and 3 of the MDA would be deleted; four windows in the conical section of the MDA would be deleted; and a viewport would be provided to support unmanned rendezvous and docking.

Letter, H. T. Luskin, NASA Hq, to Leland F. Belew, MSFC, Thomas W. Morgan, KSC, and Robert F. Thompson, MSC, "Status of MDA Task Force Activities," 24 June 1968.

24 — The 2.4-m-diameter tank tests at McDonnell Douglas were nearing completion. The test tank which consisted of a waffle-pattern wall structure, internal insula-

1968
June

tion, and aluminum foil liner, successfully passed static firings and launch sequences to evaluate the ability of the materials and structure to withstand the thermal loads under operational conditions. The tank would be shipped to MSFC in July for outgassing tests.

NASA, "Manned Space Flight Weekly Report," 24 June 1968.

27–28

An experiment review was held at MSC in January to determine what progress had been made in the development of experiment hardware for the AAP. Some key problems identified at the review were the following:

- There was no organized development on AAP medical and habitability experiments.
- There was no existing program authority at MSC to initiate development of medical and engineering experiments.
- Work statements had not been prepared for the experiment groups; many of the experiments were not yet defined. On 27–28 June another experiments review was held at MSC. Overall results of the review indicated very slow progress on all experiment activity at MSC. The status was critical from the standpoint of overall motivation.

OMSF, *History of the Apollo Applications Program, 1966 to 1 September 1968*, pp. 2-21—2-24.

July
5

NASA Hq authorized a letter amendment to the AM contract with McDonnell Douglas from 30 June through 31 December 1968. During this six-month extension, MSC was to negotiate a definitized contract incorporating recent program guidelines and covering the total airlock effort beginning in August 1966.

TWX, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, "Airlock Letter Amendment to Contract NAS 9-6555," 5 July 1968.

8

Apollo Applications Program Managers met at Goddard Space Flight Center. Among the items discussed were coordination and distribution of AAP directives, delineation of management responsibilities, medical experiment support, and the waste management system for the OWS.

Memorandum for record, John H. Disher, NASA Hq, "Summary of Discussions with AAP Program Managers at GSFC," 8 July 1968.

12

Martin Marietta, Denver Division, completed an Earth resources experiment compatibility analysis and an experiment conceptual analysis. The analyses were conducted in compliance with an MSC AAP payload integration task during the period 16 January–30 June 1968. Results of the study indicated that a selected group of Earth resources experiments could be integrated into the AAP–1/AAP–2 Orbital Workshop with only minimum design impact.

Martin Marietta Corp., *AAP Payload Integration Final Report*, 12 July 1968.

1968 July 20 — The Post Apollo Advisory Committee, authorized by the NASA Administrator to evaluate and make recommendations on post-Apollo space activities, issued its report which confirmed the basic objectives of the AAP and played a deciding role in its later evolution. The Committee, headed by LaRC Director Floyd Thompson, held meetings at MSFC, MSC, NASA Hq, and KSC on 25 January, 15 February, 12 March, and 25–26 March 1968, respectively.

Post Apollo Advisory Committee Report, 20 July 1968; memorandum, Robert F. Thompson, MSC, to Dist., "Ad Hoc Studies of Alternate Apollo Applications Program Plans," 17 January 1968; letters, James E. Webb, NASA Hq, to F. L. Thompson, MSC, Leland F. Belew, MSFC, and Thomas W. Morgan, KSC, "AAP 5, 6, and 7 Mission Definition," 1 February 1968.

23–24 — At NASA Hq, movements were underway to select a new name for post-Apollo manned space flight (AAP)—one that would be more descriptive of the agency's real goals and objectives. At the Planning Study Group meeting, Douglas R. Lord, Chairman of the Working Group on Extension of Manned Space Flight, was asked to recommend a new name for NASA's Earth-orbital flight program of the mid-1970s. However, AAP Director Charles W. Mathews urged that the name AAP be retained because NASA had a good deal invested in it. On 26 July, Julian M. West wrote Lord recommending that NASA choose some other name to cover both AAP and an interim space base of the mid-1970s (dubbed the "IOWS" program, for Interim Orbital Workshop). West urged that all such names as "AAP," "Workshop," and "Extension of Manned Space Flight," be dropped because they did not accurately describe what he saw as "the major goal—manned space flight itself." West voted for a name put forward by George Trimble of MSC, "Space Base Program," which he believed covered NASA's mid-1970s missions. "We are establishing a foothold for man in space."

Letter, Julian M. West to NASA Hq, Attn: Chairman of Working Group on Extension of Manned Space Flight, MTD, "Program Name for Post-Apollo Earth Orbital Flight Test Program," 26 July 1968.

31 — Agreement was reached on the availability and utilization of an acceptance checkout equipment station at MSFC for the ATM. Availability of the acceptance checkout equipment station would be contingent upon successful completion of the Apollo program and the assumption that any contingencies that might arise adversely affecting the Apollo schedule would also impact Apollo Applications checkout need dates.

Letters, H. T. Luskin, NASA Hq, to Leland F. Belew, MSFC, 31 July 1968; Charles W. Mathews, NASA Hq, to Wernher von Braun, MSFC, 23 July 1968.

August 1 — Following receipt of NASA direction to limit Saturn V production to Vehicle 515, MSFC began terminating production of engine hardware for the Apollo and Apollo Applications programs. The action involved 27 H–1, eight F–1, and three J–2 rocket engines.

Letters, George E. Mueller, NASA Hq, to James E. Webb, NASA Hq, "S-1C Long Lead Hardware Procurement Contract," 3 June 1968; James E. Webb to George E. Mueller, "Termination of the Contract for Procurement of Long Lead Time Items for Vehicles 516 and 517," 1 August 1968.

1968 August

ATM film and camera storage during launch, throughout the mission, and during reentry was reviewed. North American representatives covered the command module's capability for film return, and Grumman representatives discussed the lunar module's crew provision storage. Principal Investigators and MSFC ATM personnel attended the presentation. 9

NASA, "Manned Space Flight Weekly Report," 16 August 1968.

ATM experiments would be designed to observe and record solar features or regions of interest by using a variety of scientific instruments and recording devices. Observations would be made over a wide range of energy wavelengths in the form of both solar images and solar spectra. They would be preserved for future study by recording them on photographic film or magnetic tape. These experiments would provide new knowledge of the Sun, solar features, solar phenomena, and the solar processes of energy release. 9

MSC, "ATM Mission Review," 9 August 1968.

MSFC issued a request for proposals to design and develop an actuator system for the ATM. The device, expected to weigh about 9 kg, would deploy the ATM's solar panels once the vehicle was placed in orbit and docked with the Workshop. 12

MSFC News Release 67-178, 12 August 1968.

McDonnell Douglas, Grumman, and Massachusetts Institute of Technology made presentations to MSC on an automated rendezvous study effort. It was the final meeting of an ad hoc study group which agreed that automated rendezvous and stationkeeping were feasible and would not impose severe hardware or operational constraints. The MSC AAPO was preparing a report on the study results. 13

NASA, "Manned Space Flight Weekly Report," 16 August 1968.

NASA issued a directive providing program standards for achieving uniformity of terms, practices, and criteria to be used throughout the AAP in the generation of nonconformance data that could be readily combined, compared, and assessed for potential program impact. 15

AAP Directive No. 10, "AAP Nonconformance Reporting and Corrective Action," 15 August 1968.

NASA announced award of a cost-plus-incentive-fee contract to Bendix Corporation to develop one prototype and five flight-model star trackers for the ATM. 28

1968

MSFC News Release 68–196, 28 August 1968.

August

28 MSFC informed MSC that General Electric Company had been awarded a contract for "Human Engineering Criteria for Maintenance and Repair Study." The contract would yield data directly applicable to the AAP–2 and AAP–4 flights, as well as later missions. The underwater testing portion of the study required the use of space suits, and it was felt that the most useful data would be achieved if Apollo-type space suits could be used. MSC was requested to furnish two suits for that portion of the study to be performed at General Electric's Valley Forge, Pennsylvania, facility in October 1968.

Letter, J. O. Aberg, MSFC, to Richard Johnson [sic], MSC, "Spacesuit support," 28 August 1968.

29 NASA established policy for nonmetallic materials selection, control, test, and evaluation in the AAP, emphasizing the importance of the nonmetallic materials program and its relationship to crew safety and mission success. The directive reflected a unified multicenter approach for obtaining maximum benefits from nonmetallic technology.

AAP Directive No. 16, "Apollo Applications Program Nonmetallic Materials Policy," 29 August 1968.

September

4 MSFC Director Wernher von Braun performed a full-pressure suit test in the Saturn I Workshop immersed in the Neutral Buoyancy Tank. He reported that the upgraded seals used in the aft dome penetration sealing study were "very good," but recommended additional handholds and tether points.

Memorandum, W. Kuers, MSFC, to D. S. Akens, MSFC, "Historical Data," July–September 1968.

10 Seeking a better balance between Apollo and AAP workloads, NASA Hq authorized the transfer of program development responsibility for the AM and the LM/ATM from MSC to MSFC. This move represented a major shift in AAP management and placed AAP design and integration responsibilities under a single NASA center. Those responsibilities included not only hardware design, but also systems engineering, development testing, and integration to ensure compatibility between flight hardware and ground support equipment.

Memoranda, Charles W. Mathews, NASA Hq, to James E. Webb, NASA Hq, "AAP Management," 20 August 1968; James E. Webb to George E. Mueller, same subject, 10 September 1968; undated plan, "Delineation of Management Responsibilities, Apollo Applications Program," cosigned by Robert R. Gilruth, MSC, K. H. Debus, KSC, and Wernher von Braun, MSFC.

17 An AAP experiment-integrated test program and requirements for a fit and function test of experiment flight hardware were established. The program would

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September

provide firm need dates of equipment keyed to test dates rather than launch dates; limit the period of continuing engineering modifications and redesign; verify the man and machine interfaces, using flight hardware well in advance of the equipment reaching KSC; and ensure availability of flight-qualified experiments to support assigned missions.

Memoranda, H. T. Luskin, NASA Hq, to Dist., "AAP Experiment Flight Article Integrated Testing," 17 September 1968.

17

Supporting development work in AAP was eliminated, except that of an urgent or critical nature, such as the integrated medical and behavioral laboratory measurement system. This reduction in program supporting development work was the result of budget restrictions when available appropriated funds were reduced from $32.0 million to $18.2 million for Apollo and AAP.

Letter, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, 17 September 1968.

23–26

A preliminary design review for the ATM was held at MSFC. Working groups composed of scientists, engineers, and astronauts covered specific areas such as pointing control, electrical and electronic support equipment, mission operations requirements, mechanical and thermal considerations, instrumentation, communications, control and display equipment, crew station, experiments, and quality and reliability during testing and manufacture.

Memorandum, Robert F. Thompson, MSC, to Dist., 11 September 1968; MSFC News Release 68-221, 23 September 1968; NASA, "Manned Space Flight Weekly Report," 7 October 1968.

October

2

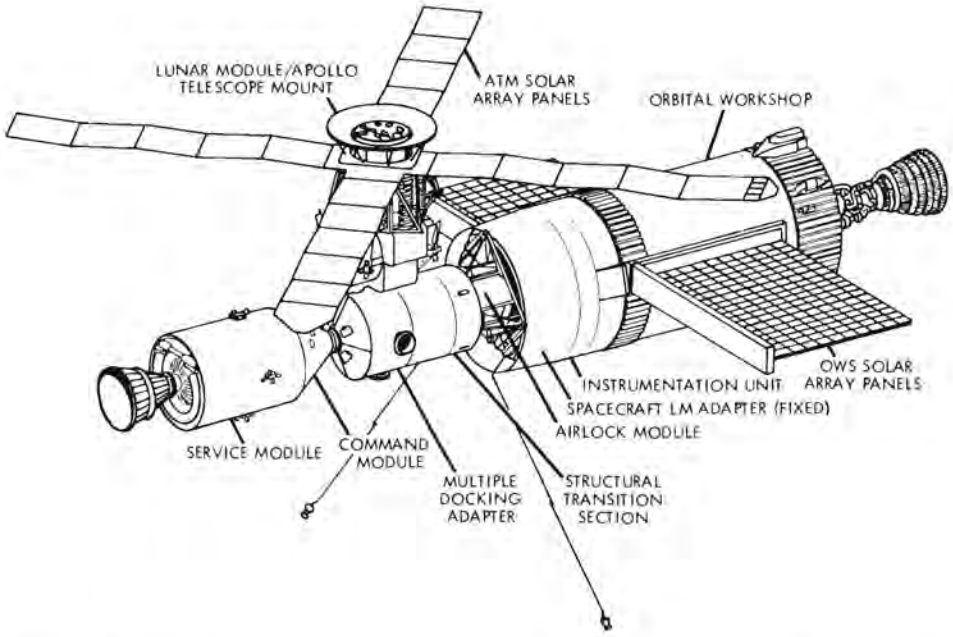
MSFC and KSC officials agreed upon procedures for maintaining the capability to check out and launch the remaining Saturn IB vehicle inventory. Their joint recommendations included a phasedown on contractor activity following the AS–205 launch; deactivation of Launch Complexes 34 and 37 to allow maximum storage of equipment and minimum maintenance on items remaining in place; and continuance of KSC analysis of manpower required to support the AAP dual launch requirement, with contractor participation at the earliest date.

Memorandum, K. H. Debus, KSC, to Dist., 2 October 1968; KSC, "Weekly Report," 18 October 1968.

2

A procedure that defined and detailed AAP inter-Center interface management procedures and the operation of a repository for AAP inter-Center interface control documents (ICD's) and interface revision notices was published.

Memorandum, Robert F. Thompson, MSC, to Dist., "AAP Intercenter ICD Management Procedure," 2 October 1968; AAP Intercenter ICD Management Procedure Document No. IMP001, September 1968.



The AAP cluster as visualized by personnel of NASA's Office of Manned Space Flight in Washington in September 1968.

1968

October

8 MSFC was requested to proceed with the definition of a system to transmit television from orbiting Apollo Applications spacecraft to selected Manned Space Flight Network ground stations. Design of the system would include use of equipment developed from previous programs and elimination of elaborate tests, qualifications, and paperwork in its definition.

Letter, H. T. Luskin, NASA Hq, to Leland F. Belew, MSFC, "An RF TV Link for the AAP," 8 October 1968.

8–11 A lunar module preliminary design review was held at Grumman. The review indicated that an adequate basis existed for continued design and development. Some decisions on the LM which would require MSFC implementation were simplification, rearrangement, and appropriate relocation of crew provisions, restraints, and controls in the LM crew compartment and updating of plans and specifications for the modifications.

Memorandum, Robert F. Thompson, MSC, to Dist., "Apollo Telescope Mount (ATM) and AAP LM Preliminary Design Reviews (PDR's)," 11 September 1968; NASA, "Manned Space Flight Weekly Report," 21 October 1968.

21 In the transfer of the AM contract and its management responsibilities from MSC to MSFC, agreements were reached on the content of the work statement and its appendices, contract-required plans, performance and configuration specification, and list of government-furnished equipment. McDonnell Douglas was requested to proceed with technical briefings for MSFC prior to the formal transfer of

1968

October

management responsibility of the AM from MSC to MSFC. (See 10 September entry.) Transfer of the technical management of the AM from MSC to MSFC would become effective 1 December.

Letters, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, K. H. Debus, KSC, and Wernher von Braun, MSFC, 1 October 1968; Robert F. Thompson, MSC, to Leland F. Belew, MSFC, "MSC plans for definitization of the baseline for the Airlock Contract," 1 October 1968; NASA, "Manned Space Flight Weekly Report," 21 October 1968; TWX, Robert F. Thompson to Leland F. Belew, "Transferring Technical Management of the Airlock Module Contract," 2 December 1968.

November

5

MSFC was requested to initiate a study and propose plans for incorporation of a teleprinter in AAP spacecraft. The plans would consider a teleprinter in both the AM and LM; a teleprinter in the AM; a portable teleprinter which would be used in either the AM or the LM.

Letter, H. T. Luskin, NASA Hq, to Leland F. Belew, MSFC, "A Teleprinter for AAP Spacecraft," 5 November 1968.

20

At KSC, program responsibility for the Saturn IB vehicles and LC–34 and LC–37 was transferred from the Apollo Program Manager to the AAP Manager. Among the management functions transferred were chairmanship of the Apollo Applications Launch Operations Panel, KSC cochairman of the Systems Integration Panel, KSC senior member of the Mission Evaluation Panel, Configuration Control Board chairman for Apollo Applications, direct interface with KSC Design Engineering Directorate, and authority to validate performance and requirements specifications.

Memoranda, K. H. Debus, KSC, to George E. Mueller, NASA Hq, 2 October 1968; R. O. Middleton, KSC, and Thomas W. Morgan, KSC, to K. H. Debus, 28 October 1968, approved by K. H. Debus, 20 November 1968.

21

An analysis was made of CSM modifications proposed for AAP. The AAP spacecraft requirements and the subsequent subsystem modifications from the Apollo spacecraft resulted from the longer mission duration, increased mission support, docked attitude constraints, and cost and weight factors involved in AAP.

Letter, H. T. Luskin, NASA Hq, to Associate Administrator for Manned Space Flight, "CSM Modification Requirements for AAP," 21 November 1968.

21

MSC responded to a 4 October 1968 request from NASA Hq to further study selected SLA modifications and a short MDA docking tunnel. MSFC asked North American to study two cases involving SLA modifications. In both cases, North American utilized the probe cover configuration: (1) case I utilized a nose cone, rocket jettison motor, a modified Apollo SLA, and the Apollo SLA ordnance separation system; (2) case II utilized a lightweight segmented nose section designed as an integral portion of a modified Apollo SLA. This case also used the Apollo SLA ordnance separation system with a lateral jettison of the integral nose section/SLA enclosure.

1968

November

Review of this study indicated that in either case, although both could be considered technically feasible, additional analyses would be required including dynamic analysis (recontact), thermodynamic analysis, and modifications to ground support equipment. MSFC had reexamined the possibility of shortening the MDA docking tunnel, which would eliminate the need for a SLA modification. Two constraining factors governing the modification were (1) sufficient tunnel standoff distance from MDA pressure to assure no LM contact with the MDA and (2) launch clearance between the MDA Port I cover and the interior surface of the SLA.

It was felt that any compromises that would necessarily complicate the design and operation of orbiting spacecraft hardware (MDA) as opposed to modification of expendable (SLA) hardware would not be the best choice, and MSFC therefore recommended that the "short tunnel" not be pursued further.

Letter, Leland F. Belew, MSFC, to H. T. Luskin, NASA Hq, "Payload Enclosure for AAP–2 and AAP–4," 21 November 1968.

25

Harold T. Luskin, Director of Apollo Applications in NASA Office of Manned Space Flight, died in Bethesda, Maryland, of respiratory illness. He had joined NASA in March 1968 and had become Apollo Applications Director in May.

NASA Special Announcement, 26 November 1968.

27

MSC awarded a contract to Allis-Chalmers Manufacturing Company to flight-qualify the improved fuel cell electrical power system for AAP. The fuel cell system had been developed under three previous contracts that began in 1962. Under the present contract (to run through February 1970), Allis-Chalmers would try to achieve fuel cell lifetimes of 2500 hours to ensure adequate margins to satisfy 1500-hour manned AAP missions. (See 18 July 1969 entry.)

MSC News Release No. 68–83, 27 November 1968.

December

17

MSC awarded a two-year, cost-plus-incentive-fee support contract to TRW Inc., Redondo Beach, California, for mission trajectory control and spacecraft systems analysis programs. The mission control part of TRW's contract involved flight trajectories and mission simulation, while the latter aspect encompassed systems engineering and analysis of systems and subsystems aboard the spacecraft.

MSC News Release 68–86, 17 December 1968.

18

William C. Schneider was appointed NASA Director of the Apollo Applications Program, succeeding the late Harold T. Luskin. Schneider had formerly been Mission Director in the Apollo Program and Gemini Program Director.

NASA News Release 68–217, "Schneider Heads AAP," 18 December 1968.

1968
December
31

MSC awarded a contract to North American Rockwell, Downey, California, for preliminary design of modifications to the Apollo block II command and service modules for use in long-duration AAP missions.

MSC News Release 68-88, 31 December 1968.

1969
January
8

Installation and instrumentation of a 2.4-m-diameter tank in the MSFC vacuum chamber test tower for an OWS insulation liner outgassing test was completed. The testing simulated part of the passivation phase of the AAP-2 mission to evaluate the outgassing and heat transfer characteristics of the OWS insulation liner and the resultant atmosphere and environment inside the Workshop. Testing was performed by MSFC personnel with McDonnell Douglas test support personnel making the outgassing measurements.

NASA, "Manned Space Flight Weekly Report," 13 January 1969.

8

An AAP baseline configuration review was held at NASA Hq. Attendees included the Center AAP Managers, the AAP Director, and key Center and Headquarters personnel. Headquarters presented a new AAP-2 experiments list. MSC and MSFC presented the weight status of the AAP missions, recommended control weights for the modules, and proposed weight management systems. MSC presented a status report on a joint study by MSFC and MSC of the stowage list for the AAP flights and gave a status report on plans for AAP space suits and space suit support.

Letter, William C. Schneider, NASA Hq, to Robert F. Thompson, MSC, Leland F. Belew, MSFC, and Thomas W. Morgan, KSC, "Minutes of AAP Baseline Configuration Review Held January 8, 1969," 13 January 1969.

14

A controls and displays review, the third and final one, was held at North American Rockwell, Downey, with an astronaut review team in attendance. North American gave a review of the major reorientation of the controls and displays, and the significant systems modifications which occurred since the previous meeting. As a result of the three reviews, very little controls and displays activities would be necessary at the command module and service modules preliminary design review.

NASA, "Manned Space Flight Weekly Report," 27 January 1969.

14-15

A meeting was held at Martin Marietta, Denver, to discuss improvements to the experiment integration requirements document in the areas of experiment test and checkout. Representatives from KSC, MSFC, and MSC established a set of guidelines and instructions that would identify the hardware flow plan and test activity associated with the experiment integration and prelaunch phase. Martin Marietta was directed to use the instructions for future issues or revisions to the experiment integration requirements document.

1969 "Apollo Applications Test, Weekly Highlights Report," 22 January 1969.

January

15 Management of the Saturn IB project and AAP-assigned spacecraft was transferred from the Apollo program to AAP. This transfer of management responsibility included Saturn IB launch vehicles SA–206 through SA–212 and Saturn IB unique spares and unique facilities. The Apollo program would continue to fund the Saturn IB effort through FY 1969, except for that effort unique to AAP. Beginning in FY 1970, the Saturn IB funding would be an AAP responsibility. This transfer of responsibilities placed management of the Saturn IB project under control of the program that would use it and relieved Apollo management of some responsibilities, allowing more time for concentration on the mainline Apollo program.

Letters, S. C. Phillips and W. C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Transfer of Saturn IB Project Management to the AAP," 15 January 1969; George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, 22 January 1969.

15 NASA reported that considerable progress had been made during the underwater test program begun at MSFC's neutral buoyancy simulator several years earlier. The program was providing information essential for design of the first U.S. space station. Technicians, design engineers, and professional divers in space suits and scuba gear were conducting tasks similar to those necessary to activate an orbiting Workshop, in a 5300-cu-m (1.4-million-gal) tank containing mockups of the AAP cluster elements (Workshop, Apollo telescope mount, solar observatory, and airlock and multiple docking adapter), simulating weightlessness of space. Conclusions from the tests would be reflected in the Workshop's final design, with a decision expected in May 1969.

NASA News Release 69–4, 15 January 1969.

20 Following six weeks of familiarization with the OWS, R. Walter Cunningham made a number of recommendations for modification of its interior. Among these were discontinuance of hardware development conceived to support the concept of compression walking; elimination of a settee from the food management compartment; discontinuance of any consideration of a cot for zero-g sleep stations; simplification of fire extinguisher brackets; and discontinuance of development of a cargo transfer device in the OWS and AM.

Memorandum, R. Walter Cunningham, MSC, to Director of Flight Crew Operations, MSC, "Apollo Applications Program Orbital Workshop," 20 January 1969.

20 MSC announced a reorganization of the AAPO in Houston: the Future Missions Project Office was redesignated the Command and Service Module Project Office; the Program Control Office became the Management Operations Office; the Systems Engineering Office was redesignated the Engineering Office; the Test Operations Office became the Manufacturing and Test Office; the Mission Oper-

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ations Office was redesignated the Missions Office; and the MSC AAPO Resident Office at St. Louis was closed. This reorganization was a result of the reassignment of AAP management responsibilities to MSFC in September 1968, the transfer of which had recently been concluded.

MSC Announcement 69-7, "Organizational Changes and Personnel Assignments Within Apollo Applications Program Office," 20 January 1969.

24

A meeting was held at McDonnell Douglas, Huntington Beach, to discuss habitability support system requirements and concept selection. It was decided to investigate moving partitions between the waste management and food management compartments to improve the distribution of space. A quick analysis indicated little program impact from the change; however, the preliminary requirements review would be based on the existing floor plan.

MSFC, "Weekly Activity Report for Two Weeks Ending 2-4-69," 7 February 1969.

27

A meeting to discuss the feasibility of space stations as the major post-Apollo manned space flight program was held at NASA Hq. Some comments from attendees follow:

Edgar M. Cortright, Director, LaRC

- The 1975 launch date would preclude major advances in technology at the outset of the core space station.
- A regenerative life support system would be needed for minimum resupply.
- Replaceable rather than expendable units would require a new philosophy.
- Too advanced missions should be avoided at the outset.

Abe Silverstein, Director, Lewis Research Center

- NASA must do initial homework on size, weight, orbits, programs and experiments, logistic support, power, and communications. These factors would all need to be defined.

Wernher von Braun, Director, MSFC

- NASA should spell out the sciences, technology, applications, missions, and research desired.
- NASA should define a 1975 station as a core facility from which the ultimate space base can grow in an efficient orderly evolution through 1985.

Robert R. Gilruth, Director, MSC

- NASA should be looking at a step comparable in challenge to that of Apollo after Mercury.

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• Design should emphasize the utility of the space base as a waystation to the Moon and Mars.

• Cargo and passenger transfer without extravehicular activity should be available.

• The logistics vehicle support system should be decoupled from the station-building launch capability at the outset.

George E. Mueller, Associate Administrator for Manned Space Flight

• Perhaps the logistics shuttle system should be developed first, before space station characteristics are decided on.

James C. Elms, Director, Electronics Research Center

• We should design for artificial gravity and maybe later use the space station without it. You can easily decide to stop something you decided to spin, but it's a diode: you can't later decide to spin something you didn't design to spin.

Extracts from NASA Administrator Thomas O. Paine's "Notes From Meeting on Space Stations," 27 January 1969.

28 Development tests to verify the design concept of the chain drive mechanisms of the ATM solar array system were completed. Preliminary data and operation were very promising. This hardware would be utilized in assembly of a complete solar array to be used for deployment testing.

NASA, "Manned Space Flight Weekly Report," 3 February 1969; "Apollo Applications Test Weekly Highlights Report," 29 January 1969.

30 MSFC definitized the existing letter contract with Martin Marietta for the payload integration and systems engineering effort for AAP, as well as the control and display console for the ATM. Estimated value of the contract was $98.2 million. The work, begun under letter contract in January 1968, would extend through the end of November 1972 and covered AAP Flights 1, 2, 3, 3A, and 4.

MSFC News Release 69–43, 18 March 1969.

February

3 Director of AAP William C. Schneider emphasized the magnitude of procurement actions for the program. He pointed out that "procurement actions for AAP have in a sense pioneered a procurement philosophy that may be considered unique. We seem to constantly seek new ways, or develop procurement methods out of the ordinary to accomplish our changing program objectives. I am determined . . . that procurement will not be a hindrance, but rather take the lead in this effort. . . . I can foresee the need for even deeper and quicker and greater procurement involvement over the next 12 months as the tempo of our program increases." Schneider suggested that additional procurement personnel

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be assigned to meet the needs as AAP emerged from its formative stage into full maturity.

Letter, W. C. Schneider, NASA Hq, to NASA Director of Procurement, "Procurement Support for AAP," 3 February 1969.

4–5

A meeting of the ATM Contamination Working Group was held at KSC. Representatives present were from NASA Hq, KSC, MSC, and MSFC. Experiment Principal Investigators also attended. Items covered included real-time contamination monitoring during thermal vacuum testing, thermal vacuum test plans, optical degradation from vacuum chamber operations, and cluster effluent studies. Several of the Principal Investigators expressed a desire for real-time contamination monitoring during thermal vacuum tests of the ATM. The Naval Research Laboratory was trying to develop a monitor for the ultraviolet region and was planning to submit an engineering change proposal to provide an ultraviolet source for the tests. This would allow them to operate their instruments and obtain data on their efficiency during such tests.

"Apollo Applications Test Weekly Status Report," 12 February 1969; NASA, "Manned Space Flight Weekly Report," 17 February 1969.

4–14

A preliminary design review for the AAP CSM mockup was held at Downey, 10–14 February. It followed an astronaut review of the mockup 4–6 February. A total of 404 review item discrepancies, consisting mainly of detailed changes to documentation and design, were identified. General satisfaction with the mockup was expressed by the astronauts.

NASA, "Manned Space Flight Weekly Report," 17 February 1969; brochure, Space Division of North American Rockwell, "Apollo Applications Program Preliminary Design Review CSM SD69–252," undated.

4–19

Orbital Workshop solar array system preliminary requirements review presentations were made 4 February. On 5 February problem areas were discussed; no major problems were identified. Primary areas of concern were time of deployment, from power and thermal considerations, and contamination of solar cells after deployment. On 13 February the board convened to dispose of the accepted requests for change. The only request for change of programmatic importance was the need for a checkout of the solar array pointing system at the Sacramento Test Operations Facility.

NASA, "Manned Space Flight Weekly Report," 25 February 1969.

7

AAP Director William C. Schneider, in a letter to MSFC's AAP Manager Leland F. Belew, said that Belew's letter of 7 January 1969 reflecting the results of a preliminary investigation to determine the feasibility of operating the Harvard College Observatory's ultraviolet spectrometer experiment in an unmanned AAP mode was interesting. Schneider said the preliminary results indicated the possi-

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bility of only minor programmatic impacts to provide a fixed pointing position capability during the aforementioned period and asked Belew to pursue this minimal approach coordinating directly with the observatory. Schneider suggested that MSFC should study ground support and Manned Space Flight Network requirements and coordinate them with MSC. He further requested that any significant impacts imposed on program costs, schedules, or performance as a result of the implementation of the proposed operational change be brought to his immediate attention.

Letter, William C. Schneider to Leland F. Belew, "HCO Proposal for Automated ATM Operation," 7 February 1969.

12 NASA launched another AAP-related Aerobee 150 sounding rocket from White Sands Missile Range. The rocket carried a Naval Research Laboratory payload to 187.9-km altitude to record photographically 18 extreme ultraviolet spectra of solar photosphere, chromosphere, and corona, using a flight design verification unit of the high-resolution spectrograph planned for ATM–A and ATM–B. Rocket and instruments performed satisfactorily.

NASA, "Report of Sounding Rocket Launching."

18 An early test model of the ATM control computer was delivered by Bendix Corporation to MSFC where it was undergoing performance tests. This was a preproduction unit and did not include all the functions that would be in the flight version. The first flight unit was scheduled for delivery in September 1969.

MSFC, "AAPO Weekly Activity Report," 24 February 1969; "Apollo Applications Test Weekly Status Report," 28 February 1969.

26 NASA announced it would negotiate with North American Rockwell for modifications to four Apollo spacecraft for AAP.

Letter, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, 26 February 1969.

26 MSFC hosted an AAP medical experiments review attended by representatives from NASA Hq, KSC, MSC, and MSFC. Purpose of the meeting was to discuss the status of the development of medical experiments and to assess their ability to meet program need dates. Medical experiments were being developed that would provide flight hardware to support scheduled launch dates. However, flight hardware would not be available to support fit and function tests of experiments in the OWS or the MDA. Alternate methods would be investigated using flight configured hardware rather than actual flight hardware to satisfy these test requirements.

Letter, William C. Schneider, NASA Hq, to Robert F. Thompson, MSC, and Leland F. Belew, MSFC, "Review of AAP Medical Experiments," 18 February 1969; "Minutes of Medical Experiments Meeting—MSFC," 25 February 1969; "Apollo Appli-

cations Test Weekly Status Report for Week Ending February 26, 1969," 28 February 1969.

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During the Month

Massachusetts Institute of Technology published its final report (R634 dated February 1969) covering a series of eight software tasks that had been assigned to them during the initial phases of AAP. Study results included a computer subroutine for CSM local vertical hold; a technique for performing differential CSM jet firings for more precise attitude control; and an autopilot, similar to the present one, to control attitude during spinup, spindown, and reorientation for the docked CSM/LM/ATM.

NASA, "Manned Space Flight Weekly Report," 24 March 1969.

March

4

A review of some potential color application processes for the OWS was held at MSFC with McDonnell Douglas. The prime contender for the exterior of the OWS was a gold porcelain enamel. Other processes in development testing were a teflon coating for the aluminum foil in the OWS interior and the application of porcelain enamel or micatex paint for other interior areas.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 20 March 1969; NASA, "Manned Space Flight Weekly Report," 24 March 1969.

4

An AAP baseline configuration review was held at NASA Hq. During the review, MSC and MSFC presented the results of a study of the AAP backup and alternate missions. MSFC led discussions on a proposed major design review and presented results of a study on a flexible airlock module, the status of work related to stowage problems, and a review of the cluster instrumentation and communications systems. MSC made a presentation on launch windows for the AAP missions, gave a status report on a study of combining the AAP–3A and AAP–4 missions, and proposed deletion of the lunar module abort guidance system.

Letter, William C. Schneider, NASA Hq, to Robert F. Thompson, MSC, Leland F. Belew, MSFC, and Thomas W. Morgan, KSC, "Minutes of AAP Baseline Configuration Review Held March 4, 1969," 11 March 1969.

4–22

A series of ATM extravehicular activity neutral buoyancy tests were performed at MSFC. Astronauts participated in both scuba gear and pressurized space suits. Purpose of the tests was to evaluate the performance and procedures for moving film cassettes to the two ATM work stations and to perform some of the tasks required at these stations. Recommendations were made for the improvement of most of the features evaluated. As a result of the tests, equipment and procedures modifications were made.

MSFC Process Engineering Laboratory, "Neutral Buoyancy Simulator Daily Log," 4 March 1969; "Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 6 March 1969; "Apollo Applications Test Weekly Status Report," 6 March 1969; "Weekly Progress and Problem Summary Report for

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the Administrator—Apollo Applications Program," 28 March 1969; "Apollo Applications Tests Weekly Highlights Report," 27 March 1969.

March

5–6 At Huntsville, representatives from Headquarters, MSC, KSC, and MSFC conducted a preliminary requirements review of various crew equipment aboard the Apollo Applications Program Workshop. The review constituted a significant milestone toward establishing firm requirements for items such as the waste management system, sleep restraints, and off-duty equipment for the crew. The continuous search to reduce program costs led to elimination of the automatic data management and optical verification systems and to simplification of the water system aboard the craft. Also, the hygiene system would be government-furnished equipment, and designers imposed strict limits on use of off-duty equipment.

"Weekly Progress and Problem Summary for the Administrator-Apollo Applications Program," 14 March 1969; MSFC, "Weekly Activity Report," 14 March 1969; NASA, "Manned Space Flight Weekly Report," 17 March 1969.

10 A test to evaluate the hydrogen-helium outgassing characteristics of the OWS during passivation was conducted in the vacuum chamber at MSFC. Total pressure and partial pressure were monitored over a 40-hour simulated passivation period. Test reports indicated that all measurable traces of hydrogen disappeared in four to six hours, while traces of helium remained throughout most of the passivation period.

NASA, "Manned Space Flight Weekly Report," 10 March 1969.

11 During an AAP briefing at MSC, Deputy Director of Apollo Applications John H. Disher said ". . . we are in manned flight today, in a position roughly comparable to that in 1910 for airplanes . . . and in 1910, or in 1909, it was the well-known physicist of his day, Simon Newcomb, . . . who said anyone who thinks that the airplane will sometime replace the train is out of his mind. . . ." Disher was describing AAP: what the program was and what it planned to accomplish.

Text of Apollo Applications Program Briefing, John H. Disher, NASA Hq, 11 March 1969.

18 A definitive contract for payload integration in support of AAP was awarded to Martin Marietta. In addition to systems engineering and integration relating to the payloads for each vehicle and the entire cluster, Martin Marietta would develop and fabricate the control and displays for the ATM. The major portion of the work would be performed at Martin Marietta's Denver plant.

NASA Hq News Release 69–43, "AAP Support Contract," 18 March 1969; letter, William C. Schneider, NASA Hq, to Deputy Associate Administrator for Manned Space Flight, "Background Information on Martin and GE Support for the AAPO," 17 March 1969.

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March
19

The abort guidance system was deleted as backup to the primary navigation guidance system during unmanned rendezvous and docking in AAP. An important factor in the decision to delete it from the baseline configuration was the fact that the system provided only a partial backup to the primary navigation guidance system during unmanned rendezvous and docking. Deletion of the abort guidance system would result in a cost savings of approximately $8.7 million.

Letters, William C. Schneider, NASA Hq, to Robert F. Thompson, MSC, "Deletion of the Lunar Module Abort Guidance System as Backup to Primary Navigation Guidance System During Unmanned Rendezvous and Docking," 19 March 1969; William C. Schneider to Robert F. Thompson, Leland F. Belew, MSFC, and Thomas W. Morgan, KSC, "Minutes of AAP Baseline Configuration Review," 11 March 1969.

24

A meeting at MSFC examined design changes leading to weight increases in the OWS. The major changes were: a high-performance installation on the forward dome that increased weight because of purge requirements producing structural adjustments; thermal extensions to the meteoroid shield to minimize heat leaks; solar array system modification requirements; and updating of the intercommunication system weight.

NASA, "Manned Space Flight Weekly Report," 1 April 1969.

26–27

The interface status of the CSM and MDA was reviewed at MSFC with representatives from NASA Hq, MSFC, MSC, Martin Marietta, and North American Rockwell. The closing mechanism appeared to be working well; the caution and warning criteria would require additional systems engineering attention.

NASA, "Manned Space Flight Weekly Report," 7 April 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 4 April 1969.

28

As a result of the MSFC structural analysis meeting held at MSFC, the following actions were planned in the AM/MDA test program: to increase loading capacity, a small number of rivets would be changed to the next largest size in an area near the joint section; the structural test article would be shipped by *Guppy*, arriving at MSC by 1 May; integrated test preparations would begin at MSFC during the first week in May, and static tests would start on 15 June.

NASA, "Manned Space Flight Weekly Report," 7 April 1969; "Weekly Progress and Summary Report for the Administrator—Apollo Applications Program," 4 April 1969; "Apollo Applications Test Weekly Status Report," 3 April 1969.

During the Month

The ATM would be a manned solar observatory making measurements of the Sun by telescopes and instruments above the Earth's atmosphere. The instruments would obtain data on the transitions occurring in elements ionized in the vicinity of the Sun's surface—data contained in the ultraviolet and x-ray spectrum absorbed by the Earth's atmosphere. Orbiting telescopes would also observe

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flares and regions of the corona hidden to Earth-bound telescopes or covered by scattered light.

NASA Technical Note D-5020, "Scientific Experiments for the Apollo Telescope Mount," March 1969.

April
1–3

A critical design review of the Bendix Corporation cryogenic storage system was conducted at Davenport, Iowa. The review item discrepancies were primarily in procedures and documentation rather than in design adequacy. A NASA, North American, and Bendix team was assigned action to update the process specifications, quality assurance controls, and buyoffs and to complete the qualification test plan.

"Apollo Applications Test Weekly Highlights Report," 9 April 1969; "Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 10 April 1969; NASA, "Manned Space Flight Weekly Report," 14 April 1969.

7

A small film canister, designed and fabricated at MSFC, was delivered to KSC for flight test on Apollo 10. The canister, packed with a variety of photographic film, would obtain information on the sensitivity of film to the thermal, pressure, and radiation environment of space, in part equivalent to those which would be experienced by the ATM in flight. The test would also complement ground testing and theoretical analyses that were conducted to evaluate potential film fogging in a space environment.

"Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 10 April 1969; NASA, "Manned Space Flight Weekly Report," 14 April 1969.

7

MSFC and MSC recently reorganized their AAP offices to reflect the realignment of hardware development responsibilities within AAP. The MSFC AAP reorganization created project offices for each spacecraft module, e.g., AM, LM, and ATM. The MSC AAP reorganization was structured to include four functional and two project offices.

Memorandum, Robert F. Thompson, MSC, to Dist., "Procedures for AAP Correspondence to MSFC," 7 April 1969.

9–10

An AAP mission requirements meeting was held at MSC. The following items were among those on the agenda: weight and performance status; need for buoyancy tests and additional ballast for AAP CSM which were heavier than Apollo's; and the proposal that a flexible scientific airlock be abandoned due to high cost.

"Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 23 April 1969.

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9–11

MSC conducted a formal mockup review of the CSM-airlock tunnel interfaces to establish detailed design requirements for all mechanical, umbilical, and electrical interfaces. Technical reviews underway at North American Rockwell and MSC included crew systems, fuel cells, and environmental control. North American was ordered to proceed with the AAP SM configuration. The return battery pack was deleted (batteries would be provided in the CM, and the fuel capacity of the reaction control system would be enlarged from 545 to 1633 kg).

NASA, "Manned Space Flight Weekly Report," 14 April 1969.

10

An ATM-acceptance checkout equipment meeting was held at MSFC. The meeting ended with an informal concurrence on the content of an acceptance checkout equipment inter-Center agreement. The agrement covered deactivation, transportation, installation, and certification of satisfactory operation of the MSFC acceptance checkout equipment station. It also covered the responsibilities of each of the participating Centers (MSFC, MSC, KSC) with regard to the design, modification, maintenance, operation, and software development of the station.

"Apollo Applications Test Weekly Status Report," 16 April 1969; MSFC, "Weekly Activity Report," 17 April 1969.

15–16

A meeting was held at MSFC with representatives of the camera manufacturers, North American, Grumman, and MSFC to review ATM camera stowage and handling and the CSM and LM stowage. The following areas were discussed and assigned for further study: environment (thermal, shock, and vibration); interface control documents for the cameras and carriers; LM and CM stowage volume and weight limitations and their effect on camera configuration; and camera extravehicular activities.

Memorandum, T. C. Winters, Jr., Naval Research Laboratory, to Dist., "ATM Camera Coordination Meeting," 16 April 1969; NASA, "Manned Space Flight Weekly Report," 5 May 1969.

17

A prenegotiation conference for the AM and OWS contracts was held at NASA Hq. The most significant program changes concerned the following:

- Delayed delivery of the backup hardware to conserve FY 1970 funds and eliminate ground support equipment duplication.
- Deletion of acceptance testing for backup in the initial contract.
- Deletion of certain mockups and trainer updates.

NASA, "Manned Space Flight Weekly Report," 28 April 1969; "Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 28 April 1969.

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18 MSFC issued requests for proposals for manufacture of solar arrays to convert solar energy into electrical power to operate the OWS. The OWS would have two wings covered with solar cells—a total area of 111 sq m. Each of the wings would be composed of 120 sections. Together the wings would produce 12 000 watts to power the OWS. A preproposal conference on the requests was scheduled for 1 May at MSFC.

MSFC News Release 69–116, 18 April 1969.

22 NASA Hq recommended that the palatability of food and water be enhanced for longer duration manned flight. To accomplish this, a food development plan would be directed toward the following objectives: utilization of more conventional foods; resolution of stowage and preservation problems for inflight foods; development of facilities to enable more conventional food preparation and eating in space; and application of principles and practices already utilized by the food industry for commercial products.

Letters, William C. Schneider, NASA Hq, to Robert F. Thompson, MSC, "In-Flight Food and Water System for AAP," 22 April 1969; William C. Schneider to Leland F. Belew, MSFC, "In-Flight Food and Water Heating and Cooling Capabilities for AAP," 22 April 1969.

29 Apollo Spacecraft Program Manager George M. Low advised Robert F. Thompson, MSC Apollo Application Program Manager, of the problems the Apollo program had encountered in caution and warning systems, saying that "during the past two years, we have had caution and warning changes at nearly every Configuration Control Board meeting." Low said that from that experience he had reached the following conclusions: "(1) Caution and warning parameters should be carefully selected and, when in doubt, the answer should be that the parameter should not be on the caution and warning system. Only those parameters that could change rapidly (e.g., between two ground stations) and that would require immediate action to avoid a catastrophic situation should be displayed on a C&W system. (2) The caution and warning limits should be easily adjustable, certainly up to the time of launch, and, preferably, even in flight. The settings should be adjustable so that a limit could be opened up or closed down as the need arises. (3) It should be possible to disable each individual caution and warning system in flight."

Memorandum, George M. Low to Robert F. Thompson, "Caution and warning systems," 29 April 1969.

May

1 An OWS meeting was held at MSFC in an effort to finalize the interior OWS color. Flaking from exposure to the cryogenic tank temperatures precluded the use of an otherwise acceptable MSFC developed paint. During the meeting a presentation was given by McDonnell Douglas on coloring processes that were technically acceptable for preinstallation applications. Green alodine was approved for the coloring process to be used for the aluminum foil fire retardant

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liner. Loewy and Snaith, Inc., was to prepare an OWS model with a recommended color scheme compatible with the green alodine foil liner.

MSFC, "Weekly Activity Report," 16 May 1969; NASA, "Manned Space Flight Weekly Report," 12 May 1969.

1

An AM arrived at MSFC for ground testing. It formed part of the AAP OWS cluster. The AM would be joined to the MDA and would provide an interconnecting passageway between the S-IVB stage and the MDA in flight. The AM would also condition environmental gases and provide instrumentation, data management, intercommunications, and other services.

MSFC News Release 69-124, 1 May 1969; "Apollo Applications Test Weekly Highlights Report," 8 May 1969; MSFC, "Weekly Activity Report," 8 May 1969; "Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 8 May 1969.

2

Acting on a suggestion made to him several months earlier by George E. Mueller, Associate Administrator for Manned Space Flight, AAP Director William C. Schneider established an AAP Software Board headed by Schneider and including members from the manned space flight Centers, as well as NASA Hq. Such a board, Schneider said, was needed so that AAP flight software could be developed promptly and smoothly—and with an eye toward overall system implications. Also, such a board would facilitate the task of coordinating software work between the Centers. The board, said Schneider, would review software-related problems and requirements and would afford an avenue for management visibility into the software area comparable to that available for hardware-type problems at periodic configuration reviews.

Letter, William C. Schneider to Leland F. Belew, MSFC, Robert F. Thompson, MSC, and Thomas W. Morgan, KSC, "AAP Software Board," 2 May 1969.

2

In response to a NASA Hq query regarding computer selection for the OWS attitude control system, MSFC responded that several factors influenced the decision to select an analog rather than a digital system. According to a thorough technical and cost evaluation tradeoff study, the analog computer would save half a million dollars, while providing required redundancy with less system complexity. In addition, there was an associated weight and power saving of 27 kg and 160 W.

Letter, Leland F. Belew, MSFC, to William C. Schneider, NASA Hq, "Workshop Attitude Control System (WACS) Control Computer Selection and Electronics Location," 2 May 1969.

13

A payload integration management meeting was held at Martin Marietta, Denver, with representatives from NASA Hq, MSFC, and MSC. Emphasis of the meeting was on Martin Marietta resources to continue the AAP, management of assigned tasks, and impact of the Viking Project, if Martin Marietta were selected

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for it. A continuing review process had been employed by Martin Marietta to correlate tasks assigned by MSC, MSFC, and Headquarters and to eliminate redundancy and nonproductive effort.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 16 May 1969.

15

In reviewing the last three years of AAP—its changing objectives, late decisions, experiment priority shifts—and in looking forward to the uncertainties of NASA space flight after AAP, MSFC officials found it difficult to visualize that the Office of Manned Space Flight and the manned space flight Centers would be able to carry out a program defined for an integrated OWS/ATM in 1972. A major difficulty would be in keeping AAP from being continually impacted as the leading edge of space station activity.

Letter, Leland F. Belew, MSFC, to William C. Schneider, NASA Hq, "Impact Assessment to AAP Core Program Due to OMSF Proposed Saturn V Dry Launched Self Dependent Workshop with an Integrated ATM," 15 May 1969.

20

A payload shroud preliminary design review was held at MSFC. Representatives from NASA Hq, MSC, KSC, MSFC, Grumman, McDonnell Douglas, Martin Marietta and Bellcomm, Inc., attended. Areas that received the most discussion included access doors and platforms for on-pad servicing and checkout, acoustic criteria-requirements and tests, and the functional subsystems interfacing with the payloads.

"Apollo Applications Test Weekly Highlights Report," 28 May 1969; MSFC, "Weekly Activity Report," 22 May 1969.

21

MSC Director Robert R. Gilruth established a Space Station Task Group, headed by Rene A. Berglund, to oversee the Center's various studies (both in house and under contract) associated with the phase B definition of a space station. These studies were predicated upon a successful AAP which was essential for data in a number of areas of direct implication for more elaborate space stations: the physiological effects of weightlessness for extended periods of time; demonstrated performance capabilities of the crewmen aboard the station; data on the long-term habitability of the station; flight qualification of many new hardware components (e.g., large solar arrays, control moment gyros, and molecular sieves); and broad experience in logistical and orbital operations in general, including crew transfers and resupply of scientific equipment and consumables.

MSC Announcement 69-67, "Establishment of Space Station Task Group," 21 May 1969.

21

At the Manned Space Flight Management Council meeting held at MSC, Associate Administrator George E. Mueller sounded out the Center Directors and AAP officials regarding program options facing AAP and the direction that the

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program should take. These options, discussed at length during the meeting, derived primarily from the choice of a Saturn IB "wet" Workshop versus a Saturn V "dry" Workshop (with several possible approaches for ATM and CSM operation).

On 23 May, MSFC Director Wernher von Braun responded at length to Mueller's request for recommendations from the field. Foremost, von Braun stated, AAP's basic objectives (long-duration manned space flight and solar observations) could be achieved within present resources and schedules (though it would require some "hard-nosed scrubbing down" of current methods). Of the several possible program options, the MSFC Director voted for the Saturn V-launched "dry" Workshop. His recommendation derived from several factors. A principal one was NASA's astonishing record of success with the basic Saturn V launch vehicle. Also, several important benefits derived from launching the Workshop in a fully equipped configuration rather than using the Saturn IB's second stage:

- Because of greater weight carrying ability many experiments could be carried that heretofore had been too heavy to be included,
- Great improvement could be made in the habitability of the Workshop.
- Some expendables could be offloaded from the proposed AAP–4 flight, thus ensuring that the mission would remain within the Saturn IB's payload capability.
- Redundancy and spare components would enhance overall mission success and reliability.
- The dry-launched Workshop allowed installation and checkout of all Workshop equipment on the ground prior to lanuch, as well as eliminating the complications of forcing the S–IVB stage to serve as a propulsive stage as well as space laboratory.

In short, von Braun told Mueller, the Saturn V-launched Workshop offered "real and solid" advantages without any attendant program perturbations. Such a move he called an "organic and logical step for gaining experience" in long-duration flight and said it would "allow us to qualify subsystems for the full-fledged space station/space base."

Three days later, MSC Director Robert R. Gilruth responded to Mueller and voiced almost the same ideas. Gilruth, too, recommended that AAP adopt the Saturn V Workshop concept, which was essentially the Saturn IB model launched aboard the first two stages of the Saturn V. Thus, AAP would enjoy the luxury of a "ready-for-use" vehicle of a much improved configuration. This latter concept pointed to achievement of AAP's basic objectives which remained unchanged: 56-day missions, solar astronomy, and—an implied AAP objective—early space flights at minimum cost looking ahead toward NASA's getting an early go-ahead on the space station and the space shuttle programs during the latter half of the 1970s.

1969

May

Letters, Wernher von Braun to George E. Mueller, 23 May 1969; Robert R. Gilruth to George E. Mueller, 26 May 1969; J. M. West, MSC, to Robert R. Gilruth, "Extended AAP Flight Program," 25 April 1969; Maxime A. Faget, MSC, to Robert R. Gilruth, "A Study of Apollo Applications Program Using Saturn V Launch Vehicles," 23 April 1969.

22 AAP baseline configuration review was held at NASA Hq. MSC and MSFC presented a status report on weight of flight modules, measurement lists by modules, plans for controlling the lists, and criteria for measurement selection. KSC gave a report on the status of LC 34/37 equipment and facilities and plans for getting them ready for AAP. MSFC presented the status of a joint MSC/MSFC study of stowage on AAP–2, a status report on the caution and warning system, and the current plan for LM/ATM extravehicular activity film exchange. MSC reviewed plans for the development of mission operations documentation and presented the results of a joint MSFC/MSC study on the use of the CSM to rescue a malfunctioned LM/ATM.

Letter, William C. Schneider, NASA Hq, to AAP Program Managers, MSFC, MSC, and KSC, "Minutes of AAP Baseline Configuration Review," 22 May 1969.

22–23 KSC hosted a meeting of the AAP Principal Investigators to familiarize them with KSC facilities and equipment. Items covered included experiment timelining, ATM test and checkout, KSC AAP–4 vehicle flow plans, and quick-look data systems.

NASA, "Manned Space Flight Weekly Report," 2 June 1969; "Apollo Applications Test Weekly Highlights Report," 28 May 1969.

25 An OWS project management meeting was held at Huntington Beach. Representatives from MSFC, MSC, NASA Hq, and McDonnell Douglas attended. A summary of McDonnell Douglas' program status was presented, and immediate program problems were discussed. Some of these problems were interface documents, preliminary design review requirements, MDA weight and volume requirements, meteoroid shield icing, instrumentation, trajectory requirements, ventilation and thermal control, mission support, and engineering mockup fidelity.

"Apollo Applications Test Weekly Highlights Report," 28 May 1969; NASA, "Manned Space Flight Weekly Report," 2 June 1969.

26 North American Rockwell briefed MSC on recommended service module reaction control system modifications to reduce system costs. The most significant of these changes was a recommendation to reduce the number of propellant modules from six to three as a means of cutting down the number of components in the reaction control system, the manufacturing and checkout time, and the complexity of the system.

NASA, "Manned Space Flight Report," 26 May 1969; "Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 28 May 1969.

1969
May
27

A spacecraft fire hazards meeting was held at MSC. Representatives attended from Lewis Research Center, NASA Hq, Electronics Research Center, MSFC, KSC, MSC, and the Air Force Manned Orbiting Laboratory Safety Office. Fire hazard detection techniques and systems suitable for development for use on spacecraft were discussed. Heat-sensitive, sniffer, radiation, radio-frequency, mass-spectrometer, and pressure-rise detector methods were discussed.

Letter, P. T. Hacker, Lewis Research Center to Dist., "Minutes of May 27, 1969 meeting," 23 June 1969.

June
10

The critical design review of the ATM control computer was held at MSFC. All submodules of the flight module control computer, with one exception, were reported as designed. An engineering model control computer was available for examination at the review.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 12 June 1969; "Apollo Applications Test Weekly Highlights Report," 11 June 1969; NASA, "Manned Space Flight Weekly Report," 16 June 1969.

10–23

The DOD announced cancellation of its MOL Program. The program was initiated in 1965 to advance the development of both manned and unmanned defense-oriented space equipment and to ascertain the full extent of man's utility in space for defense purposes. Following MOL termination, NASA requested that the MOL food and diet contract with Whirlpool Corporation and the space suit development contract with Hamilton Standard Division, United Aircraft Corporation, be transferred to NASA.

DOD Release 491–69, 10 June 1969; TWXs, J. W. Scheer, NASA Hq, to Robert R. Gilruth, MSC, 10 June 1969; William C. Schneider, NASA Hq, to Robert F. Thompson, MSC, 10 June 1969; Robert F. Thompson to William C. Schneider, 23 June 1969; George E. Mueller, NASA Hq, to James T. Stewart, USAF, 23 June 1969; letters, Robert F. Thompson to Dist., "MSC Involvement in USAF's MOL Program Phaseout," 11 June 1969; G. J. Vecchietti to all Center Procurement Officers, "Termination of MOL Contract by USAF," 1 July 1969; Robert F. Thompson to William C. Schneider, "Termination of USAF MOL Program," 2 July 1969.

11

KSC was examining alternate methods of nitrogen purging on LC–34 and LC–37 in order to reduce costs of line leakage during standby. Among alternatives being studied were using dry air for purging lines since dry air could be used for purging the payload shroud; starting up the nitrogen converter compressor facility rather than purchasing gaseous nitrogen from suppliers; or tapping into the supply of gaseous nitrogen being supplied through pipeline in bulk form at low cost to Launch Complex 39.

"Apollo Applications Test Weekly Highlights Report," 11 June 1969; "Weekly Progress and Problem Summary Report," 12 June 1969.

18

North American Rockwell was directed to effect a three-month delay in the AAP CSM critical design review and in the delivery of flight spacecraft. The delay was authorized in anticipation of pending AAP modifications.

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TWXs, Robert F. Thompson, MSC, to William C. Schneider, NASA Hq, Leland F. Belew, MSFC, and Thomas W. Morgan, KSC, "AAP Core Program Flight Schedule," 19 June 1969; H. E. Gartrell, MSC, to L. M. Tinnan and R. K. Swim, (North American Rockwell), 18 June 1969.

20

NASA Hq informed MSC that it was of immediate importance in planning future manned space flight programs to understand the extent to which a common CSM configuration could be used to satisfy the requirements for lunar exploration, as well as for the AAP in conjunction with the Saturn V Workshop and early support of the space stations. It was Headquarters' desire that a common CSM be evolved that could serve the purposes. Some compromise in performance might be necessary for one or the other of these uses, but the advantages of producing only one set of modifications should be great. MSC was requested to institute a feasibility study by the Apollo Space Program Office and Apollo Applications Program Office personnel, using North American personnel as appropriate. Headquarters asked an initial appraisal of the concept by telephone 23 June, and results of a more thorough assessment by 7 July.

TWX, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, "CSM Configuration for Lunar Exploration and AAP," 20 June 1969.

23

In response to a TWX from NASA Hq (see 20 June entry) Kenneth S. Kleinknecht and Robert F. Thompson of MSC talked to John H. Disher (NASA Hq) at the suggestion of Apollo Spacecraft Program Manager George M. Low. Also listening to the conversation were Robert V. Battey and Harold E. Gartrell of MSC. (Low had suggested the call be made to William C. Schneider of NASA Hq, but he was not available.)

Kleinknecht reiterated to Disher that from the beginning of both the AAP and the Apollo Lunar Exploration Mission (ALEM) consideration had always been given to maintaining the maximum degree of commonality between the basic CSM and those required for both programs without creating severe constraints on the objectives of either mission.

Kleinknecht pointed out different requirements of the program and how they clearly indicated some major configuration differences between AAP and ALEM:

- Long duration of the AAP mission.
- Backup reaction control system deorbit capability of AAP.
- Thermal characteristics of AAP missions because of long attitude holds.
- Use of batteries in lieu of fuel cells in the CSM (if the Saturn V Workshop became a reality the CSM would be quiescent for long periods of time).

Kleinknecht added that "inasmuch as ALEM is still required to do lunar-landing missions as well as collect orbital scientific data, we cannot tolerate any weight penalties that may be associated with scar weights [weights incurred by using a

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common CSM for multiple missions with modification kits used for each mission, and consequent weight in the basic CSM not usable for all missions] resulting from commonality with the AAP vehicle. . . ." He also recognized that there would be more commonality between the AAP and ALEM should the Workshop become official because expendables could then be supplied to the CSM from the Workshop rather than carried in the CSM. He added that about three and one-half months had been spent in studying and defining the ALEM CSM, and a major change to provide commonality with the AAP CSM would result in that time being lost and at least three and one-half months delay in the launch readiness of the first ALEM mission.

Kleinknecht concluded that MSC agreed in principle with Headquarters in providing as much commonality as possible, but recommended that the 20 June TWX from Headquarters be rescinded and that MSC not pursue a commonality study with North American.

Four days later, MSC received another TWX from George E. Mueller (NASA Hq) saying, ". . . it is our understanding that you will continue your in-house evaluation of the differences in requirements and the impact of these differences on the configuration of CSM's to support lunar exploration, AAP Saturn V Workshop, and early space station missions. This further assessment should be available for discussion by July 7 and will likely be presented to the Management Council in executive session on July 8 or 9."

Memorandum, Kenneth S. Kleinknecht to Manager, Apollo Spacecraft Program, "CSM configuration for lunar exploration and AAP," 23 June 1969; TWX, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, "Ref: My June 20, 1969 TWX to You Re. CSM Configuration for Lunar Exploration and AAP," 27 June 1969.

July

1

A study was conducted to determine the feasibility of providing an artificial gravity operating mode for a second OWS. Study results indicated there were several areas of the OWS that would require unique configuration characteristics. Among the areas of concern were antenna location and coverage; CSM/MDA docking interface strength; reaction control system characteristics, propellant consumption, and attitude control logic to maintain solar orientation in the face of gravity gradient torques; ATM mounting and deployment provisions; and the ATM solar array structure.

Letters, William C. Schneider, NASA Hq, to Deputy Associate Administrator for Manned Space Flight, "Artificial Gravity Using a Second Dry Workshop," 1 July 1969; William C. Schneider to Robert F. Thompson, MSC, "Artificial Gravity Experiment in AAP," 22 August 1969.

1

A preliminary requirements review for an experiment support system was held at MSC. The system was being developed by MSFC for MSC. It was designed to provide fluids, electrical, and instrumentation support to a number of AAP biomedical experiments.

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"Apollo Applications Test Weekly Highlights Report," 2 July 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 3 July 1969.

8–9

The results of a dry OWS study effort performed by KSC, MSFC, MSC, and major AAP contractors were presented to the Manned Space Flight Management Council. The basic dry OWS configuration and associated cost and schedule estimates resulting from the study were discussed and approved. The AAP Director then presented the proposal to the NASA Administrator. (See 18 July entry.)

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 11 July 1969.

9

A meeting was held at MSC to discuss a teleprinter system on the AM. MSFC presented a system that would be compatible with the Manned Space Flight Network and would utilize the digital command system. MSC presented a system that would utilize the CSM voice link, tying into the onboard audio system and not having to go through the environmental control system to get input data to the teleprinter. An evaluation of both systems would be made prior to making a final recommendation on a teleprinter system for the AM.

MSFC, "Weekly Activity Report," 29 July 1969.

11

MSC terminated the development of the A9L space suit. The AL7 space suit, used in the Apollo program, would continue in use until replaced by a flight-qualified, constant-volume suit. During the Mercury program a modified version of the Goodrich Navy Mark IV suit was used. In the Gemini program a modified version of a suit developed by David Clark Company for the USAF was used. Hamilton Standard had overall development responsibility for the Apollo suit and associated portable life support system. A subcontract was awarded to International Latex Corporation for development of this suit. After suit development was completed, the production contract was awarded to International Latex, and the initial suit was designated A5L. The A6L design incorporated a thermal/meteoroid garment. Following the Apollo fire, the suit was redesigned to eliminate flammable materials and was designated A7L (designation A8L was never used). Two hard-shell, constant-volume suits were under development, an extravehicular suit was being developed by Litton Industries, and an intravehicular suit was being developed by AiResearch Corporation. Both of the latter would be used in the Apollo Applications Program.

"Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 11 July 1969; letters, John H. Disher, NASA Hq, to Director Apollo Applications Program, "Synopsis of Space Suit Development for Manned Space Flight," 21 March 1969; William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "MOL Suit Development Control," 11 July 1969.

15

A number of organizations were studying the possibility of zero-g showers for use in manned space flight. In a letter J. Hall (LaRC), C. C. Johnson (MSC) related

the following: 1969

"MSC has some excellent films of Jack Slight showering in the KC–135 at zero-gravity. July

"The motion pictures of Jack showering are quite revealing—not of Jack, of the action of water at zero-gravity. . . . The interesting point is that the water strikes Jack, bounces off in droplets, but then recollects as jelly-like globs on various parts of his body. He can brush the water away but it will soon reattach elsewhere."

Letter, C. C. Johnson, MSC, to J. Hall, LaRC, "Zero-gravity showers," 15 July 1969.

Apollo 11 was launched from Pad A, Launch Complex 39, KSC, with astronauts Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin, Jr., aboard. The flight went according to plan, and the spacecraft and lunar module entered lunar orbit three days later. On 20 July, at 1:11 p.m. EDT, Armstrong and Aldrin separated the LM from the CSM and began descent to the lunar surface, landing safely in the Sea of Tranquility at 4:18 p.m. They stepped onto the lunar surface later that day, becoming the first men ever to achieve this goal. Then followed several EVAs, during which they collected samples, planted an American flag, and gained the first experience of man's ability to perform duties in the one-sixth gravity conditions. They lifted off from the Moon in the ascent stage of the LM 21 July, rendezvoused and docked with the CSM, transferred their cargo to the CSM, and started their homeward journey shortly after midnight 22 July, landing safely in the Pacific Ocean 24 July. 16–24

Apollo 11 Mission Report, MSC 00171, November 1969.

NASA Administrator Thomas O. Paine approved the shift from a "wet" to a "dry" Orbital Workshop concept for AAP following a review presentation by program officials on the potential benefits of such a change. On 22 July, AAP Director William C. Schneider ordered program managers at the three Centers to implement the change, abandoning the idea of using a spent Saturn IB second stage for a Workshop and adopting the concept of a fully equipped "dry" configuration—with the ATM integrated into the total payload—launched aboard a Saturn V. Schneider ordered the Centers to reorient their respective programs, both in house and under contract, as necessary, to accommodate the new program plan. Among the actions required were 18

- Termination of the letter contract with Grumman, since the LM would no longer be required to house the ATM.
- Termination of North American's stop efforts with Allis-Chalmers Manufacturing Company for long-duration fuel cells and with Bendix Corporation for the cryogenic tank system effort.
- Suspension of negotiations with North American for modifications to the CSM for AAP, and the requesting of a reproposal in light of the lessened demands on the spacecraft to meet AAP's requirements.

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• Redirection of contractual effort on the Workshop itself, as well as the AM.

• Redirection of minor contracts and procurements as required, as well as in-house efforts at the several Centers.

Several other elements of the program also changed as a result of the reorientation: AAP changed from five to four launches, since a separate launch vehicle was not required to launch the ATM; Launch Complex 39 at KSC would be required for AAP, although Complex 37 would not be needed. Although these changes left basic program objectives unchanged, a secondary objective of an unmanned rendezvous between the LM/ATM and the cluster was eliminated. Finally, the launch date for the first AAP flight was slipped from November 1971 to July 1972.

Letters, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, 28 July 1969; William C. Schneider to MSC, Attn: Manager, AAP, "AAP PAD Change Request," 29 July 1969, with attachment, "PAD Change Request/Authorization," 17 July 1969; William C. Schneider to Associate Administrator for Manned Space Flight, "AAP Contract Status Pending Saturn V Workshop Decision," 8 July 1969; TWXs, William C. Schneider to Leland F. Belew, MSFC, Robert F. Thompson, MSC, and Thomas W. Morgan, KSC, "Re-Orientation of AAP to Saturn V-Dry Workshop Integrated ATM Configuration," 22 July 1969; Robert F. Thompson to William C. Schneider, 24 July 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 31 July 1969; MSFC, "Weekly Activity Report," 29 July 1969.

18

A meeting at MSC with personnel from NASA Hq, MSC, and North American Rockwell resulted in an agreement that North American would present for a joint review by the Apollo and AAP offices its concept of a common approach for the AAP and ALEM and CSMs. The meeting was scheduled for 6 August 1969.

The meeting generated much discussion on definition of "common CSM," and the following summarizes the general conclusions or represents added guidelines arrived at following the meeting. (1) The real objective of achieving increased commonality in CSMs was to find a means of reducing the cost of procurement-modified spacecraft for both ALEM and AAP. In pursuing this objective, it was agreed the state of completion of the spacecraft involved and the design status for modifications must be carefully considered. (2) It was clear that in those areas where the two programs had identical requirements, and schedule considerations permitted, such requirements should be satisfied by common design. Where requirements were not identical, but were not conflicting, the desirability of commonality would be determined on a case-by-case cost and schedule analysis. (3) When requirements were conflicting, it should be determined if compromises could be achieved to remove the conflicts and permit consideration of a common approach.

Those attending the meeting included William E. Stoney and Philip E. Culbertson of NASA Hq, Wesley L. Hjornevik, Robert F. Thompson, and Kenneth S. Kleinknecht of MSC, and Dale D. Myers of North American.

Memorandum, John H. Disher and William E. Stoney, NASA Hq, to Samuel C. Phil-

lips and William C. Schneider, NASA Hq, "Common CSM meeting at MSC, July 18, 1969," 28 July 1969.

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NASA formally announced the AAP project reorientation to the "dry" Workshop configuration—both the fully outfitted Workshop and integrated ATM launched aboard a single Saturn V (see 18 July). Program objectives for AAP remained unchanged, however. The schedule called for first launch in 1972. The Workshop would be placed in a circular orbit first. About a day later, the three-man crew would ride aboard a Saturn IB into orbit to link up with the Workshop-ATM cluster, thus beginning the manned portion of the mission.

22

NASA News Release 69-105, "AAP Orbital Workshop," 22 July 1969.

NASA announced selection of two aerospace firms—McDonnell Douglas and North American—to conduct phase B planning studies of 12-man orbiting space stations that could be developed by the mid-1970s. The parallel 11-month program definition studies were a prelude to even larger semipermanent space bases during the later 1970s and 1980s.

23

NASA News Release 69-108, 23 July 1969.

A critical design review was held on the two H-Alpha telescopes being provided for the ATM by Perkin-Elmer Corporation. Representatives from NASA Hq, KSC, MSC, MSFC, Harvard College Observatory, and Naval Research Laboratory attended. Except for the mechanical reticle subsystem, a requirement recently added to the telescope system, the Perkin-Elmer design appeared sound. Only minor discrepancies were noted.

29–31

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 11 August 1969; NASA, "Manned Space Flight Weekly Report," 11 August 1969.

MSFC was studying three options for the ATM pointing control system dry OWS attitude control. Option one was basically the same ATM pointing control system as previously configured, with an additional digital computer; option two was an all-digital computer system; and option three was primarily digital, but retained portions of the analog computer for ATM experiment pointing control.

30

"Apollo Applications Test Weekly Highlights Report," 30 July 1969.

Acting on an offer made by the Defense Department to assign a number of astronauts from the defunct MOL project to NASA, Associate Administrator for Manned Space Flight George E. Mueller chose seven astronauts to augment MSC's flight crews. They were Karol J. Bobko, Charles G. Fullerton, Henry W. Hartsfield, and Donald H. Peterson (USAF); Richard H. Truly and Robert L. Crippin (USN); and Robert F. Overmyer (USMC). The decision to utilize these individuals, Mueller stated, derived from their extensive training and experience on the MOL project and the important national aspect of future manned space flight programs.

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4

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Letters, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, 4 August 1969; Robert R. Gilruth to Amil Rusk, NASA Hq, "Military detail of seven MOL astronauts to the Manned Spacecraft Center," 22 August 1969.

5

Following the decision to implement the Saturn V dry Workshop, LM–2 was the only flight LM article to remain on Earth. Therefore, NASA Hq requested MSC consideration for early disposition of it to the Smithsonian Institution as an artifact of historical interest. Since it was expected that the Smithsonian would exhibit LM–2 as a replica of LM–5, Headquarters also requested that MSC consider refurbishment to provide a more accurate representation of the LM–5 configuration before its transfer to the Smithsonian.

TWX, S. C. Phillips, NASA Hq, to MSC, "LM–2 Disposition," 5 August 1969.

6–21

A neutral buoyancy chamber exercise for the ATM was conducted at MSFC. The purpose was to examine some extravehicular activity concepts under development to determine their validity for incorporation into the dry OWS configuration. Crewmen were somewhat constrained and uncomfortable because, while the suits were neutrally buoyant, crewmen inside the suits were not. The neutral buoyancy exercise was followed by an ATM extravehicular activity crew station engineering review. It consisted of a suited and unsuited walk through evaluation of the ATM film replacement work stations. Several modifications were recommended.

Memorandum, T. C. Winter, Jr., Naval Research Laboratory, to Dist., "EVA Review at MSFC on 20–21 August 1969," 21 August 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 14 August 1969 and 29 August 1969.

7

MSFC awarded a contract to Martin Marietta for the fabrication, testing, and delivery of 15 Saturn V OWS rate gyro processors, a module test set, and the retrofit of 22 ATM rate gyro processors. The rate gyro packages would fly on the OWS and would provide precise attitude control of the OWS cluster, including the ATM.

MSFC News Release 69–173, 7 August 1969.

7

A meeting at NASA Hq briefed George E. Mueller, Associate Administrator for Manned Space Flight, on problems connected with Apollo/Apollo Lunar Exploration Mission/AAP. Attending the meeting were J. Bates, W. B. Bergen, R. E. Carroll, E. R. Gross, G. W. Jeffs, D. D. Myers, and L. M. Tinnan, all of North American; P. E. Culbertson, J. H. Disher, A. J. Evans, C. C. Gay, Jr., G. H. Hage, J. W. Hughes, G. E. Mueller, S. C. Phillips, J. F. Saunders, Jr., M. Savage, W. C. Schneider, and J. B. Skaggs, all of NASA Hq; and H. W. Dotts, H. E. Gartrell, R. C. Hood, K. S. Kleinknecht, J. C. Shows, R. F. Thompson, and H. P. Yschek, all of MSC.

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In a memorandum for record, Kleinknecht outlined the activities of the meeting. The first two parts of the briefing covering North American manpower projections for AAP and joint use of test vehicles and mockups showed there would be a substantial reduction in required resources because of the decision to change from the AAP wet Workshop to the dry Workshop. They had, in fact, reduced their manpower by 400 by 8 August 1969, based on a July 1972 launch readiness for the first AAP mission.

Kleinknecht noted a personal concern with respect to the AAP/ALEM schedules, saying that AAP schedules were fluid and were being established before full definition of either the Workshop or the CSM. He said it was his understanding that NASA was committed to a July 1972 AAP launch, but there was no contingency in the schedule for problems or changes. "Experience has indicated," he said, "that, with such an approach, schedules cannot be met."

The remaining parts of the briefing covered the subjects of AAP/ALEM commonality, CSM status and earliest effectivity of common configuration, and refurbishment of the command module for future reflight. Kleinknecht said these subjects were very much related and the advisability of such an approach was questionable from both economical and technical considerations. Kleinknecht added that Mueller's line of questioning made it apparent that he was extremely interested in the basic approach of providing a common Apollo spacecraft that could be flown for either AAP or ALEM by incorporation of modification kits which could be installed even after delivery.

Kleinknecht, in turn, presented MSC's position that when you consider commonality there were two areas of concern—economics and performance. Expanding on this, he said: ". . . we should consider the current design and manufacturing status . . . what are the economical tradeoffs of delaying the spacecraft now for unnecessary modifications versus providing commonality, with some later effectivity; and from the performance standpoint, what is the impact of commonality weight on the service propulsion system propellant budget and its effect on getting to some of the proposed lunar-exploration sites."

Mueller also emphasized his interest in refurbishing and reflying as many as seven command modules in support of the integrated plan. Kleinknecht again interjected the concern of MSC with the technical aspects of refurbishment and reflight from the standpoint of structural degradation as a result of saltwater corrosion.

Memorandum for record, Kenneth S. Kleinknecht, "Meeting with Dr. G. E. Mueller on August 7, 1969, to discuss Apollo/ALEM/AAP commonality," 26 August 1969.

8

MSFC definitized the existing contract with McDonnell Douglas for two Orbital Workshops for the Apollo Applications Program, converted S–IVB stages to be launched by Saturn V boosters. The contract was slated to run through July

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1972, with most of the work to be performed at the company's plant at Huntington Beach, California. The first Workshop was tentatively scheduled for flight in mid-1972, with the second article initially serving as a backup vehicle if needed.

MSFC Contracts Office, "Mod 9 to Contract NAS 9-6555," 8 August 1969.

12

A CSM technical management meeting was held at MSC. A status briefing was given by North American Rockwell on the environmental control electric power profile, telecommunications, and the service module reaction control system. MSFC agreed to investigate the concept of a thermal barrier between the CSM and the MDA located inside the MDA docking port. The barrier would isolate the CSM from the OWS atmosphere, thereby reducing condensation and heater power in the CSM.

"Apollo Applications Test Weekly Highlights Report," 20 August 1969; "Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 25 August 1969; MSFC, "Weekly Activity Report," 22 August 1969.

13

Functional and environmental development tests were performed on the ATM H-Alpha telescope zoom lens, temperature control, and optical subsystems. The zoom lens subsystem failed during vacuum testing and was being reworked. At a later date, the camera electronics subsystem would be subjected to temperature tests, and the mechanical reticle subsystem to thermal-vacuum and vibration tests.

"Apollo Applications Test Weekly Highlights Report," 13 August 1969.

13

NASA Hq revised AAP delivery and launch schedules, further altering the program in light of both changing resources and fiscal climate, as well as a maturing of program plans per se. The new schedule called for seven Saturn IB and two Saturn V launches, with flight of the first Workshop slated for July 1972.

NASA Hq Schedule, 13 August 1969; AAP Directive No. 4A, "Apollo Applications Program Work Authorization," 19 August 1969; Apollo Applications Program Specification, 15 August 1969.

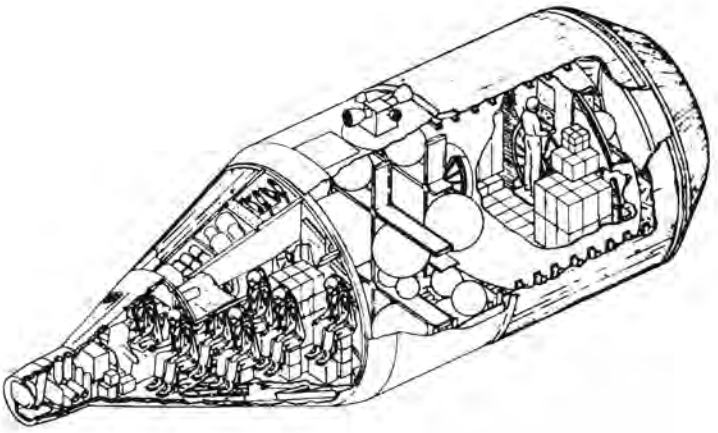
14

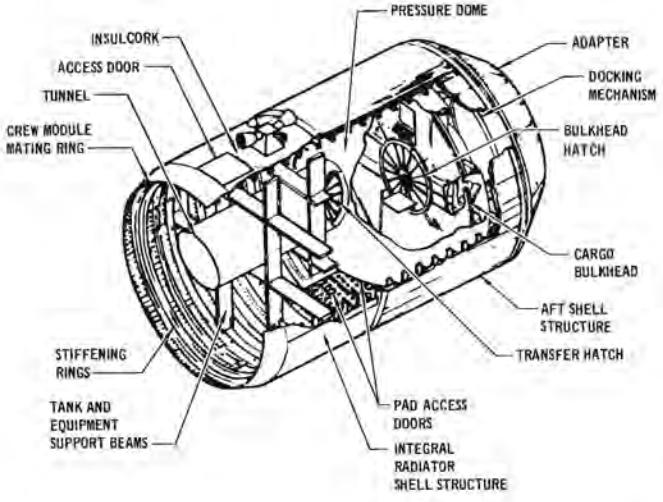
A spacecraft fire hazards meeting was held at the Electronics Research Center, Massachusetts. A demonstration was given by General Electric Company of a condensation nuclei counter and by Walter Kidde and Company of a continuous-wire fire detector. Preliminary recommendations of personnel attending the meeting were that the condensation nuclei counter be considered as a backup overheat and fire detector for spacecraft and that the continuous-wire fire detector be considered as a primary overheat and fire detection system.

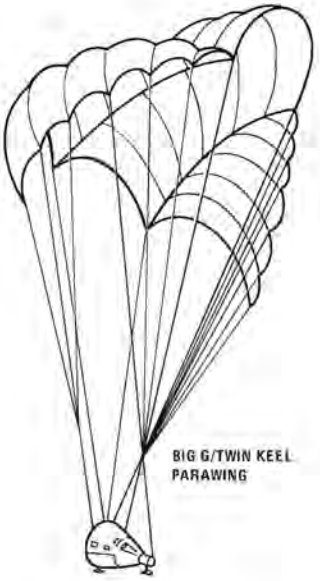
"Minutes of August 14, 1969, Spacecraft Fire Hazards Steering Committee," 9 September 1969.

21

McDonnell Douglas Corporation, under contract to MSC, submitted an eight-volume final report on a "Big G" study.







Three features of the McDonnell Douglas "Big G" study, performed under contract to MSC, are shown here. For additional information on the proposed system, see the 21 August 1969 entry. Graphics supplied by McDonnell Douglas.

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The study was performed to generate a preliminary definition of a logistic spacecraft derived from Gemini that would be used to resupply an orbiting space station. Land-landing at a preselected site and refurbishment and reuse were design requirements. Two baseline spacecraft were defined: a nine-man minimum modification version of the Gemini B called Min-Mod Big G and a 12-man advanced concept, having the same exterior geometry but with new, state-of-the-art subsystems, called Advanced Big G. Three launch vehicles—Saturn IB, Titan IIIM, and S–IC/S–IVB—were investigated for use with the spacecraft. The Saturn IB was discarded late in the study.

The spacecraft consisted of a crew module designed by extending the Gemini B exterior cone to a 419-cm-diameter heat shield and a cargo propulsion module. Recovery of the crew module would be effected by means of a gliding parachute (parawing). The parametric analyses and point design of the parawing were accomplished by Northrop-Ventura Company under a subcontract, and the contents of their final report were incorporated into the document. The landing attenuation of the spacecraft would be accomplished by a skid landing gear extended from the bottom of the crew module, allowing the crew to land in an upright position. The propulsion functions of transfer, rendezvous, attitude control, and retrograde would be performed by a single liquid-propellant system, and launch escape would be provided by a large Apollo-type escape tower.

In addition to the design analyses, operational support analyses and a program development plan were prepared.

The summary report acknowledged the cooperation of NASA Centers and companies that provided technical assistance during the study. Principal contributors were MSC, MSFC, KSC, AC Electronics Division of General Motors Corporation, Bell Aerosystems Company, Collins Radio Company, IBM's Federal Systems Division, Kollsman Instrument Corporation, Amecom Division of Litton Systems, Inc., The Marquardt Corporation, Denver Division of Martin Marietta Corporation, Government Electronics Division of Motorola Corporation, Rocketdyne Division of North American Rockwell Corporation, Space Craft, Inc., Science and Technology Division of TRW Systems Group, and Hamilton Standard System Center of United Aircraft Corporation.

McDonnell Douglas Corp. Report H321, Big G Final Report, *Logistic Spacecraft System Evolving from Gemini, Volume I—Condensed Summary,* 21 August 1969.

22

With the AAP work at Grumman canceled, NASA Hq directed the transfer of acceptance checkout equipment station number three from Grumman to MSFC. MSC would update the Grumman station to the same general configuration as KSC station number six, including documentation, and would make available to MSFC peripheral equipment not available from Grumman.

Letter, George M. Low, MSC, to S. C. Phillips, NASA Hq, "Availability of ACE-s/c station and associated peripheral GSE for ATM," 5 August 1969; TWX, S. C. Phillips to MSC, MSFC, and KSC, 22 August 1969.

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26

Discussions were held to determine the feasibility of achieving common command and service modules for use both in lunar exploration and for the OWS. The consensus was that the differences between the lunar and Earth orbital requirements were so significant that they precluded a completely common configuration.

TWXs, George E. Mueller, NASA Hq, to Robert R. Gilruth, George M. Low, and Robert F. Thompson, MSC; William C. Schneider and S. C. Phillips, NASA Hq, to George M. Low and Robert F. Thompson, MSC; memoranda, Kenneth S. Kleinknecht to George M. Low, 23 June 1969; John H. Disher and W. E. Stoney, NASA Hq, to William C. Schneider and S. C. Phillips, 28 July 1969; note, John H. Disher to William C. Schneider, 24 June 1969; memorandum for record, Kenneth S. Kleinknecht, 26 August 1969.

27–28

An OWS habitability support system preliminary design review was held at MSFC. Representatives from NASA Hq, MSFC, KSC, MSC, and McDonnell Douglas attended. The investigators, astronauts, and industrial design consultants emphasized their desires for a more comfortable environment than would have been possible in the wet Workshop configuration.

NASA, "Manned Space Flight Weekly Report," 8 September 1969; "Apollo Applications Test Weekly Highlights Report," 3 September 1969.

27–28

A preliminary requirements review of the OWS CSM flight systems was held at Downey. Discrepancies were discussed, and follow-up actions assigned. A number of technical requirements impacting the CSM were not adequately resolved and would require extensive coordinated study between MSFC and MSC.

"Apollo Applications Test Weekly Highlights Report," 3 September 1969.

28

KSC officials and AAP managers recommended to the Manned Space Flight Management Council that the Saturn IB AAP launches take place from LC–37 rather than LC–34. They were incorporating the recommendation into the latest program operating plan proposals. If the recommendation were accepted, LC–34 would be partially deactivated and placed in a "down-mode" condition.

Letter, Thomas W. Morgan, KSC, to William C. Schneider, NASA Hq, 8 August 1969; TWX, Thomas W. Morgan to Robert F. Thompson, MSC, Leland F. Belew, MSFC, W. Teir, MSFC, and William C. Schneider, "LC 34/37 Operations," 28 August 1969.

29

MSFC requested McDonnell Douglas and Martin Marietta to develop preliminary design and cost data on a number of OWS system elements that were previously planned for in-house development. Among these were fixed payload shroud, oxygen, and nitrogen bottle installation; cooling of the ATM control and display; deletion of the scientific airlock; design and fabrication of the solar array system; installation of experiments; and MDA integration and checkout.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 29 August 1969.

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3 A meeting was held at MSFC that provided the ATM Principal Investigators an opportunity to express their desires regarding experiment operation during unmanned periods of the ATM OWS mission. AAP personnel from NASA Hq, MSC, and MSFC, as well as ATM Principal Investigators, attended. The investigators felt strongly that their early participation in program decisions that affected experiments would permit a much more effective experiment program without significant budget or schedule changes.

Letters, G. Newkirk, Jr., High Altitude Observatory, to George E. Mueller, NASA Hq, 25 July 1969; George E. Mueller to G. Newkirk, Jr., 28 August 1969; unofficial minutes of the September 3 ATM Principal Investigator's meeting, 10 September 1969.

4 The critical design review on the ATM charger battery regulator module was held with satisfactory results. Numerous tests on the module components were conducted. An engineering prototype was undergoing thermal cycle, charge, and discharge test.

MSFC, "Weekly Activity Report," 11 September 1969.

5 Apollo documentation would be used as the initial baseline documentation for AAP. As AAP progressed, supplements or addenda would be prepared to meet AAP-peculiar requirements.

TWX, H. E. Gartrell, MSC, to G. W. Jeffs, North American, W. C. Schneider, NASA Hq, et al., "Contract NAS 9-9224, AAP Documentation," 5 September 1969.

5 The objectives, constraints, and guidelines for a second OWS were stated in general terms along the following lines:

- OWS would reflect the same physical features and capabilities exhibited by the initial Workshop and would use the flight hardware to be procured as backup for the first Workshop missions.
- Crew complement would consist of three men (at least one scientist astronaut).
- Operating life would be 12 to 24 months, nominally continuously manned.
- Orbital altitude would be in the range of 390 to 500 km at an inclination up to 55°.
- Orientation would be inertially stabilized for solar arrays in either a solar or X–POP (the X-axis perpendicular in orbital plane) mode and would permit experiment pointing for solar, stellar, and Earth survey observations.
- Experiment development schedules would be consistent with an early FY 1974 launch of the OWS.
- Some period of time during the mission would be devoted to experimental artificial gravity operations.
- Planning would utilize currently developed hardware to the maximum extent practical to reduce cost, and consideration would be given to approaches that permit significant cost reductions in payload development.

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• Payload elements would emphasize the experimental facility approach (in contrast to individual experiments) to the maximum extent possible.

• FY 1970 and 1971 funding requirements would be minimized consistent with realistic resource requirements to meet an early FY 1974 launch date.

Letter, William C. Schneider, NASA Hq, to Managers, Apollo Applications Program at MSFC, MSC, and KSC, "Preliminary Mission Definition and Program Planning for the Second Saturn Workshop," 5 September 1969; memorandum, H. E. Gartrell, MSC, to Dist., "Second Workshop Mission Planning Task Force," 26 September 1969.

10

AM simulation test plans were reviewed by MSFC and McDonnell Douglas representatives at MSFC. It was agreed that MSFC would do minor hardware modifications and that McDonnell Douglas would deliver modification kits on major changes to MSFC for installation. McDonnell Douglas would support the various development tests as observers and would participate in the tests when requested by MSFC. Close liaison would be maintained between MSFC and McDonnell Douglas design engineers so that one-g, neutral-buoyancy and zero-g trainers would reflect the current design configuration of the AM.

NASA, "Manned Space Flight Weekly Activity Report," 22 September 1969; MSFC, "Weekly Activity Report," 22 September 1969.

10–11

An OWS test planning meeting was conducted at McDonnell Douglas with representatives from MSFC, KSC, NASA Hq, and McDonnell Douglas. The discussion covered the tests to be conducted on all systems of the Workshop flight item except the habitability support systems. A significant point in the general plan was that experiment equipment would be delivered to McDonnell Douglas, installed, and checked out, so that a completely integrated and checked out module would be delivered to KSC. The checkout sequence would include inverting the Workshop of the module to evaluate the crew quarters and experiment hardware in a simulated orbital configuration, as well as a launch configuration.

"Apollo Applications Test Weekly Status Report," 19 September 1969.

11

Two major directions were identified for manned space flight in the next decade. These were further exploration of the Moon, with possibly the establishment of a lunar surface base, and the continued development of manned flight in Earth orbit, leading to a permanent manned space station supported by a low-cost shuttle system. To maintain direction, the following key milestones were proposed:

1972—AAP operations using a Saturn V launched Workshop
1973—Start of post-Apollo lunar exploration
1974—Start of suborbital flight tests of Earth to orbit shuttle
—Launch of a second Saturn V Workshop
1975—Initial space station operations
—Orbital shuttle flights
1976—Lunar orbit station

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—Full shuttle operations
1977—Nuclear stage flight test
1978—Nuclear shuttle operations—orbit to orbit
1979—Space station in synchronous orbit
By 1990—Earth orbit space base
—Lunar surface base
—Possible Mars landing

Letter, George E. Mueller, NASA Hq, to Robert R. Gilruth, MSC, 11 September 1969.

16 The change in AAP from the wet to the dry OWS substantially improved the probability of mission success and crew safety. Some of the hardware and operational improvements contributing to crew safety were increased payload capability, which would reduce risks from submarginal booster performance; launching the ATM as an integral part of the OWS, thus eliminating an extra launch that involved a complex and operationally difficult unmanned rendezvous and docking; standardizing the three manned launches, using proven software and training techniques, thereby reducing some of the risks associated with new operational phases and missions; and the powering down of the CSM to a quiescent state during the orbital period of operation, with a consequent reduction in wearout or limited-life failures.

Letter, William C. Schneider, NASA Hq, to Acting Director Manned Space Flight Safety, "Semi-Annual Report on NASA Safety Efforts," 16 September 1969.

17 An ATM control moment gyro was subjected to thermal-vacuum, vibration, and electromagnetic interference development environmental testing. Tests indicated that, with proper insulation, no major problems existed in the thermal-vacuum area. However, with the extended requirements for the OWS, command moment gyro actuator lifetime was a concern. In addition to converting to a wet lubricant system, Bendix Corporation and Battelle Memorial Institute, Columbus, Ohio, were asked to study other steps that might be taken to ensure a 300-day lifetime for the control moment gyro actuators.

"Weekly Progress and Program Summary Report for the Administrator—Apollo Applications Program," 22 September 1969; "Apollo Applications Test Weekly Activity Report," 22 September 1969; NASA, "Manned Space Flight Weekly Report," 22 September 1969.

23 An AAP test planning meeting was held at KSC. Representatives from KSC, MSC, MSFC, and NASA Hq attended. Purpose of the meeting was to review the status of factory acceptance test planning for all modules, the preliminary CSM interface test requirements at KSC, and the KSC planning pertinent to conducting AAP integrated module tests. Open issues that would require resolution included flight experiment delivery dates, flight ATM control and display availability for integration into the MDA and compatibility for integration into

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the MDA, and compatibility of flight and prototype ATM delivery dates to support KSC checkout and integrated module test need dates.

"Apollo Applications Test Weekly Status Report," 25 September 1969; MSFC, "Weekly Activity Report," 23 September 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 1 October 1969; KSC, "Weekly Progress Report," 24 September 1969.

23

A technical management review of the CSM caution and warning system was conducted at MSC. Among the topics discussed were caution and warning parameters, the effect of providing memory and inhibit capability, and the cluster interface. About 15 parameters would be monitored by the caution and warning system, a significant decrease from previous estimates. It appeared that ground monitoring would be adequate for the deleted parameters.

NASA, "Manned Space Flight Weekly Report," 29 September 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 1 October 1969.

25

A preboard preliminary requirements review was conducted at MSC. Among the topics discussed were the following:

- MSC agreed to revise the loading requirements and send nearly all food on the AAP–1 launch.
- Food loading time on AAP–2 was moved back from 7 days before launch to about 30 days before launch.
- Preconditioning temperatures for loading the food were relaxed.
- Some of the tolerances on food constituent accuracy and temperature controls were relaxed.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 3 October 1969.

30

An ad hoc group to formulate plans for defining a second OWS met at MSFC. The agenda included goals, constraints, guidelines, payloads, justification for the mission, output, schedule, work plan, and responsibilities for the definition activities. Tradeoffs between mission content and launch date, budget levels, and long-term evolution of manned space flight were some of the issues discussed.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 3 October 1969.

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5

A meeting on the habitability support system and crew quarters layout was held at McDonnell Douglas. Representatives from NASA Hq, MSC, MSFC, and Loewy and Snaith, Inc., attended. McDonnell Douglas proposed an active, closed-loop cooling system to provide for food refrigeration, water chilling, and urine freezing capability. The proposed system would require less power than the existing system and would eliminate waste heat inputs to the Workshop atmos-

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phere. Agreement was reached on ways of improving crew comfort and convenience; however, implementation would depend on the results of tradeoff studies on cost, schedule, and technical factors.

NASA, "Manned Space Flight Weekly Report," 13 October 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 13 October 1969.

6 Program responsibility for Saturn launch vehicles at the Headquarters level was divided between the Apollo Program Office (APO) and AAP Office. Each office was responsible for ensuring that its actions with regard to common hardware elements and facilities were compatible with the other program. To accomplish this, APO would establish an individual as a point of contact on AAP-related matters. In like manner, AAP would establish an individual as a point of contact for APO-related matters.

Memorandum of understanding between the Apollo and Apollo Applications Program Offices on Saturn vehicle management interfaces, R. A. Petrone, APO, 6 October 1969, William C. Schneider, AAP, 13 October 1969.

7 MSFC signed a contract with General Electric Company for support work for AAP. Under the terms of this agreement, General Electric agreed to provide ground support equipment and launch systems for the ATM, MDA, and airlock, as well as for the Saturn V Workshop itself.

Contract NAS 8-25150, 7 October 1969.

8 For some time into the future, all personnel going into space, whether as crews or passengers, would need a reasonable level of training for the environment. This would include aircraft flying, zero-g, centrifuge, and altitude training. Depending on final definition and mission of the space station, crews would consist of pilots, flight engineers, technicians, and scientists. The last three categories would not be trained as pilots. A reasonably stringent selection process would still be required to ensure the compatibility of the crew.

Letter, Robert R. Gilruth, MSC, to George E. Mueller, NASA Hq, 8 October 1969.

8 A meeting was held at North American Rockwell to discuss the AM in connection with its modification and installation in the OWS. Representatives from MSFC, MSC, NAR, McDonnell Douglas, The Boeing Company, Brown Engineering Company, and Martin Marietta participated. Drawings, data, and an AM were examined. The AM would require replacement of certain materials as a fire preventive measure before use in the OWS.

Memorandum, W. K. Simmons, Jr., MSFC, to Leland F. Belew, MSFC, "Workshop Project Weekly Notes," 10 October 1969.

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10

NASA Hq defined the requirements, responsibilities, inter-Center coordination, and review necessary for the development, revision, and checkout procedures applicable to AAP hardware at KSC.

AAP Directive No. 26, "Intercenter Responsibilities for Support and Preparation of KSC Test and Checkout Plans and Procedures," 10 October 1969.

14

At a meeting with AAP officials in Washington, Associate Administrator for Manned Space Flight George E. Mueller reviewed various habitability aspects of the AAP dry-launched Workshop concept. Mueller repeatedly emphasized that the fundamental goal of the AAP Workshop was to gain an understanding of habitability conditions wherein men could live and work in space over long periods of time—factors that could subsequently be applied to the design of a space station. The AAP Workshop, Mueller affirmed, should include a number of critical habitability devices, so that the crews could evaluate various alternatives and select the most desirable designs.

In line with this thinking, Mueller approved the "wardroom" concept for the Workshop, a combined dining and recreational area for the crew. Also, he approved deletion of the Defense Department's sleeping compartment experiment to allow more room inside the wardroom.

Letters, R. L. Lohman, NASA Hq, to Dist., "Space Station Inputs to AAP Habitability Experiment," 16 October 1969; William C. Schneider, NASA Hq, to Robert F. Thompson and C. C. Johnson, MSC, Leland F. Belew, MSFC, and Thomas W. Morgan, KSC, "Review of Habitability Aspects of the Saturn Workshop," 30 September 1969; Donald K. Slayton, MSC, to Manager, Apollo Applications Program Office, MSC, "Orbital Workshop Crew Quarters," 12 December 1969; Mueller Meeting, 15 October 1969.

15

To achieve clarity in AAP documentation relationships and to ensure that baseline controls were clearly identified and understood, the following relationships were delineated:

- The Program Approval Document and the Procurement Plan would represent the basic agreements between the NASA Administrator and the Associate Administrator for Manned Space Flight.
- The Flight Missions Assignment Document and the level one schedule, analysis, and review procedure schedule would serve as the formal controls between the Associate Administrator for Manned Space Flight and the Apollo Applications Director.
- Mission Directives and Program Directives, which included specifications and work authorizations, would be the control documents between the AAP Director and the Center Program Manager.
- The Mission Requirements Document, the Baseline Reference Mission Document, and the end-item specifications would be used as the control channels for the Center Program Managers to the support elements.

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• The AAP Missions Requirement Document for the Orbital Workshop configuration was published and distributed. The Baseline Reference Mission was scheduled for distribution near the end of November. AAP Directive No. 26, KSC Test and Checkout Procedures, was approved by NASA Hq on 10 October 1969.

Manned Space Flight Management Council Meeting, 15 October 1969; NASA, "Manned Space Flight Weekly Report," 20 October 1969.

21

An MSC plan to do both Apollo and Apollo Applications work at North American Rockwell under a single contract was approved by NASA Hq. The Apollo Spacecraft Program Office and the Apollo Applications Program Office were working together on procedures for maintaining or reestablishing major CSM subcontractor capabilities. Fuel cells and cryogenic tanks were being given particular attention.

TWX, G. J. Vecchietti, NASA Hq, to D. W. Lang, MSC, "Letter Contract NAS 9-9224—Apollo Applications CSM Program—Definitization Under Basic Apollo Contract," 21 October 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 24 October 1969; NASA, "Manned Space Flight Weekly Report," 27 October 1969.

22

AAP was implementing manned space flight safety by establishing systems safety requirements; ensuring compliance with established safety requirements by formal audits of design, test, manufacture, operations, and reliability disciplines; participating in program milestone reviews; conducting formal reviews and checking concurrence in procedures to be used during hazardous testing, checkout, launch, and mission operations; and conducting formal tracking and disposition of safety problems identified in various engineering analyses, mockup reviews, and procedural reviews.

AAP Directive No. 31, "The Implementation of AAP System Safety Requirements," 22 October 1969.

24

A special reliability analysis, "Descent Battery Pack Monitoring," was completed. The study was performed to determine the monitoring parameters planned for the service module descent battery pack. The pack consisted of three 500-amp/hr silver-zinc batteries used for the CSM deorbit maneuver. Command module batteries provided redundancy for the deorbit maneuver.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 24 October 1969.

27

As a result of an AAP management meeting at MSFC, the AAP Director approved the following changes in the OWS: reinforced floor, hard ceiling, access hatch, window, and wardroom concept. Inversion of the Workshop floor was given tentative approval.

NASA, "Manned Space Flight Weekly Report," 3 November 1969; "Weekly Progress and Problem Summary Report," 4 November 1969; NASA News Release 69–164, "Orbital Workshop Design Changes," 11 December 1969.

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27

An ATM program review was held at MSFC. ATM Principal Investigators and representatives from NASA Hq, MSC, and MSFC attended. Among the areas discussed were unmanned operations, thermal control, operating lifetime, and availability of acceptance checkout equipment. A study was being conducted to identify the amount of thermal control required during inflight storage periods. In addition, life testing was being performed to determine capability for extending the operating lifetime of the ATM.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 4 November 1969; NASA, "Manned Space Flight Weekly Report," 3 November 1969.

31

MSFC was requested to manage a study to define the performance characteristics and related costs and schedules for development of an ATM–B stellar telescope to be used with a second OWS. Results of the study were considered to be significant in determining whether such a program should be undertaken and what measures were required to establish characteristics and requirements that would support development of large telescopes of the future.

Letters, George E. Mueller, NASA Hq, to Director, Marshall Space Flight Center, "Apollo Telescope Mount (ATM–B) Stellar Telescope Study," 31 October 1969; George E. Mueller to Associate Administrator for Advanced Research and Technology, "Apollo Telescope Mount (ATM–B)," 31 October 1969.

November

1

A major study was performed by KSC, The Boeing Company, and Chrysler Corporation to determine the feasibility of launching S–IB vehicles from LC–39. Major facilities and equipment needed to convert LC–39 to an elevated pedestal configuration were studied, as well as estimated cost figures, program schedules, and interrelationships with other NASA programs. The study indicated that use of the elevated pedestal concept in LC–39 appeared technically and operationally feasible. However, because of the close operational coupling of the Apollo and AAP if this concept were implemented, it was decided to defer further consideration of this concept.

KSC AAPO, "Utilization of LC–39 for AAP Saturn IB Launches," 1 November 1969.

3

LaRC issued a request for proposal for a zero-g body shower that would be developed for use on extended manned space missions.

Letter, E. M. Cortright, LaRC, to Robert R. Gilruth, MSC, "Evaluation of Proposals in Response to NASA RFP L13–442, 'Development of a Zero Gravity Whole Body Shower,' " 3 November 1969.

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4

Two Apollo ATM-related Aerobee rockets were launched from the White Sands Missile Range, New Mexico. The rockets achieved expected performance, solar pointing systems functioned properly, payloads were successfully recovered, and preliminary results appeared excellent. The information obtained by the rocket flights on solar emission intensity, filter performance, film response, and exposure time would be available in time to provide a useful and effective feedback into the ATM instruments development program.

MSFC, "Weekly Activity Report," 3 and 17 November 1969; letter, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Apollo Telescope Mount (ATM) Rocket Flight," 7 November 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 14 November 1969; "Minutes, MSF Management Council Meeting," 5 December 1969.

4–7

A preliminary design review on the AAP CSM was held at North American Rockwell, Downey. Major configuration items which resulted from the review were reindexing the CSM by 180 degrees, based on a crew requirement to be able to realign the astronaut maneuvering unit before undocking from the cluster, and installation provisions for two reentry control system propellant tank farms. Both recommendations would be subjected to further review.

NASA, "Manned Space Flight Weekly Report," 10 and 17 November 1969; letter, G. W. Jeffs, North American Rockwell, to Robert F. Thompson, MSC, "Contract NAS 9–9224, Minutes of AAP PDR," 14 November 1969; "Minutes, MSF Management Council Meeting," 5 December 1969.

5

Olin E. Teague, Chairman of the House of Representatives Committee on Science and Astronautics Subcommittee on Manned Space Flight, suggested that space rescue and emergency coordination would offer opportunities to bring the space-faring nations of the world closer together. In an initial response to the letter, NASA Hq appointed a Space Station Safety Advisor and established a Shuttle Safety Advisory Panel.

Letters, Olin E. Teague to the President, 5 November 1969; L. A. DuBridge, Science Advisor, to T. O. Paine, NASA Administrator, 17 November 1969; M. L. Raines, MSC, to Manager, Advanced Missions Program Office, "Safety posture for advanced programs," 12 December 1969.

12–13

During a meeting at McDonnell Douglas, the following Workshop subsystems were reviewed: refrigeration, electrical power and waste heat, trash disposal, urine collection and processing, and crew compartment. Presentations were offered on the various subsystems. In the crew compartment, McDonnell Douglas was proceeding with a new access door arrangement in the experiment area with a window in the wardroom. This would eliminate disturbing the wardroom installation if on-the-pad access was required.

"Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 21 November 1969.

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13

President Richard M. Nixon announced his nomination of George M. Low as Deputy Administrator of NASA. Low had served in the U.S. space program since 1949, when he joined the National Advisory Committee for Aeronautics, NASA's predecessor.

White House Press Release, " George M. Low Nominated Deputy Director of NASA," 13 November 1969.

18–19

A preliminary design review on AAP ground support equipment was held at North American Rockwell. Purpose of the review was to evaluate preliminary details of the ground operational system documentation and ground support equipment preliminary designs. Attendees recognized that the required AAP equipment should be adequate to do the job, but absolutely minimal in cost and simple to operate. It was agreed that design management meetings would be held periodically on each major piece of ground support equipment when 30 or 40 percent of the design was completed.

"Apollo Applications Test Weekly Status Report," 26 November 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 28 November 1969; "Minutes, MSF Management Council Meeting," 5 December 1969.

19

A meeting was held at North American Rockwell, Downey, to discuss MDA docking checkout features. It was agreed that docking tests would be conducted at MSFC with North American fixtures to verify the capability of the MDA ports for docking with the command modules.

MSFC, "Weekly Activity Report," 2 December 1969.

19–20

An AM system review was held at McDonnell Douglas, St. Louis. The review, plus a crew walk-through, provided the first concentrated crew input to the AM dry concept design. It also provided an up-to-date summary review of the overall AM design status.

MSFC, "Weekly Activity Report," 2 December 1969.

24

Inflight activities for AAP missions would be conducted on a 24-hour cycle. For previous manned space flights, the basic onboard time reference for manned space flights was mission elapsed time (MET), which began at liftoff and accumulated as hours/minutes/seconds for the flight duration. Reasons for the change from MET to the 24-hour cycle were that eating and sleeping activities would follow a 24-hour cycle, and the postflight data correlation, particularly with ground data, would be greatly assisted by a 24-hour timekeeping system. MET would continue to be used in the command module for contingency and final reentry planning.

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Memorandum, T. U. McElmurry, MSC, to Dist., "On-board time reference during Apollo Applications Flights," 24 November 1969.

December

2–4

A review team representing NASA Hq, the three manned space flight Centers, the several prime contractors involved, and many of the Principal Investigators for experiments conducted the AAP cluster systems review at MSFC. Cluster hardware subjected to scrutiny included attitude control, thermal, instrumentation and communications, structural, electrical, and crew systems, as well as mission requirements and the overall system-level capability of the AAP cluster to meet those objectives. In one significant design decision, program officials decided to parallel the electrical power system of the ATM with the rest of the cluster through the airlock to increase overall reliability of the cluster's electrical power system.

MSFC, "Weekly Activity Report," 9 December 1969; NASA, "Manned Space Flight Weekly Report," 8 December 1969; "Weekly Progress and Problem Summary for the Administrator—Apollo Applications Program," 9 December 1969.

9

NASA Hq issued a directive which established program standards for achieving uniformity of terms, practices, and criteria for use throughout AAP in the generation of nonconformance data that could be readily combined, compared, and assessed for potential program impact. For the purpose of the directive, nonconformance was defined as a failure or defect.

AAP Directive No. 10A, "AAP Nonconformance Reporting and Corrective Action," 9 December 1969.

10

NASA Hq issued a program directive that authorized and directed the work to be accomplished in AAP for FY 1970. Its mission and major flight hardware summary provided flight numbers and objectives, assigned by number the launch vehicles and the CSM, and designated the launch complexes.

AAP Directive No. 4B, "Apollo Applications Program Work Authorization," 10 December 1969.

10–11

An AM management meeting was held at McDonnell Douglas. Based on a review of design, test, and procurement schedules, it appeared that an extremely tight schedule existed on all aspects of the project.

MSFC, "Weekly Activity Report," 18 December 1969; "Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 11 December 1969; NASA, "Manned Space Flight Weekly Activity Report," 15 December 1969.

11

Recent discussions produced oral agreements by NASA Hq, MSFC, and MSC management to use progressive crew station reviews at prime hardware contractor plants for operational verification of hardware before critical design reviews. Some points relating to the crew station reviews were:

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• Reviews would be conducted at McDonnell Douglas for the OWS and the AM, at Martin Marietta for the MDA, and at MSFC for the ATM.

• Appropriate one-g engineering mockups would be provided at each contractor plant. These would be continuously updated to reflect the latest design.

• Attendance at the reviews would be held to a minimum.

• Reviews would be conducted as required, beginning in December 1969.

• A complete crew station review would be conducted as part of the critical design review.

Letter, Donald K. Slayton, MSC, to Manager, Apollo Applications Program, MSC, "Progressive Crew Station Review of Saturn V Workshop Hardware, 11 December 1969.

11

McDonnell Douglas evaluated a recent test failure of a structural transition section window in the AM. Preliminary findings were that an improper test setup and procedural error probably caused the window failure. The window failed under a pressure seven to eight times the maximum operating pressure of the AM. Test procedures were being reviewed and repeat testing was planned. The structural transition section contained four windows that provided visibility. When not in use, these windows were protected by an external movable cover actuated from within the AM.

"Weekly Progress and Problem Summary Report for the Administrator—Apollo Applications Program," 11 December 1969; NASA, "Manned Space Flight Weekly Report," 15 December 1969.

15

Because of stringent budget restrictions MSFC was requested to carefully scrutinize the ATM experiment and supporting systems requirements and eliminate any existing or proposed modifications that were not mandatory to the successful accomplishment of the scientific experiment objectives. Modifications which were not yet implemented would be carefully examined to determine:

• If the requirements matched the approved experiment objectives.

• If the requirements could be met without the change.

• If funding or development schedules would be impacted in an unfavorable manner if changes were authorized.

• If alternate approaches could be taken to meet objectives of required changes with a less unfavorable impact on funding and schedules.

Letter, William C. Schneider, NASA Hq, to Manager, Apollo Applications Program, MSFC, "ATM Schedules and Resources," 15 December 1969.

18

KSC Director Kurt H. Debus announced that LC–34 would be used for Saturn IB-related AAP manned launches (scheduled to begin in mid-1972), while LC–37 would be placed in a semideactivated "minimum maintenance" condition. Thomas W. Morgan, AAP Manager of the Florida Center, said that design of modifications to LC–34 to meet the needs of AAP would begin on 1 January

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1970, while the modifications to the pad itself would begin around the end of the summer. The current estimate for the cost of modifying the complex and bringing it to a state of readiness was about $3.7 million.

Spaceport News, Vol. 8, 18 December 1969, p. 8.

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January

2

MSFC shipped a test version of the Saturn V third (S–IVB) stage to McDonnell Douglas to be converted into a Workshop test article for use in AAP dynamics and acoustics testing. The stage had earlier been used as a Saturn V facilities vehicle to check out manufacturing, testing, and launching facilities during the Apollo/Saturn V program.

MSFC Project Logistics Office, Flight Operating Log, 2 January 1970; MSFC, "Weekly Activity Report," 15 January 1970; NASA, "Manned Space Flight Weekly Report," 19 January 1970.

3

AAP involved the conduct of long-duration manned missions under two concepts. The first was the conduct of long-duration orbital missions by the use of spacecraft originally developed for the Apollo lunar mission operating in conjunction with an OWS. This concept required providing sufficient expendables to sustain individual long-duration missions and planning so that they would continue for predetermined durations as long as no major flight hardware problems arise. The second concept was that of revisitation and reuse of multimodule assemblies left in orbit.

These concepts were influenced by two major factors. The first was the need to use Apollo and Gemini hardware and technology for the most economical accomplishment of significant advances in manned space flight orbital operations. The second factor was the desire to exploit the long-duration operational potential of the hardware as rapidly and economically as technology would permit.

Letter, William C. Schneider, NASA Hq, to Manager, Apollo Applications Program, MSFC, MSC, and KSC, "Test Requirements for AAP Long Duration Missions," 3 January 1970; *NASA Handbook 8080.3*, Appendix D, "Apollo Applications Test Requirements," Change 1, 23 December 1969.

6–9

An Earth resources experiments package (EREP) preliminary requirements review was held at MSC. Representatives from NASA Hq, MSC, MSFC, KSC, and Martin Marietta participated. Based on the results of the review, MSFC and MSC were reviewing the dynamic loads, vibration and acoustics, and film temperature environments for EREP. Discussions were also being held with the Office of Space Science and Applications to determine detailed plans on EREP.

NASA, "Manned Space Flight Weekly Report," 19 January 1970.

7

The Apollo 20 mission was deleted from the program. MSC was directed to take some immediate actions including determination of the disposition of CSM–115A, pending a final decision as to its possible use in a second Workshop mission.

TWX, Rocco A. Petrone, NASA Hq, to MSC, "Apollo 20 deletion," 7 January 1970. **1970**

January

The Air Force Eastern Test Range was planning to deactivate two high-resolution tracking radars at the Cape. The radars provided the earliest acquisition of S–IB launches of all available radars and permitted lower visibility ceilings for these launches. KSC requested a temporary postponement of the deactivation until a determination could be made of the impacts, if any, to launch constraints and until alternate radars could be specified. **7**

KSC, "Weekly Progress Report," 7 January and 14 January 1970.

Saturn V launch vehicle 513 was designated for the first AAP Workshop launch. For planning purposes, launch vehicle 515 was being considered for use with either a backup or second Workshop. **7**

TWX, William C. Schneider and Rocco A. Petrone, NASA Hq, to MSFC, MSC, and KSC, "Saturn V Launch Vehicles for AAP," 7 January 1970.

Dale D. Myers was appointed NASA Associate Administrator for Manned Space Flight with an effective date of 12 January. He succeeded George E. Mueller, who left NASA on 10 December 1969 to become a vice president of General Dynamics Corporation. Prior to his acceptance of the NASA position, Myers was Vice President and General Manager of the Space Shuttle Program at North American Rockwell. **8**

NASA News Release 70–4, 8 January 1970.

The mission requirements panel met at KSC. The baseline reference mission document was being updated to incorporate a 50-degree orbital inclination for the OWS. In current plans, AAP–3 would be launched on day 183, mission elapsed time. This would permit daytime launches and recoveries for all the manned missions. The possibility that the orbit of the jettisoned payload shroud might recontact the OWS orbit was being evaluated in order to identify preventive measures. **14–15**

NASA, "Manned Space Flight Weekly Report," 26 January 1970.

Apollo Applications Program Managers met at MSFC and conducted a full review of the ATM status. Among the items covered were the film vault design, film test program, subsystems status, module ground test program, quality and reliability, mission operations support to MSC, prototype refurbishment, project schedules, and funding. **22**

NASA, "Manned Space Flight Weekly Report," 2 February 1970.

The recommendation was made that serious consideration be given to providing training in solar physics to the Skylab astronauts in the immediate future. Purpose **February**

4

1970
February

of the training would be to obtain maximum benefit from the ATM experiments by equipping the astronauts with a well-rounded knowledge of solar physics and the training required for them to become experienced solar observers.

Letter, R. Tousey, Naval Research Laboratory, to Robert F. Thompson, MSC, 4 February 1970.

6 NASA management conducted a briefing in the Health, Education, and Welfare auditorium, Washington. Purpose of the briefing was to explain to industry and labor NASA's plans for the coming year, following a 12-percent budget cut.

NASA Industry Briefing, 6 February 1970.

9 With the termination of the Manned Orbiting Laboratory, the Air Force provided MSFC with three environment conditioning units capable of delivering fresh air into a small enclosed space at a desired temperature and humidity. The units would be used during bench checks and troubleshooting on the ATM experiments and the related ground support equipment during storage and the preinstallation period.

NASA, "Manned Space Flight Weekly Report," 9 February 1970.

13 A meeting was held at MSFC to discuss long-term storage of launch vehicle stages. A preliminary plan was to store four S–IVB stages and four S–II stages in the Vehicle Assembly Building at KSC. Deletion of certain checkout functions formerly accomplished before delivery of hardware to KSC was also discussed.

KSC, "Weekly Progress Report," 18 February 1970.

13 Kenneth S. Kleinknecht was named Manager of MSC AAP, succeeding Robert F. Thompson who was appointed Manager of the newly established Space Shuttle Program Office at MSC. Clifford E. Charlesworth was appointed AAP Deputy Director.

MSC News Release 70–25, 13 February 1970; MSC Announcement 70–33, "Establishment of the Space Shuttle Program Office and Key Personnel Assignments," 13 February 1970.

PART III

Skylab Development and Operations

February 1970 through November 1974

PART III

Skylab Development and Operations

February 1970–November 1974

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17

NASA announced that the Apollo Applications Program had been redesignated the Skylab Program. The name Skylab, a contraction connoting a laboratory in the sky, was proposed by Donald L. Steelman, USAF, while assigned to NASA. The name was proposed following an announcement by NASA in 1968 that they were seeking a new name for AAP. Then NASA decided to postpone renaming the program because of budgetary restrictions. Skylab was later referred to the NASA Project Designation Committee and was approved 17 February 1970.

Memoranda, George E. Mueller, NASA Hq, to J. Scheer, NASA Hq, "Request to NASA Project Designation Committee to Select a New Name for AAP," 15 October 1968; D. D. Myers, NASA Hq, to Deputy Administrator, "New Name for Apollo Applications Program," 23 January 1970; George M. Low, NASA Hq, to Assistant Administrator for Public Affairs, "Naming of Several Projects," 11 February 1970; J. Scheer to D. D. Myers, 18 February 1970; letter, William C. Schneider, NASA Hq, to Dist., "Program Name Change," 24 February 1970; NASA News Release 70–30, "NASA AAP Designated Skylab," 24 February 1970; NASA SP–4402, *Origins of NASA Names,* Washington, 1976.

17

A ground support equipment meeting was held at MSFC with representatives from NASA Hq, MSC, MSFC, McDonnell Douglas, and General Electric Company participating. Purpose of the meeting was to establish lines of communication and to discuss test and checkout philosophies and responsibilities, ground support equipment status, and problems of common interest. On 18 February a similar meeting was held to discuss ground support equipment associated with the ATM project.

MSFC, "Weekly Activity Report," 27 February 1970.

19

At an AM management review held at McDonnell Douglas, a two-month slip in the AM delivery was predicted. Reason for the slippage was attributed to design changes in the caution and warning system.

NASA, "Manned Space Flight Weekly Report," 27 February 1970.

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25–26 A meeting was held at MSFC on experiment locations in the Orbital Workshop. Representatives from MSC, McDonnell Douglas, Martin Marietta, and MSFC attended. Several Principal Investigators also attended. In general, the experiment locations were considered acceptable.

MSFC, "Weekly Activity Report," 5 March 1970.

26 KSC Director Kurt H. Debus announced administrative changes creating a Center Planning and Future Programs Directorate. G. Merritt Preston, Director of Design Engineering, was named to head the new element. The Center Planning and Future Programs Directorate was responsible for space transportation systems, Earth-orbital vehicles, and planetary manned and unmanned vehicles. The Advanced Programs Office of the AAP Manager's organization, together with AAP supporting research and technology tasks related to future requirements, were transferred to the new group. Also assimilated into the new directorate were portions of the Design Engineering Directorate's Future Studies Office. Grady F. Williams, former Deputy Director of Design Engineering, succeeded Preston as Director of Design Engineering.

Spaceport News, 26 February 1970, p. 1.

March

1 Wernher von Braun left MSFC to become NASA's Deputy Associate Administrator for Planning in Washington. Eberhard F. M. Rees, who had served as the MSFC Deputy Director Technical since 1963, became Director of MSFC.

MSFC, *Marshall Star*, 4 March 1970, p. 1.

7 In a statement from the White House, President Richard M. Nixon announced his proposed space goals for the 1970s. He listed six specific objectives for the program. Objective No. 4 stated: "We should seek to extend man's capability to live and work in space. The experimental space station—a large orbiting workshop—will be an important part of this effort. We are now building such a station—using systems originally developed for the Apollo program—and plan to begin using it for operational missions in the next few years. We expect that men will be working in space for months at a time during the coming decade."

Text of statement by the President, 7 March 1970.

9 McDonnell Douglas and Martin Marietta were conducting analyses for their areas of hardware responsibility to determine the types, quantities, and locations of materials that might present a fire hazard. They were assessing flash points and propagation mechanisms for the various materials and areas. This would provide the basis for determining the quantity, type, and location of fire sensors for Skylab.

Letter, William C. Schneider, NASA Hq, to Director, Manned Space Flight Safety, "Semiannual Report of Manned Space Flight Safety Studies and Activities—Skylab Portion," 9 March 1970.

1970
March
15

Definition studies for a second Orbital Workshop (Skylab II) were under study. Mission objectives would respond to the following major objectives: continued development and expansion of the ability to live, work, and operate effectively in space; exploitation of space for practical benefits through the observation of Earth and its environment; and the use of space for scientific research.

Letters, William C. Schneider, NASA Hq, to Managers, Apollo Applications, MSFC, MSC, and KSC, "Definition Studies for a Second Workshop," 25 November 1969; P. E. Culbertson, NASA Hq, to MSFC and MSC, "Payload Planning for Skylab II Mission," 15 March 1970.

18

MSFC recommended disapproval of a space bath on Skylab based on the following:

- The cost was considered excessive.
- The requirement was not mandatory for mission success.
- The schedule impact was unacceptable.

Letter, Leland F. Belew, MSFC, to William C. Schneider, NASA Hq, "Space Bath," 18 March 1970; TWX, R. M. Jacobs, McDonnell Douglas, to MSFC, "Space Bath Tub for Whole Body Cleansing," undated.

23–26

A CSM meeting was held at North American Rockwell. Purpose of the meeting was to review experiment hardware need dates and review experiment test requirements. Displays, controls, and contractor-furnished crew equipment were satisfactory. However, government-furnished crew equipment and several stowage areas lacked some detail. No significant communications or instrumentation design changes were necessary.

MSC, "Skylab Weekly Activity Report," 30 March and 7 April 1970.

March 31–April 3

During a NASA management tour of Skylab facilities at McDonnell Douglas, Los Angeles, K. S. Kleinknecht (MSC) recommended that a high fidelity mockup of the OWS be provided at the plant. While MSFC had an engineering mockup that attempted to duplicate changes made to the OWS, Kleinknecht suggested that MSFC was too distant from McDonnell Douglas to maintain up-to-date changes.

Memoranda, Donald K. Slayton, MSC, 19 June 1970; T. U. McElmurry, MSC, 4 September 1970; message, William C. Schneider, NASA Hq, 10 September 1970.

April
3

NASA Hq issued its policy for delivery, installation, integration testing, and checkout of experiment flight hardware with flight modules before and after delivery to KSC. Flight experiments would be delivered installed in their respective modules or in bonded packages with the flight module to KSC. Experiments not accompanying the modules would be delivered to KSC by the integration center on previously agreed to dates.

1970

April

Letter, William C. Schneider, NASA Hq, to Managers, Skylab Program, MSFC, MSC, and KSC, "Experiment Flight Hardware and Module Integration Policy," 3 April 1970.

3

A KSC procurement plan for Skylab Program launch operations requirements for CSM hardware was approved by NASA Hq. The plan would provide for a new KSC contract covering the period from 1 December 1970 to 31 December 1972.

KSC, "Weekly Progress Report," 8 April 1970.

7

A Manned Space Flight Management Council meeting at KSC focused on a second Skylab Program. Issues discussed were whether there should be a Skylab II, and, if so, what its fundamental mission and configuration should be, how long it should stay in orbit, what its experiment payload should be, and how many manned launches should be planned for it. MSC recommended that artificial gravity and expanded Earth-survey experiments be included as major objectives of a second Skylab Program.

MSC, "Skylab Weekly Activity Report," 13 April 1970; memorandum, John H. Disher, NASA Hq, to P. Culbertson, NASA Hq, "Narrative Description on Apr 7 Management Council Discussion of Skylab II," 3 April 1970.

8–9

An ATM crew station review was held at MSFC. Results of the review included the following:

- MSFC would investigate ATM timing sources to satisfy the 16-mm Maurer control and display sequence camera timing and sequencing requirements.
- An improved layout of control and display circuit breaker panel was suggested by the crew.
- The impact of providing a display designed to show the crew that the ATM digital computer had accepted a console-initiated keyboard command was being assessed by MSFC.

NASA, "Manned Space Flight Weekly Report," 20 April 1970.

10

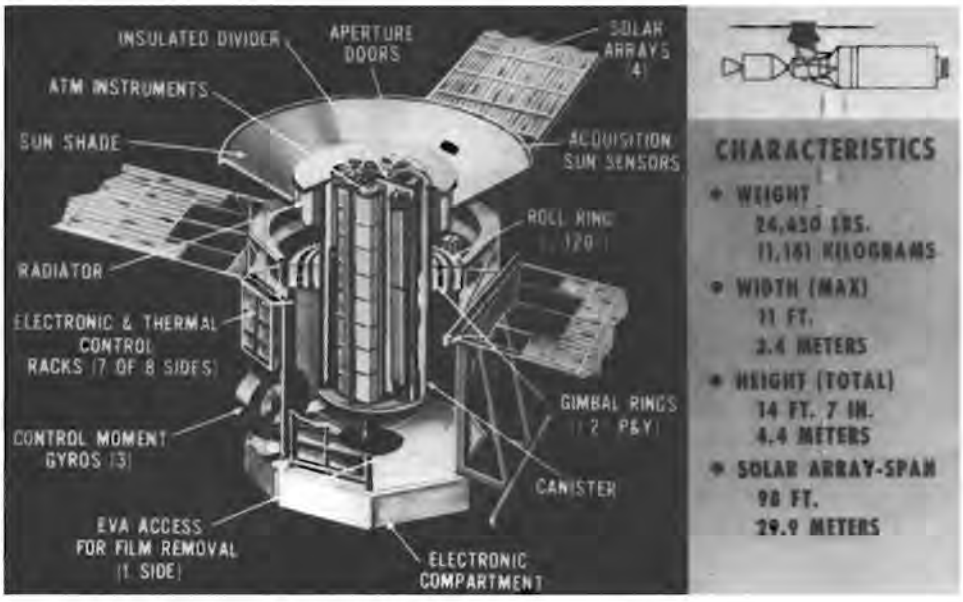
A contract was awarded to Itek Corporation by MSC for the design, development, and delivery of multispectral photographic equipment (S190A) for the Skylab Program. The contract called for delivery by July 1971 of a six-lens camera unit which would become part of the Earth resources experiment package in the Skylab missions.

MSC News Release 70-41, 10 April 1970.

10

The Skylab Program would operate under the following mission constraints:

- All Skylab missions would use a northerly launch azimuth.



Sketch of the Apollo telescope mount.

1970

April

• The Skylab orbital inclination would be such as to ensure virtually complete local vertical coverage of the 48 contiguous states.

• The OWS would be placed in an orbit sufficiently high to ensure a minimum altitude of 389 km (210 nm) eight months after launch.

• Docking of the CSM to the Workshop would be confined to the axial docking port of the MDA.

• The Earth resources experiment package would be scheduled for at least 45 passes over the chosen ground sites.

Skylab Program Directive No. 43, "Operations Directive for the Skylab Program," 10 April 1970.

21

NASA might scrap two of its six scheduled Moon flights, the *Washington Daily News* said. Apollo 18 and 19 might be scrapped because some NASA planners wanted to use the boosters and spaceships already being built to speed the space base and space station programs. Assistant Administrator George M. Low was reported as saying NASA already was studying the possibility of canceling Apollo 19 and using its Saturn V booster and the Apollo spacecraft for a second Skylab. NASA said there was sentiment for using Apollo 18 equipment for an even more ambitious venture—base station—that would stay aloft for 10 years (vs. 1 year for Skylab) and could be added onto until it could accommodate 100 men.

Washington Daily News, 21 April 1970, p. 7.

22–23

An AM management meeting was held and a crew station review conducted at McDonnell Douglas. Martin Marietta MDA personnel attended the review to ensure some standardization between the AM and the MDA. MSC suggested

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that the teleprinter be made an inflight replaceable item and that a spare be carried on Skylab 1.

MSFC, "Weekly Activity Report," 30 April 1970.

23

Garrett Corporation, AiResearch Division of Los Angeles, was awarded a contract by MSC for a portable astronaut life support assembly (ALSA) for use in the Skylab Program. The assembly would ensure that astronauts performing extravehicular activity and intravehicular activity would have an adequate supply of oxygen.

MSC News Release 70-43, 23 April 1970.

27

A directive defining the work to be accomplished in the Skylab Program for Fiscal Year 1970 was issued by NASA Hq. Its mission and major flight hardware summary provided flight numbers and objectives of each flight; assigned by number the launch vehicles and CSM, and designated the launch complexes.

Skylab Program Directive No. 4C, "Skylab Program Work Authorization," 27 April 1970.

May

4

A system flexibility study was being conducted of systems and subsystems within the Skylab cluster in order to achieve the best possible flexibility in case of a malfunction. The focus was on those actions available to ensure the rapid return of command and service modules in the event of a malfunction forcing an abort and possible actions that would permit completion of OWS onboard functions to ensure acquisition of maximum experiment data.

NASA, "Manned Space Flight Weekly Report," 4 May 1970.

6

North American Rockwell completed a verification evaluation of the CSM hardware for a 120-day capability and transmitted the certification matrices to NASA. If there were no changes in CSM mission performance requirements, verification for a 120-day mission would not present a problem.

"Skylab Program Test Weekly Status Report," 6 May 1970; NASA, "Manned Space Flight Weekly Report," 8 May 1970; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 8 May 1970.

7

MDA crew station review was held at Martin Marietta. Results of the review showed, among other things, that the MDA docking port heat loss was such that the hatch and tunnel walls could reach a temperature of 216 K (−70°F). Unless the heat loss could be prevented, this temperature would preclude a shirt-sleeve entry.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 25 May 1970.

1970
May
7

A design review was conducted of the Spacecraft Acoustic Laboratory at MSC. The review included the physical design of the reverberation chamber, operational features required for the facility, and the expected technical performance capability of the laboratory.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 8 May 1970.

14

The feasibility of docking a second Orbital Workshop to Skylab 1 had been under consideration. However, the practical problems that would be engendered by such an operation were formidable. They included such items as docking loads, docking control, flight attitude of tandem Skylabs, consumables, and in-orbit storage of Skylab 1.

Letter, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Docking Skylab II to Skylab 1," 14 May 1970.

15

NASA Hq announced that both the manned and unmanned (Saturn IB and Saturn V) launches of the Skylab Program would be from KSC LC–39. Previous plans were to conduct the Saturn IB launches from LC–34, a part of the U.S. Air Force Eastern Test Range used by NASA, a tenant at Cape Canaveral Air Force Station, Florida. However, program studies showed the feasibility of the pedestal concept of launching the Saturn IB from LC–39 and indicated a cost savings of $13.5 million.

The pedestal would be of standard steel structural design; however, there were unique conditions considered. One of these was the requirement to withstand engine exhaust temperatures of 3000 K (5000°F). Another dealt with winds. The pedestal was designed to launch an S–IB at maximum vehicle allowed winds (59.4 km) and to withstand a 200-km per hr hurricane without the launch vehicle.

Launch Complex 34, which became operational in 1961, was placed in a standby condition after the *Apollo* 7 flight in October 1968. It would have required extensive updating of equipment and repairs to ready it for the Skylab Program.

NASA News Release 70–70, "Skylab Launch Site Change," 15 May 1970; MSC News Release, 70–49, 15 May 1970; Chrysler, Report CCSD–TR–FO–800–8, *Study Report Launch of Saturn IB/CSM From Launch Complex 39,* 15 April 1970; memoranda for record, T. F. Goldcamp, KSC, "Skylab Saturn IB/CSM Launches from LC–39," 10 May and 19 May 1970; letters, G. F. Williams, KSC, to Manager, Skylab Program, KSC, "AAP Saturn IB/CSM Launches from LC 39," 10 April 1970; W. J. Kapryan, KSC, to Manager, Skylab Program, KSC, "Skylab Saturn IB/CSM Launches from LC–39," 10 April 1970; R. E. Godfrey, MSFC, to T. W. Morgan, KSC, "Utilization of Launch Complex 39 for Skylab Saturn IB Launches," 15 April 1970; J. R. Martin, MSFC, to W. Strickland, MSFC, "Wind Consideration for Saturn IB launch from LC–39," 17 April 1970; R. E. Godfrey to T. W. Morgan, 5 May 1970; D. D. Myers, NASA Hq, to NASA Administrator, "Skylab Saturn IB CSM Launches from LC 39," 7 May 1970; T. W. Morgan to Dist., "Skylab Saturn IB Launches from LC–39," 12 May 1970; G. M. Low, NASA Hq, to Associate Administrator for Manned Space

1970 May

Flight, "Skylab IB Launches from Launch Complex 39," 14 May 1970; G. M. Low to C. P. Anderson, U.S. Senate, 15 May 1970; E. F. M. Rees, MSFC, to K. H. Debus, KSC, "MSFC assessment of KSC proposal to abandon LC-34 and LC-37 and to commit two mobile launchers to support Skylab launches," 4 June 1970; W. C. Schneider, NASA Hq, to Manager, Apollo-Skylab Programs, KSC, "Safety Aspects of Launch of Saturn IBs from Launch Complex 39," 19 June 1970; D. D. Myers to K. H. Debus, 22 June 1970; R. E. Godfrey to T. W. Morgan, "Launch of Saturn IB Vehicles from Launch Complex 39," 29 June 1970; D. D. Myers to Deputy Administrator, "Safety Aspects of Skylab Saturn IB/CSM Launches from Launch Complex 39," 30 June 1970; J. D. Phillips, KSC, to R. H. Curtin, NASA Hq, 26 January 1972.

20 A meeting was held at MSFC to give NASA management direct exposure to two proposed concepts for urine collection and sampling. General Electric Company presented their concept for a urine sampling volume measuring subsystem. Fairchild Hiller Corporation presented their concept for a 24-hour pooling collection and sampling subsystem. A proposed plan for implementation and integration for each of these systems was presented by McDonnell Douglas. Following the presentations it was agreed that MSFC would implement the Fairchild Hiller concept, and that a test model would be constructed for verification in zero gravity on a KC-135 aircraft. On 27 May 1970, a preliminary design review was held, and general agreement was reached on all significant points. Fairchild Hiller had completed a model of the collection and measurement system, and its various functions were effectively displayed.

Letter, W. K. Simmons, Jr., MSFC, to Dist., "Urine Collection Briefing Minutes," 20 May 1970; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 5 June 1970.

20 During a Skylab Workshop management review, McDonnell Douglas was directed to proceed with the design and fabrication of a high-fidelity mockup of the OWS. The mockup and installed equipment would simulate actual equipment to the extent necessary to assess crew tasks and facilitate in-depth reviews of the tasks. The mockup would be located at the McDonnell Douglas, Huntington Beach facility.

MSFC, "Weekly Activity Report," 21 May 1970; NASA, "Manned Space Flight Weekly Report," 25 May 1970.

26 The AM static structural qualification testing was completed at MSFC, with the successful completion of the 125-percent liftoff loads test. The AM structural test article used for this test was later modified to become the dynamic test article used in the payload assembly vibroacoustic test at MSC.

MSFC, "Skylab Program Office Weekly Activity Report," 2 June 1970.

26 The ATM critical design review was completed, with the Critical Design Review Board meeting at MSFC. This review gave formal approval to the ATM design.

MSFC, "Skylab Weekly Activity Report," 21 and 26 May 1970.

1970 May 26

A Skylab logistics support status review was held with representatives from NASA Hq, MSFC, KSC, and MSC participating. Primary purpose of the meeting was to establish the nature and degree of the logistics support required from KSC by the design Centers.

Letter, A. F. Hinger, NASA Hq, to J. P. Field, Jr., NASA Hq, "Skylab Logistics Support Status Review," 26 May 1970.

28

The consolidation of the Skylab and Apollo Program Offices at KSC was approved by T. O. Paine, NASA Administrator. Thomas W. Morgan was appointed Manager of the combined functions. R. C. Hock was named acting Deputy Manager, Apollo-Skylab, on 5 June 1970.

Memoranda, K. H. Debus, KSC, to Dist., "Apollo Program Manager," 1 June 1970; "Designation of Acting Deputy Program Manager," 5 June 1970; KSC, "Weekly Progress Report," 3 June 1970.

June 3

The ATM thermal systems unit was delivered to MSC from Marshall. It was subjected to the temperature and vacuum extremes of a space environment in the MSC thermal vacuum chamber as part of the qualification program of the ATM.

MSFC, "Skylab Program Office Weekly Activity Report," 9 June 1970.

4

MSC announced a supplemental agreement to the Apollo contract with North American Rockwell to provide four CSMs for the Skylab Program. The agreement definitized a letter contract issued in March 1969.

MSC News Release 70-62, 4 June 1970.

5

NASA announced selection of General Electric Company and Singer-General Precision, Inc., for competitive negotiations leading to a contract for development of the crew training simulator for the Skylab Program at MSC. The contract would include design, fabrication, installation, checkout, simulation programs, onsite systems engineering, and supporting documentation.

MSC News Release 70-64, 5 June 1970.

18

Martin Marietta Corporation was awarded two contract modifications from MSFC. The first one involved work on systems integration for the MDA. The second covered design development, fabrication, assembly, integration, and testing of MDA equipment.

MSFC Contracts Office, Mod. 144 to Contract NAS 8-24000, 9 June 1970, and Mod. 145 to Contract NAS 8-24000, 18 June 1970.

1970
June
18 — NASA announced selection of Honeywell, Inc., of Boston for award of a contract for the design, development, and delivery of a 10-band multispectral scanner instrument for use in the Skylab Program. The multispectral scanner would be flown as part of Skylab's Earth resources experiment package. Purpose of the scanner would be to detect and measure radiated and reflected solar energy from materials on Earth.

NASA News Release 70–99, 18 June 1970.

18–19 — Representatives from McDonnell Douglas and MSFC attended a meeting at MSC to discuss crew participation in the OWS factory checkout. Crew compartment fit and function was the main topic of discussion. Because of the meeting, McDonnell Douglas was in a better position to plan the man-machine portions of the checkout.

MSFC, "Weekly Activity Report," 25 June 1970.

19 — An AM crew station review was held at McDonnell Douglas. A discussion on the content and conduct of the critical design review-crew system review was held. General agreement was reached that the AM/MDA stowage should be reviewed to the maximum extent possible.

"Manned Space Flight Weekly Reports," 22 and 29 June 1970; MSFC, "Weekly Activity Report," 25 June 1970.

19 — General Electric Company, Valley Forge, Pennsylvania, was awarded a contract for the design, development, and delivery of a microwave radiometer-scatterometer/altimeter instrument for the Skylab Program. The instrument would be part of the Earth-resources experiment package, which also included a multispectral photographic facility, an infrared scanner, and a 10-band multispectral scanner. Objectives of the microwave radiometer-scatterometer/altimeter experiment would be to determine the usefulness of active and passive microwave systems in providing information on land and sea conditions.

MSFC Contracts Office, memorandum of contract action, 19 June 1970; MSC News Release 70–70, 22 June 1970.

25 — An OWS fire study meeting was held, with astronauts and system safety personnel participating. A study was initiated to cover such items of fire safety as escape routes for the crew; materials and flammability; fire detection and extinguisher locations; suit locations; effect of fire debris on the command module; ground monitoring of fire detection; pressure buildup from a fire; and crew response after 50 days in space.

NASA Hq, "System Safety Weekly Activity Report," 1 July 1970.

1970
June
29

MSFC completed installation of a complete functional ventilation system in the OWS mockup and began testing the system. Airflow profiles were being mapped throughout the crew quarters. Preliminary acoustic tests indicated that the noise levels were acceptable.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 29 June 1970; NASA, "Manned Space Flight Weekly Report," 29 June 1970.

29–30

During a press briefing and tour of production facilities at MSFC, NASA Skylab Program Director William S. Schneider said of the project, "[we are] in the critical phase of firming up our designs." Three missions were planned for the eight-month lifetime of the 14.6-m-long Workshop. The primary task of the first mission would be to study physiological and psychological aspects of space flight for 28 days. The second mission, for 56 days, would operate telescopes. The third, also 56 days, would survey Earth resources.

MSFC PAO, *Visitors Program Record,* 29–30 June 1970.

July
1

KSC awarded contracts to AC Electronics Division, General Motors Corporation, and General Electric Company. The AC Electronics contract would provide Apollo CSM and LM guidance and navigation systems test and mission support at KSC for the Apollo and Skylab Programs.

The General Electric contract would provide personnel and equipment for maintenance and operation of acceptance checkout equipment and quick look data systems which were designed and built by General Electric.

Spaceport News, 2 July and 30 July 1970.

4

Cutler-Hammer, Inc., was awarded a contract for the design and development of an L-band microwave radiometer for use in the Skylab Program. The radiometer would measure brightness and temperature of the terrestrial surface of the Skylab ground track.

MSC News Release 70–86, 4 July 1970.

7–8

Concern over the Skylab (SL) food program and the habitability aspects of the Orbital Workshop led to an exchange of correspondence and considerable discussion on the subjects during a Skylab Program review held at MSFC. Personnel from NASA Hq, MSC, KSC, and MSFC attended the review. Among the items discussed were elimination of perishable foods, high cost of the food development system, need for an entertainment console, type of lighting, and color scheme of the OWS interior. Prior to the review, a Skylab food systems meeting was held at MSC on 3 June 1970. Items on the agenda included freezer temperature requirements; the food preparation concept; a galley appliance

1970

July

concept; and food stowage requirements. Other items of major interest were the following:

- The basic design philosophy was reaffirmed, with some interpretation.
- The basic configuration was reaffirmed; some agreements were made to modify certain systems and to investigate others, reflecting recent engineering design change requests.
- The July 1972 launch date for SL–1 and SL–2 was reaffirmed.
- The cost plan was not deviated from, although concern was expressed at ability to complete the program with the cost plan.
- The open-ended philosophy for the 28-day- and 56-day-mission duration was reiterated.
- Operational planning guidelines were modified to encourage more emphasis on experiments time allowance.

"Minutes of Skylab Program Review," 6–7 July 1970; "Weekly Progress Report for the Administrator—Skylab Program," 15 June 1970; memoranda, C. C. Kraft, Jr., MSC, to MSC Director, "Habitability of Skylab," 6 April 1970; C. A. Berry, MSC, to Manager, Skylab Program, MSC, "Deletion of requirements of perishable food," 21 April 1970; TWXs, W. C. Schneider, NASA Hq, to K. S. Kleinknecht, MSC, and L. F. Belew, MSFC, "Food System Interface With Orbital Workshop," 28 July 1970; W. C. Schneider to L. F. Belew, K. S. Kleinknecht, and T. W. Morgan, KSC, "OWS Stowage and Food System Changes," 13 July 1970; K. S. Kleinknecht to W. C. Schneider, "Changes in Skylab Program Food System Interface," 13 August 1970; letters, R. R. Gilruth, MSC, to E. F. M. Rees, MSFC, 10 April 1970; W. C. Schneider to R. F. Thompson, MSC, "Inflight Food and Water Systems for AAP," 22 April 1969; W. C. Schneider to K. S. Kleinknecht, "Deletion of requirements for perishable food," 26 May 1970; R. R. Gilruth to E. F. M. Rees, 26 May 1970; E. F. M. Rees to R. R. Gilruth, 27 May 1970; E. F. M. Rees to D. D. Myers, NASA Hq, 15 June 1970; E. F. M. Rees to R. R. Gilruth, 16 June 1970; W. C. Schneider to Manager, Skylab Program, MSC, "Deletion of Requirements for Perishable Food Aboard Skylab," 19 June 1970; D. D. Myers to R. R. Gilruth, 22 June 1970; L. F. Belew to K. S. Kleinknecht, "Engineering Design Change Request—173 Food System and Storage," 23 June 1970; K. S. Kleinknecht to W. C. Schneider, "Food system interface with orbital workshop," 17 July 1970; E. F. M. Rees to C. W. Mathews, NASA Hq, 21 July 1970; W. C. Schneider to Managers, Skylab Program, MSC and MSFC, "Transfer of Skylab Food Heater System Responsibility from MSFC to MSC," 25 August 1970.

8

MSFC modified its existing contract with Martin Marietta Corporation for additional work on the Skylab Program. The contract modification covered development, implementation, and operation of a change integration and configuration control system.

MSFC Contracts Office, MOD 150 to Contract NAS 8–24000, 8 July 1970.

10

A study was made of the effect of contamination on all critical surfaces of the Skylab vehicle. Potential contamination sources which violated cluster requirements specifications were evaluated by the Contamination Control Working Group. The study indicated that the MOL sieve and the OWS waste tank vents would, in combination, present a potential contamination threat to nearly all the external OWS windows.

1970 July

Letters, William C. Schneider, NASA Hq, to Manager, Skylab Program, MSFC, "Skylab Contamination Control," 20 March 1970; Leland F. Belew, MSFC, to W. C. Schneider, "Skylab Contamination Control," 10 July 1970; NASA, "Manned Space Flight Weekly Report," 27 July 1970; "Weekly Progress and Problem Summary for the Administrator," 27 July 1970.

16

A meeting was held at NASA Hq to discuss unmanned ATM operations. ATM Principal Investigators and personnel from MSC, MSFC, KSC, and NASA Hq attended. Following presentations by MSC and MSFC and statements by the investigators, a daily eight-hour unmanned operation of the ATM was baselined.

Letters, William C. Schneider, NASA Hq, to Leland F. Belew, MSFC, Kenneth S. Kleinknecht, MSC, and Thomas W. Morgan, KSC, "Unmanned ATM Experiment Operations Meeting," 20 July 1970; Kenneth S. Kleinknecht to Directors of Flight Operations and Flight Crew Operations, MSC, "Unmanned ATM Operations," 30 July 1970.

17

MSFC issued a contract change order to McDonnell Douglas changing the food management concept from a soft to a canned food package, which provided additional food storage. Modification of the wardroom table to mount a new serving tray with hotplate cavities for heating the food was also included in the change.

Change Order 128, Contract NAS 9-6555, Schedule 11, 17 July 1970.

23

MSFC modified an existing contract with McDonnell Douglas for additional work on the Skylab airlock. The AM was a 1.6-m-diameter tunnel attached to the top of the Workshop. It provided the major work area and support equipment required to activate and operate the Workshop and also formed a passageway for the astronauts to move from the Apollo CM and MDA into the Workshop. The airlock could also be depressurized and sealed off for exit into space outside the vehicle.

MSFC Contracts Office, MOD 55 to Contract NAS 9-6555 Schedule 1, 23 July 1970.

27–31

Representatives of government and industry participated in a Skylab AM and MDA crew station review at McDonnell Douglas in St. Louis. Storage areas, equipment, and crew operations were discussed. Astronauts attending the review conducted walk-throughs of the AM and MDA, major elements of the Skylab cluster that would also include large solar observatory quarters for long stays in space. McDonnell Douglas was developing the AM. The MDA was being built by MSFC; and Martin Marietta, Denver Division, was integrating equipment and experiments.

MSFC News Release 70-146, 28 July 1970; MSFC, "Weekly Activity Report," 6 August 1970; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 7 August 1970; NASA, "Manned Space Flight Weekly Report," 10 August 1970.

1970 July 30 — KSC awarded a contract to Reynolds, Smith, and Hills of Jacksonville, Florida, for architectural and engineering services in modification plans for adapting existing Saturn V facilities at Launch Complex 39 to launch Saturn IB space vehicles. A launcher-umbilical tower would require a major modification, and minor modification would be required in the service platforms of the Vehicle Assembly Building, where space vehicles were assembled and checked out before being moved to the launch pad. The firm, fixed-price contract had a performance period of 200 days, with work to be performed at the Center and in Jacksonville.

Spaceport News, 30 July 1970, p. 5.

30 — Skylab Program Managers Thomas W. Morgan, KSC, Leland F. Belew, MSFC, and Kenneth S. Kleinknecht, MSC, approved an inter-Center agreement on the use and control of acceptance checkout equipment-spacecraft (ACE-S/C) for the checkout of the ATM at all locations and the AM downlink at KSC.

"MSC/KSC/MSFC Inter-Center Agreement on the Use and Control of ACE-S/C for the Checkout of ATM at All Locations and AM (Downlink) at KSC," 30 July 1970; MSFC, "Weekly Activity Report," 7 August 1970; KSC, "Weekly Progress Report," 12 August 1970.

31 — A thermal attitude control system review was held at MSFC. A request by MSC for isolating the 22-bottle cold gas system into two banks to protect the system from leakage was rejected on the basis that adequate attitude control would still be maintained in the event of a depleted gas supply by using control moment gyros for all mission phases except the first eight hours. On 4 August, the Manned Space Flight Management Council sustained the rejection.

NASA, "Manned Space Flight Weekly Report," 10 August 1970; letter, C. A. Sweeney, NASA Hq, to Dist., "MSF Management Council Action Items From Program Review of August 4, 1970."

August 4 — A special change review board was established to expedite and finalize decisions needed by contractors. Emphasis would be placed on resolving urgent change. The initial meeting would cover the Orbital Workshop, airlock module, and experiments. Members of the board were William C. Schneider and John H. Disher (NASA Hq), Leland F. Belew (MSFC), Kenneth S. Kleinknecht (MSC), and Thomas W. Morgan (KSC).

TWX, William C. Schneider to Leland F. Belew, Kenneth S. Kleinknecht, and Thomas W. Morgan, 4 August 1970.

6 — An MSFC Saturn Program Office review of all Skylab Program directives applicable to the launch vehicle was conducted. Essentially, the review indicated there was no incompatibility between requirements of the Skylab directives and Saturn practices as they pertained to the launch vehicle.

Letter, R. G. Smith, MSFC, to W. C. Schneider, NASA Hq, "MSFC Saturn Program Office Implementation of Skylab Directives," 6 August 1970.

1970
August
10–14

A critical design review for the AM was held at McDonnell Douglas. Personnel from NASA Hq, MSC, KSC, MSFC, and McDonnell Douglas participated. The review was a detailed technical examination of the total AM, including the environmental control systems, electrical and power management, data and communications, structural and mechanical, and other miscellaneous and experiment-support systems.

Memorandum, D. M. Green, McDonnell Douglas, "Critical Design Review," 13 August 1970; McDonnell Douglas, "Airlock Program History, 1966–1974"; NASA, "Manned Space Flight Weekly Report," 24 August 1970; letter, L. F. Belew, MSFC, to W. C. Schneider, NASA Hq, "Airlock Module Critical Design Review," 22 September 1970.

14

A meeting was held at MSFC on the OWS in-flight microbiological and odor contamination requirements. Personnel from MSC, MSFC, LaRC, McDonnell Douglas, Martin Marietta, Brown Engineering Company, and the U.S. Public Health Service attended. Considerable discussion centered about the need for a general biocide for disinfecting within the entire Skylab and the requirement for a high-level working group to review and solve microbiological growth problems for the entire cluster.

Letter, Leland F. Belew, MSFC, to Kenneth S. Kleinknecht, MSC, "Minutes to the OWS In-Flight Microbiological and Odor Contamination Requirements Review, August 14, 1970," 9 September 1970; D. D. Myers, NASA Hq, to Robert R. Gilruth, MSC, 26 August 1970.

24–27

A week-long critical design review of the Skylab MDA was completed by NASA and its contractor teams at Martin Marietta's Denver division. This was the final technical review before approval for manufacturing flight hardware.

MSFC News Release 70–168, 27 August 1970; MSFC, "Weekly Activity Report," 2 September 1970.

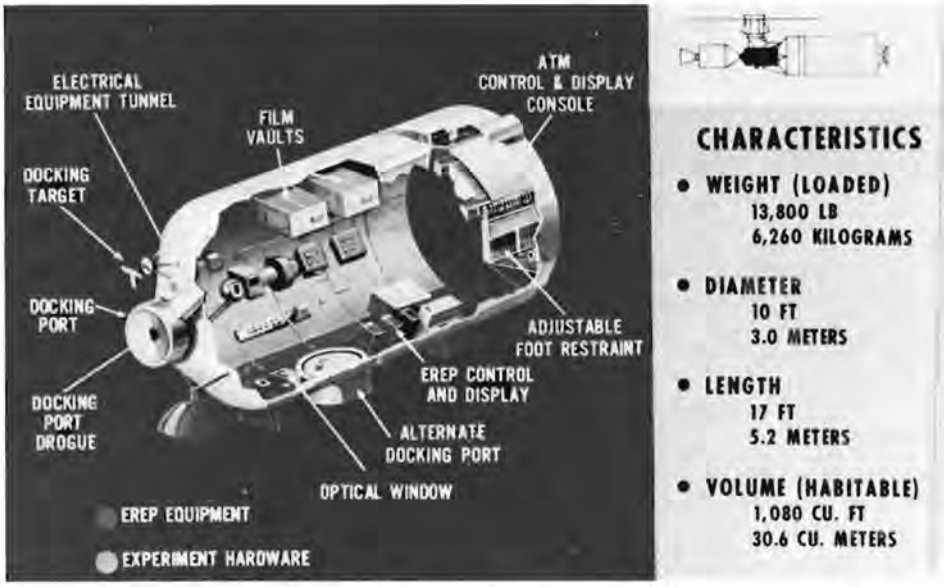
28

MSFC issued a modification to an existing contract with McDonnell Douglas for Skylab Program work. The modification would pay for the conversion of the original OWS to be launched by a Saturn IB booster to a completely outfitted Workshop to be launched by a Saturn V. Originally the plan was to launch the second stage (S–IVB) of a Saturn IB into Earth orbit. The S–IVB would be filled with fuel so that it could propel itself into orbit. Astronauts launched by a second Saturn IB would then rendezvous with the empty stage and convert it into living and working quarters. A decision was made 21 May 1969 to outfit an S–IVB on the ground and launch it ready for use on a Saturn V.

MSFC Contracts Office, MOD 84 to NAS 9-6555 Schedule 11, 27 August 1970.

28

A group of MSFC engineers successfully completed a week-long testing of Skylab Program hardware in simulated weightlessness aboard a USAF KC–135 four-engine jet research aircraft. Tests included operation of flight-configuration doors



Sketch of the multiple docking adapter.

1970

August

for film cassette compartments, retrieval and replacement of film cassettes, and evaluation of handrails and food restraints. The KC–135 was flown in parabolas, with 30 seconds of weightlessness achieved on each parabola in a technique that closely duplicated zero-g.

MSFC News Release 70–169, 28 August 1970.

31

NASA published a new Skylab launch readiness and delivery schedule which called for a Skylab 1 launch on 1 November 1972. The change was initiated as a result of the implementation of an interim operating plan which deleted two Apollo missions and called for completion of all Apollo missions by June 1972.

NASA Hq Schedule, 31 August 1970; TWX, William C. Schneider, NASA Hq, to Leland F. Belew, R. G. Smith, L. B. James, and W. Teir, MSFC, Kenneth S. Kleinknecht, MSC, and Thomas W. Morgan, KSC, "Skylab Action to Implement the Interim Operating Plan," 3 September 1970; NASA, "Manned Space Flight Weekly Report," 8 September 1970.

September

2

A study to determine optimum utilization of Launch Complex 39 culminated in the following assignments:

Apollo 14	*Apollo 15 and subsequent*
Launcher Umbilical Tower 2	Launcher Umbilical Tower 3
High Bay 3	High Bay 3 (Post-Apollo 14)
Firing Room 1	Firing Room 1
Pad A	Pad A

Skylab 1	*Skylab 2, 3, 4*	1970
Launcher Umbilical Tower 2	Launcher Umbilical Tower 1	September
High Bay 2	High Bay 1	
Firing Room 2	Firing Room 3	
Pad A	Pad B	

Letter, Thomas W. Morgan, KSC, to Dist., "LC–39 Facility Utilization," 2 September 1970.

An inquiry as to the feasibility of having a crew from another country visit the Skylab in orbit showed that, while there was nothing to indicate such a mission could not be accomplished, a considerable amount of joint planning and design would be required. 4

Letter, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "International Cooperation in the Skylab Program," 4 September 1970.

A study, which was initiated in April concerning a second Skylab Program, had generated sufficient data for planning purposes. The study indicated that a second set of Skylab missions would provide a useful and worthwhile continuation of manned space flight in the mid 1970s, even if the hardware were unchanged. It would also offer an economically feasible program option if future funding for the Space Shuttle Program fell behind the anticipated growth rate. 4

Letter, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Skylab B Planning Studies," 4 September 1970.

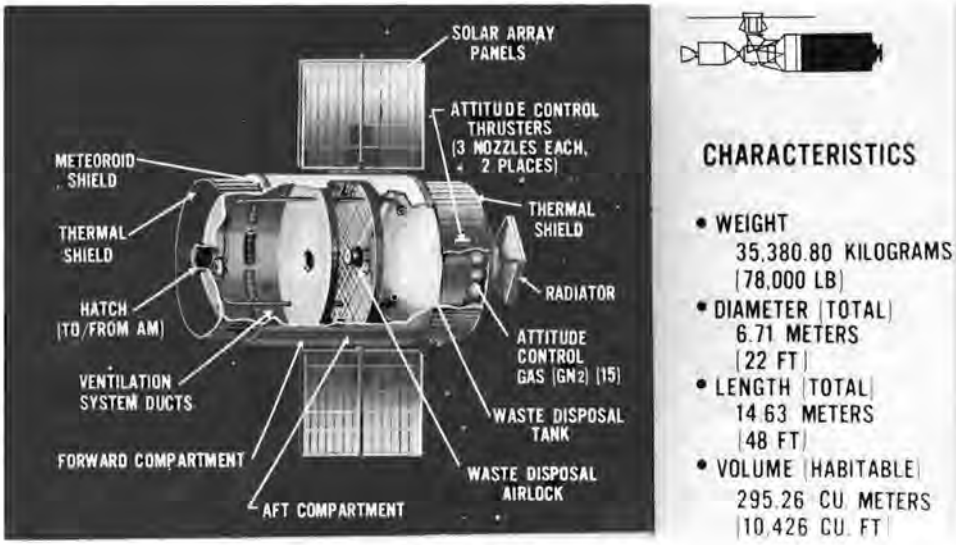
A multiple docking adapter critical design review board met at MSFC with representation from NASA Hq, KSC, MSC, and MSFC. This meeting concluded critical design reviews on the MDA and the AM. 11

NASA, "Manned Space Flight Weekly Report," 21 September 1970; MSC, "Skylab Weekly Activity Report," 18 September 1970; MSFC, "Weekly Activity Report," 16 September 1970; "Minutes of the MDA CDR Board Meeting," 24 September 1970.

An Orbital Workshop critical design review was conducted at McDonnell Douglas, Huntington Beach. Personnel from NASA Hq, MSC, KSC, MSFC, and McDonnell Douglas participated. The review was conducted by panels representing six different technological disciplines. Areas of potential major impact included the urine system, microbiological contamination, the water storage system, and the OWS window vibration test. 14–18

KSC, "Weekly Progress Report," 23 September 1970; "Skylab Program Test—Weekly Status Report," 23 September 1970.

Singer-General Precision, Inc., Link Division, Houston, was selected for the award of a contract to design, develop, install, and support a Skylab simulator to provide 15



Sketch of the Orbital Workshop.

1970

September

astronaut and ground crew training at MSC. The simulator would serve as a ground-based trainer with controls and displays similar to those used during manned operations. It would also be operated in conjunction with the command module simulator and the Mission Control Center to provide complete mission training.

MSC News Release 70–101, 15 September 1970.

16 George M. Low became Acting Administrator of NASA until a successor could be chosen to replace Thomas O. Paine who had resigned to return to General Electric Company. Low served in that capacity until the appointment of James C. Fletcher as NASA Administrator in March 1971.

TWX, A. P. Alibrando, NASA Hq, to all NASA Installation Public Information Offices, 15 September 1970; *Astronautics and Aeronautics, 1971*, p. 69.

21 A Saturn Workshop crew station review began at MSFC as part of the Skylab Program. Nine astronauts participated in the week-long review conducted in a Workshop mockup. Government and industry engineers monitored the astronauts' progress as they "walked through" many of the Workshop tasks. Medical experiments scheduled for the Skylab flight were reviewed.

Letter, Leland F. Belew, MSFC, to William C. Schneider, NASA Hq, 21 October 1970; MSFC, "Weekly Note for Week Ending 25 September 1970."

24 A technical status review was conducted at North American Rockwell. Among the major topics covered were subsystem, critical parts, stress corrosion, cost reduction, property disposition, and manufacturing and test programs. North Amer-

1970

ican's efforts to retain critical skills and maintain high-quality test and manufacturing operations were also discussed.

September

NASA, "Manned Space Flight Weekly Report," 5 October 1970.

MSFC modified the existing Skylab contract with Martin Marietta. The contract change covered ATM mission support at MSC and MSFC. 25

MSFC Contracts Office, MOD 205 to Contract NAS 8-24000, 25 September 1970.

A Skylab Subsystem Review Team was established with C. W. Mathews (NASA Hq) as chairman. Reviews were scheduled to be conducted at MSFC in November 1970, at MSC during February–March 1971, and at KSC also during February–March 1971. The subsystem review team was established based on a recommendation of the Apollo 13 Review Board. 25

Letter, C. W. Mathews to Director, Program Management, MSFC, Manager, Skylab Program, MSC, and Manager, Apollo-Skylab Programs, KSC, "Skylab Subsystems Review," 25 September 1970.

Multiple docking adapter tests using flight hardware and a CSM simulator were conducted by MSC, MSFC, and North American Rockwell. Because the docking probe was unable to maintain a constant preload setting it was returned to North American for refurbishment. 28–30

MSFC, "Weekly Activity Report," 8 October 1970.

A Skylab Contamination Control Working Group presented a summary status to the Office of Space Science and Applications, the Office of Advanced Research and Technology, and the Skylab Program Office. MSFC identified sources of contamination within Skylab and noted the actions that had been taken or were underway. W. Stroud (Goddard Space Flight Center) observed that since man's presence created major sources of contamination, failure of any Skylab experiments for this reason would have a significant impact on future manned missions. 29

Letter, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Skylab Contamination Control," 13 October 1970.

A multiple docking adapter management review was held at Martin Marietta. Areas covered included temperatures in the film vaults, installation of vent valves in the MDA, the window test program, and MDA TV system requirements. October 13

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 26 October 1970.

A reliability assessment report on CSM rendezvous maneuvers was released. The report covered critical items of the guidance and navigation control systems, 16

1970

October

service propulsion system, and service module reaction control system during CSM rendezvous maneuvers. Five mission-success single failure points were identified. Three of these were also crew-safety single failure points.

NASA, "Manned Space Flight Weekly Report," 26 October 1970; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 26 October 1970.

20

MSC announced plans to construct a dock and to dredge a channel in Clear Lake adjacent to the east gate of MSC to facilitate shipment of large Skylab test articles. Upon completion of dredging, the waterway would be 2 m deep, 18 m wide, and 914 m long.

MSC News Release 70–117, 20 October 1970.

21

Russian Cosmonauts Vitaly I. Sevastyanov and Adrian G. Nikolayev were briefed on the Skylab mission during a tour of MSFC. Sevastyanov and Nikolayev had previously been selected by the International Academy of Astronautics for the 1970 Daniel and Florence Guggenheim International Astronautics Award. The award, which was presented annually for outstanding contribution to space research and exploration, was awarded to the cosmonauts for their 17-day *Soyuz 9* mission 2–19 June.

MSFC, *Process Engineering Laboratory Neutral Buoyancy Simulator Daily Log,* 21 October 1970.

30

George M. Low (NASA Hq) wrote to E. E. Davis, Jr., Science Advisor to the President: "To forego Skylab would have a powerful negative impact on astronomy and earth resources surveys. It would leave the U.S. without the data base for any future manned mission decisions. It would surrender to the U.S.S.R. the option of having the first real space station in orbit. It would leave underdeveloped the desirable precedent of openly shared manned flight program scientific and technical results, a possibility currently underscored by the discussions in Moscow on the suggestion that the U.S. and U.S.S.R. use common docking hardware in their orbital spacecraft."

Letter, George M. Low, NASA Hq, to E. E. Davis, Jr., Science Advisor to the President, 30 October 1970.

November

2

NASA Hq concurred in the transfer of management responsibility from the Apollo Program to the Skylab Program at KSC for Launcher Umbilical Tower 1, High Bay 1, Firing Room 3, and Pad B for Skylab 2, 3, and 4 missions. Approval for the reassignment of Apollo facilities to support the SL–1 mission would be accomplished in later correspondence.

Letter, R. A. Petrone and W. C. Schneider, NASA Hq, to Manager, Apollo-Skylab Programs, KSC, "LC-39 Facility Utilization," 2 November 1970.

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November

5

Launch intervals to be used for trajectory development were 70 days between SL–2 and SL–3 and 102 days between SL–3 and SL–4. The schedule called for an SL–1 launch, 9 November 1972; SL–2, 10 November 1972; SL–3, 19 January 1973, and SL–4, 1 May 1973. The launch intervals would provide for adequate daylight in the launch abort recovery areas and the normal end-of-mission recovery zones.

NASA, "Manned Space Flight Weekly Report," 16 November 1970; "Weekly Progress and Program Summary for the Administrator—Skylab Program," 18 November 1970.

9–10

A Skylab Program Managers' meeting was held at the Michoud, Louisiana, Assembly Facility. Among the items covered were the issue of static firing of the Saturn IB on Launch Complex 39; modification of the Maurer 16-mm camera to an 8-mm frame size; continued need for experiment requirements documents; launch intervals and launch pad access for SL–1; an experiments safety plan; and manpower levels and work-cost relations.

Letter, William C. Schneider, NASA Hq, to Dist., "Skylab Managers Meeting," 16 November 1970.

16–20

An EVA critical design review was held at the Skylab mockup area and the neutral buoyancy simulator, MSFC. The week-long EVA review included astronaut performance under normal Earth gravity in the Saturn Workshop mockup and simulated weightlessness in the neutral buoyancy simulator. Ten astronauts from MSC took part in the review activities.

MSFC PAO, *Visitors Program Records*, 16–19 November 1970; MSFC News Release 70–235, 17 November 1970; MSFC, "Weekly Activity Report for Week Ending 17 November 1970"; NASA, "Manned Space Flight Weekly Report," 30 November 1970; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 2 December 1970.

17–18

A 90-day manned test symposium was held at LaRC. Representatives from NASA, industry, and universities attended. Primary subjects covered during the symposium were water management, atmosphere purification, atmosphere contamination, atmosphere supply, waste management, food management, crew selection and training, habitability, behavioral studies, acoustics and lighting, medical and physiological aspects, and crew panel discussion.

Letter, E. L. Field, MSFC, to W. K. Simmons, Jr., MSFC, "90-Day Manned Test Symposium," 27 November 1970.

17–19

A Skylab subsystem review team chaired by C. W. Mathews, NASA Hq, met at MSFC. During the meeting, the review team inspected the Skylab mockup area and simulation facilities in the Astrionics and Manufacturing Engineering Laboratories. A number of action items were compiled for MSFC resolution.

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November

Letter, C. W. Mathews to E. F. M. Rees, MSFC, 18 January 1971; MSFC News Release 70–235, 17 November 1970; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 2 December 1970.

18 The Skylab MDA flight unit was flown from MSFC to Martin Marietta's Denver division where it was to be outfitted with controls and display panels for solar astronomy and Earth resources experiments, storage vaults for experiment film, and a thruster attitude control system.

MSFC Project Logistics Office, *Flight Operating Log*, 18 November 1970; MSFC, "Weekly Activity Report for Week Ending 24 November 1970."

18 The NASA Education Programs Office was studying the use of Skylab missions as a focal point for a substantial national education program. Particular interest was being expressed in environmental and ecological education, possibly in cooperation with a new program under the U.S. Office of Education. The educational activities would include teacher workshops and preparatory courses prior to the mission, use of real-time television during the mission, and post-mission use of film and other data.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 18 November 1970.

19 NASA Hq established a flammability, explosion, and toxicity policy for material selection, control, test, and evaluation on the Skylab Program. Continuous emphasis was being given to the importance of the materials program and its relationship to crew safety and mission success.

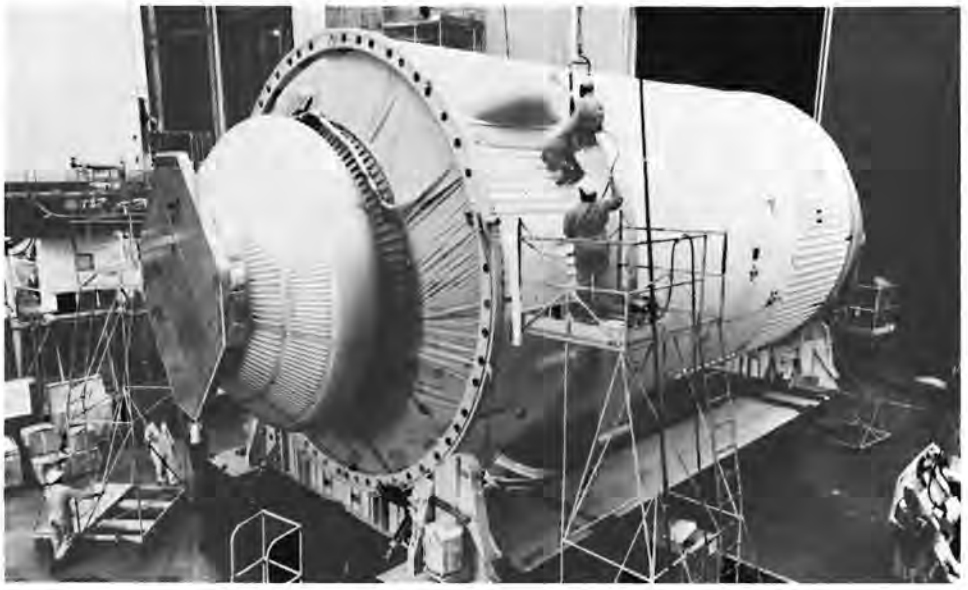
Skylab Program Directive No. 16A, "Skylab Program Materials Policy," 19 November 1970.

23 Saturn V launch vehicle SA–515 was designated as the backup launch vehicle for Skylab 1. Management responsibilities for the vehicle would be similar to those for the primary launch vehicle, SA–513.

TWX, William C. Schneider, NASA Hq, to R. G. Smith and Leland F. Belew, MSFC, Kenneth S. Kleinknecht, MSC, and Thomas W. Morgan, KSC, "Backup Saturn V Launch Vehicle for Skylab," 23 November 1970; letter, William C. Schneider to Leland F. Belew, R. G. Smith, Kenneth S. Kleinknecht, and Thomas W. Morgan, "Amendment #2 to October 13, 1969 Memorandum of Understanding Between the Apollo and Skylab Program Offices on Saturn Vehicle Management Interfaces," 2 December 1970.

December

2 A presentation on a proposed Skylab medical experiments chamber study was made at NASA Hq. Personnel from NASA Hq, MSC, and Ames Research Center attended. Following the presentation, MSC was authorized to proceed with the planning and design of a 56-day preflight chamber program to be conducted before Skylab 1 and 2. The program would later become known as SMEAT (Skylab medical experiment altitude test).



Technicians at McDonnell Douglas Astronautics, Huntington Beach, prepare the Skylab Workshop test vehicle for shipment to MSC and MSFC to undergo design verification tests. The test article was subjected to acoustic, vibration, and static forces comparable to those that would be encountered during launch and orbit.

Letters, William C. Schneider, NASA Hq, to Manager, Skylab Program, MSC, "Skylab Medical Experiments Chamber Study," 3 December 1970; Christopher C. Kraft, Jr., MSC, to Director, Skylab Program, NASA Hq, "Skylab Medical Experiments Chamber Study," 11 January 1971; memorandum, Christopher C. Kraft to Dist., "Skylab Medical Experiments Chamber Study," 11 January 1971.

1970

December

4

A ground-test version of the Saturn Workshop was shipped from the McDonnell Douglas facility at Huntington Beach, to the Michoud, Louisiana, Assembly Facility. It would undergo testing there until 30 December and then would be shipped to MSC for extensive ground tests. This Workshop was a version of one that would be used in the Skylab Program to accommodate teams of three astronauts for stays of up to 56 days in Earth orbit. NASA planned to launch the Skylab cluster with a Saturn V vehicle in 1972. Called a "dynamic test article," the Workshop model would be tested at MSC to verify its bending and vibration characteristics. The Workshop was scheduled to arrive at Michoud 17 December and at MSC 5 January.

MSFC, "Weekly Activity Report," 6 and 17 November 1970 and 10 and 24 December 1970; MSC, "Skylab Weekly Activity Report," 13 November 1970.

16

A study was underway to determine the advisability of providing the Skylab crews with fresh foods. The main area of concern centered around the probability of invalidating medical experiments because of the chemical instability of the fresh food and the wide variation between the sources of food lots.

1970

December

Letters, Kenneth S. Kleinknecht, MSC, to William C. Schneider, NASA Hq, "Perishable foods," 16 December 1970; J. W. Humphreys, Jr., NASA Hq, to Director, Skylab Programs, "Perishable Foods," 8 January 1971.

20

The payload shroud test article was successfully tested at the Plum Brook Facility of Lewis Research Center. The purpose of the payload shroud would be to cover and protect the ATM MDA, and top portion of the AM as Skylab was launched into an Earth orbit.

MSFC, "Weekly Activity Report," 24 December 1970; NASA News Release 70–214, "12-Ton Nose Cone To Be Tested," 21 December 1970; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 5 January 1971.

23

An assessment of the feasibility of providing a crew rescue capability for Skylab was conducted by KSC, MSC, and MSFC during 1970. The study culminated in a NASA Hq decision to provide a limited rescue capability should return capability fail while the CSM were docked to the OWS. The rescue vehicle for the first two manned Skylab missions would be the next CSM in flow at KSC. Should a rescue call occur, the CSM next in flow would be modified so as to permit a five-man carrying capacity. It would be launched with a two-man crew and return with the additional three astronauts.

TWXs, William C. Schneider, NASA Hq, to Leland F. Belew, MSFC, Kenneth S. Kleinknecht, MSC, and Thomas W. Morgan, KSC, "Skylab Rescue," 24 September 1970; William C. Schneider to Leland F. Belew, R. G. Smith, Kenneth S. Kleinknecht, and Thomas W. Morgan, "Skylab Rescue Study," 24 December 1970; memorandum, William C. Schneider to M. F. Sedlazek, NASA Hq, "Skylab Rescue Study," 22 December 1970; memorandum for record, M. F. Sedlazek, "Meeting—Skylab Rescue," 24 December 1970; letters, William C. Schneider to Manager, Skylab Program, MSC, "Study of Rescue Capability for Skylab," 17 April 1970; William C. Schneider to Managers, Skylab Program, MSFC, MSC, and KSC, "Skylab Rescue Study," 6 January 1970; William C. Schneider to Director, NASA Safety Program, "Input to Semi-Annual Report on MSF Safety Studies and Activities for Congressman Teague," 2 October 1970; KSC, "Weekly Progress Reports," 4 November 1970 and 2 December 1970; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 5 January 1971; North American Rockwell Studies, SD70–263, "Skylab Rescue Vehicle/Third CSM for Skylab B," July 1970; AP70–12, "Skylab Rescue," September 1970; SD–70–263–1, "Addendum to Skylab Rescue Mission," November 1970; MSC Skylab Rescue Study, 25 November 1970.

1971

January

3

The Orbital Workshop dynamic test article arrived at the Clear Lake Creek Basin adjacent to MSC aboard the barge *Orion*. It was offloaded on 7 January and moved to the MSC acoustic test facility where it was set up for vibroacoustic testing scheduled to start on 20 January. The acoustic test facility had been checked out previously, and the acoustic environments generated met simulated conditions surrounding the Skylab during Skylab 1 liftoff and Skylab 1 maximum gravity.

"Skylab Program Test Weekly Activity Reports," 6 January 1971 and 13 January 1971; MSFC, "Weekly Activity Reports," 14 January 1971, 22 January 1971, and 27 January 1971; "Weekly Progress and Program Summary Report for the Administrator

—Skylab Program," 1 February 1971; NASA, "Manned Space Flight Weekly Activity Report," 1 February 1971.

1971

January

7 An inter-Center agreement which defined the policies, procedures, and responsibilities for planning and conducting experiment integration activities at module contractors' test sites was approved.

MSC-MSFC Inter-Center Agreement, Kenneth S. Kleinknecht, MSC, and Leland F. Belew, MSFC, "Operations Policy for Checkout of Skylab Experiments at Module Contractors," 7 January 1971.

14 A technical design review of the operational bioinstrumentation system was held at Martin Marietta's Denver Division. The system would be worn by each crewman during launch, return, intravehicular activities, and extravehicular activities to measure respiration rate, heart rate, body temperature, and electrocardiogram. No significant problems were revealed in the review. A critical design review was scheduled for mid-March.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 27 January 1971.

14 Policy on the management of experiment resources was elaborated on by NASA Hq. Emphasis was that the real contribution to experiment management would come from careful planning and analysis and the attentive day-to-day management of experiments by the responsible Centers.

Letter, William C. Schneider, NASA Hq, to Managers, Skylab Program, MSFC and MSC, and Manager, Apollo-Skylab Programs, KSC, "Management of Experiment Resources," 14 January 1971.

15 A group of potential Skylab crew members was taking a course in solar physics designed to provide a background for operating the Apollo telescope mount. The course was divided into extensive reviews of the introduction of solar phenomena, the quiet Sun, the active Sun, and flares and explosive phenomena. Studies of the Sun in real time were made using closed circuit TV to bring pictures from MSC's solar telescope to the classroom.

MSC News Release 71-01, 15 January 1971.

19 NASA requested proposals from potential U.S. and foreign experimenters for investigations of data to be acquired from the Earth resources experiment package to fly on the manned Skylab spacecraft in late 1972. Data would be used in assessing the value and direct applications of space observations in agriculture, geography, forestry, geology, hydrology, oceanography, and cartography. Objectives of EREP were to extend use of sensors; use man to observe, discriminate, and select study areas; and provide an early source of unique research data for analysis.

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NASA News Release 71–5, 19 January 1971.

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19 A meeting at MSC reviewed Skylab fire extinguisher requirements. Representatives from MSC, MSFC, and NASA Hq attended. MSFC described the physical distribution of flammable materials within the OWS, AM, and MDA. MSC and MSFC representatives agreed to a joint tour of module contractor facilities, beginning 22 January, to review the location of flammable items. Recommendations would be developed from these reviews for the number and locations of fire extinguishers required for Skylab.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 27 January 1971.

19 NASA Hq issued a directive which established, for the Skylab Program, the Headquarters-to-Center relationship in the area of configuration management, as well as pertinent configuration control board (CCB) controls and reporting requirements.

Open work at KSC, associated with hardware and software delivered to KSC, would be kept to a minimum. All hardware and software, including changes approved for incorporation, would be completed in the contractors' plants before delivery unless specific approval to the contrary was granted to the responsible Center. The concurrence of the KSC Skylab Program Manager would be required in all such actions.

Skylab Program Directive No. 34, "Skylab Program CCB Controls and Reporting Requirements," 19 January 1971.

19–21 The solar array system critical design review was held at TRW. Significant discussion concerned

- Failure of individual cells due to shadowing by attitude changes; however, possible solar array degradation appeared to be within acceptable limits.
- Soldering inspection techniques which would be tightened to conform to NASA specifications.
- Use of the deployment spring material (titanium); TRW would furnish MSFC additional details on its use.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 1 February 1971; MSFC, "Weekly Activity Report," 8 February 1971.

20 MSFC reviewed options for obtaining television surveillance of EVA and the exterior of the Skylab for scientific and operational purposes. These included TV camera cable dragout from the AM TV input station through the EVA hatch; externally mounted TV input stations and mounts requiring an astronaut to connect the camera cable to the stations; and a TV camera mounted on the

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experiment T027/S073 (ATM contamination measurement) photometer extension mechanism. Of the three, MSFC favored the T027/S073 concept.

TWX, Leland F. Belew, MSFC, to William C. Schneider, NASA Hq, Kenneth S. Kleinknecht, MSC, and Thomas W. Morgan, KSC, "Addition of External TV to the Skylab Program's Basic TV Capability," 20 January 1971.

21

Status of the Orbital Workshop potable water system design and development testing was the subject of a meeting at McDonnell Douglas, Huntington Beach. Completed tests failed to indicate either the presence or absence of any system problems such as corrosion, rapid iodine depletion, and high ionic content. McDonnell Douglas was unable to determine the expected ionic levels for various metallics developed in an ion-exchange bed to remove undesirable metallic ions.

MSC, "Skylab Office Weekly Activity Report," 29 January 1971.

25

An MSC–MSFC Skylab mission data-interface agreement describing the division of responsibilities, mutual support, and interface procedures established between MSFC and MSC in the execution of their mission data handling tasks was approved by Christopher C. Kraft, Jr., for MSC, and Eberhard F. M. Rees, for MSFC.

MSCM 8010, *Program Management Guide,* 25 January 1971.

26–27

An ATM experiments Principal Investigator meeting was held at Boulder, Colorado. It was designed to ensure total agreement on experiment objectives, development, operations, and data analysis, as well as to ensure that crew and mission operations requirements would be met. Representatives of MSFC, MSC, and Martin Marietta attended the meeting. The scientists who proposed the six solar astronomy experiments also attended the meeting. An update of the proposed Martin Marietta facilities designed to support Skylab was presented. The solar data from ground observatories needed to support mission operations were described by National Oceanic and Atmospheric Administration personnel, and their recommendations were agreed to, with the stipulation that additional data were needed. The ATM film study identified some problem areas to be resolved, such as temperature control and radiation protection for film.

"Minutes of ATM PI Executive Meeting," 26–27 January 1971; MSC, "Skylab Program Office Weekly Activity Report," 5 February 1971.

28

KSC awarded a contract to The Boeing Company for the reactivation, operation, and maintenance of Launch Complex 39 launch support equipment in support of Skylab.

KSC Scheduling and Review Procedure, 3 February 1971.

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29 A Skylab trainer review was held with representatives from MSC, MSFC, and the contractors to review the trainer module status and delivery schedules, the trainer configuration management program, and the contents of the trainer turnover data packages. Due to the slip in the Skylab launch date into 1973, all module trainer delivery dates were being reassessed. (See 13 April 1971 entry.)

MSFC, "Weekly Activity Report," 12 February 1971.

February

2 During recent OWS progressive crew station reviews, concern had been expressed about a trash airlock failure, contingency trash disposal methods, and the possibility of repairing a failed airlock. In an effort to alleviate the concern, the MSC Systems Safety Office made an analysis of the problem. As a result of the study, the Systems Safety Office recommended that the following be considered for adoption within the mission rules for Skylab:

- Provide detailed contingency provisions and procedures for suitable disposition of perishable items within the OWS, to allow mission continuation.
- Familiarize crews with trash airlock repair instructions.
- Provide flight-qualified, nonflammable, gas-tight, trash stowage bags and a suitable biocide to be used for in-house trash storage if the trash airlock failed.
- Provide contingency procedures for external OWS stowage of trash during scheduled extravehicular activities.
- Do not redesign the present trash airlock system unless testing shows deficiency or identifies additional single failure points previously undefined.

Memorandum, M. L. Raines, MSC, to Manager, Skylab Program Office, MSC, "System Safety Analysis of the Orbital Workshop trash disposal airlock," 24 February 1971; study, K. W. Irwin, Boeing, "System Safety Analyses of the Orbital Workshop Trash Disposal Airlock," 2 February 1971.

2 Martin Marietta's biomedical storage cabinet design was reviewed to establish acceptable constraints for use of molded polyurethane foam in storage drawers. The drawers were found to be insufficiently tight when closed, creating a potential hazard by allowing an unlimited oxygen supply should the foam be ignited. It was also suggested that free foam particles would be created by storage container use because of shape cutouts in the foam. Investigation of nonflammable corrugated cardboard as an alternative to the foam was progressing.

MSC, "Skylab Program Office Weekly Activity Report," 5 February 1971.

3 An MSFC/KSC inter-Center review of the OWS ground support equipment was held at McDonnell Douglas. No design changes were identified.

MSFC, "Weekly Activity Report," 12 February 1971.

3 A Skylab briefing was held at the MSC News Center. Participants included William C. Schneider (NASA Hq), A. J. Calio (MSC), C. A. Berry (MSC), and

O. K. Garriott (MSC). Main theme of the briefing was the scientific applications and medical experiments that would be conducted during the Skylab Program.

"Transcript, Skylab Briefing," 3 February 1971.

5 The acoustic test of the OWS dynamic test article reached the halfway point when the last of the liftoff acoustic sequence was performed at MSC. During this sequence, the dynamic test article was exposed to the full intensity of the liftoff acoustic environment for 15 seconds to qualify the OWS structural design. A quick look at the hardware indicated no major problems. The most significant discrepancy noted was that some tie rods stabilizing the top of the floor-mounted cabinets had loosened.

MSFC, "Weekly Activity Report," 12 February 1971, "Skylab Program Engineering Weekly Status Report," 10 February 1971.

9 An Orbital Workshop management review was conducted at McDonnell Douglas. Representatives from McDonnell Douglas, NASA Hq, KSC, MSFC, and MSC attended. Significant agenda items included the program schedule, engineering changes, design status, component tests, and procurement status. The OWS flight module was about three months behind schedule. The component development and qualification testing was also behind schedule. McDonnell Douglas reorganized the procurement activity and was making a significant effort to improve this area since it directly impacted the schedule slip.

"Skylab Program Engineering Weekly Status Report," 10 February 1971.

9 A high-level advisory board responsible for guiding NASA in all aspects of mission safety held a two-day meeting at MSFC. The Aerospace Safety Advisory Panel, appointed by the NASA Administrator, was headed by Charles D. Harrington, President, Douglas United Nuclear, Richland, Washington. The group discussed safety aspects of the lunar roving vehicle, the Skylab cluster of spacecraft, and the proposed reusable space vehicle (space shuttle).

MSFC PAO, *Visitors Program Record*, 8–9 February 1971.

10 KSC awarded a contract to the Holloway Corporation of Titusville, Florida, to construct a launcher-pedestal for the Skylab Program. The 38.7-m-tall pedestal adapted to an existing launcher-umbilical tower so that manned Saturn IB space vehicles could be launched from facilities supporting the larger Saturn V rockets. Holloway contracted to construct the launcher-pedestal in 180 days after receiving notice to proceed.

KSC Scheduling and Review Procedure, 31 March 1971.

10 William R. Lucas was appointed Deputy Director, Technical, Marshall Space Flight Center. He would assume his new duties effective 15 February. Before

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appointment as Deputy Director, Lucas was Director of Program Development at MSFC.

Erich W. Neubert—serving in the capacity of Acting Deputy Center Director, Technical, as a temporary assignment—returned to his former position as Associate Deputy Director, Technical.

The position of the Director, Program Development, vacated by Lucas, was assumed by James T. Murphy in an acting capacity.

MSFC Organization Announcement No. 0101–6, "MSFC Key Personnel Announcement," 10 February 1971; letter, E. Rees, MSFC, to R. R. Gilruth, MSC, 24 February 1971.

10–11

An MSFC in-house review of experiment and cluster system compatibility found significant discrepancies between controlling documents for experiments. Since Martin Marietta supported both MSFC and MSC in configuration management and integration/development, MSFC recommended that Martin Marietta be directed to proceed with preparation of complete change packages for all experiments, to bring them up to date.

Letter, Leland F. Belew, MSFC, to Kenneth S. Kleinknecht, MSC, "Experiment Document Discrepancies," 25 February 1971; "Skylab Program Engineering Weekly Status Report," 3 March 1971.

12

Acoustic testing of the OWS dynamic test article was completed at MSC. During the final testing, the dynamic test article was exposed to the full intensity of the aerodynamic acoustic environment to qualify the Workshop structural design. No major problems were encountered. However, vibration levels in some areas exceeded the established criteria. The new vibration levels were given to McDonnell Douglas, and adjustments in the qualification test criteria were made as appropriate.

MSFC, "Weekly Activity Reports," 18 and 24 February 1971; NASA, "Manned Space Flight Weekly Report," 22 February 1971; MSC, "Skylab Program Office Weekly Activity Report," 22 January 1971; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 24 February 1971.

16–17

A meeting was held at McDonnell Douglas with representatives from NASA Hq, MSFC, Martin Marietta, and McDonnell Douglas. Purpose of the meeting was to resolve AM open issues resulting from a Martin Marietta/NASA Hq review. Significant issues resolved were adequate definition of contaminant levels, adequacy of existing design and verification for meteoroid protection, and temperature and humidity control through the environmental control system.

"Skylab Program Engineering Weekly Status Report," 3 March 1971.

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17–18

A preliminary design review of the inflight medical support system was conducted at MSC. The system was being designed and built in house by MSC using off-the-shelf hardware to the maximum extent possible. It would provide a capability to treat minor illness or injury that could be reasonably diagnosed and treated in Earth orbit, to permit Skylab mission completion.

A preliminary design review of the Skylab food system was also conducted at MSC in conjunction with the inflight medical support system review. The food system would consist primarily of the food, food containers, and food canisters. It was being developed under contract by Whirlpool Corporation. Principal areas of concern were compatibility of the food system to medical experiments and menu planning to ensure proper variety of menu.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 20 February 1971.

23

MSFC granted International Business Machine Corporation (IBM) a contract modification for the manufacture of instrument units (IU) for Saturn launch vehicles. The modification would extend IBM's delivery schedule for IUs through 31 December 1973, to be compatible with the extended Apollo and Skylab Program launch schedules. IBM was under NASA contract to build 27 IUs for Saturn vehicles: 12 Saturn IBs and 15 Saturn Vs. Ten of the Saturn IB units and 12 Saturn V units had been completed. All work was being done at the company's facilities in Huntsville. The original IU contract had been granted to IBM in March 1965 for the fabrication, assembly, checkout, and delivery of the 27 units and related support functions.

MSFC Contracts Office, MOD 1915 to Contract NAS 8–14000, 23 February 1971.

March
3

George M. Low, Acting NASA Administrator, presented NASA's FY 1972 budget request to the House Committee on Science and Astronautics: FY 1972 projects—including Apollo 15 and 16, two Mariner spacecraft, the first Earth Resources Technology Satellite, and continuing work toward future flights of Apollo 17, Skylab, Earth resources and Applications Technology Satellites, and Viking probes—represented "the fulfillment of enterprises of the 1960s, the tailing off to completion of work in progress for many years. By 1974 the number of NASA space launches per year will have declined from 26 in 1966 to 8. After the Skylab missions in 1973, we face at least four years in which there will be no United States manned flight.

"Five years ago there were over 390 000 people in industry employed on NASA work. By the end of FY 1971 that figure will be about 108 000. The decline will continue for a few more months, but we expect it to start increasing by the middle of FY 1972, with the end-of-the-year total being about equal to that at the beginning." U.S. was "running a serious risk of losing too much of the aero-

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space capability that is an essential ingredient of our long term national strength and security."

U.S. Congress, House, Subcommittee of the Committee on Appropriations, *HUD-Space-Science Appropriations for 1972: Hearings*, 92d Cong., 1st sess., 1971, pp. 1022, 1054.

3–4

A Skylab experiment ground support equipment review was conducted at KSC with representatives from KSC, MSC, MSFC, and affected contractors. The ground support equipment, test support equipment, and facilities required to support experiment test and checkout at KSC were identified. Experiment development Centers would furnish experiment-peculiar ground support equipment, and KSC would furnish the test support equipment and facilities.

KSC, "Weekly Progress Report," 10 March 1971.

4

A plan was devised to provide a rescue capability for Skylab in the event the crew became stranded in the OWS because of failed CSM. The rescue capability was based on the assumption that the stranded crew would be able to wait in the Skylab cluster with its ample supply of food, water, and breathing gases until a modified CSM capable of carrying five crewmen could be launched. If a failure occurred which stranded the crewmen in their CSM, this rescue capability would not be possible.

NASA Fact Sheet, "Skylab Rescue Capability," 4 March 1971; memorandum for record, John H. Disher, NASA Hq, "Skylab Rescue Briefing," 1 March 1971; TWX, William C. Schneider, NASA Hq, to Kenneth S. Kleinknecht, MSC, Leland F. Belew and R. G. Smith, MSFC, and Thomas W. Morgan, KSC, "Skylab Rescue Capability," 10 March 1971.

4

Dale D. Myers, NASA Associate Administrator for Manned Space Flight, testified before the House Committee on Science and Astronautics during hearings on NASA's FY 1972 authorization bill. During the past year, design and essentially all phases of development testing had been completed for Skylab, and flight hardware was in fabrication. Definition of Space Shuttle was nearing completion. To develop a limited capability to rescue Skylab astronauts from space, NASA had initiated design action on a modification kit to give Skylab the capacity to carry two men up to orbit and five men back to Earth. Stranded astronauts could use the Skylab cluster as shelter while the modification kit was installed and the Apollo-Saturn IB launch vehicle assigned to next revisit was made ready for launch.

U.S. Congress, House, Subcommittee on Manned Space Flight of the Committee on Science and Astronautics, *1972 NASA Authorization: Hearings on H.R. 3981 (Superseded by H.R. 7109)*, 92d Cong., 1st sess., 1971, pp. 1 and ff.

5

A Skylab configuration control board teleconference was held, with MSC, MSFC, KSC, and Headquarters program offices participating. Four items were dis-

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cussed: CSM micrometeoroid protection, voice scrambler, CSM schedules, and fuel cell operation/cryoventing. A test program in which sample structure cross sections of the CSM would be impacted by simulated micrometeoroid was approved. Test data would support resolution of the CSM's predicted capability to meet mission safety requirements.

"Weekly Progress and Problem Summary Report for the Administrator—Skylab Program," 5 March 1971.

5

With the issuance of the Launch Complex 34/37 Phaseout Plan, Skylab Program management responsibility for these two launch complexes was terminated. Although use of Launch Complex 37 for Space Shuttle engine testing had been considered, other options were chosen, and the complexes were to be removed from NASA operational facilities inventory.

KSC Scheduling and Review Procedure, 31 March 1971.

8

A meeting was held at MSC to identify the facilities required to support Skylab medical preflight and postflight activities. Representatives from KSC, MSC, and NASA Hq participated. It was determined that the capabilities of the Lunar Receiving Laboratory and the one-g trainer would be adequate for preflight and postflight activities when the crew was at MSC. The KSC facilities used to support Apollo would also suffice; however, minor modifications would be required for plumbing and electrical services, added workbenches, and perhaps some unique laboratory equipment.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 12 March 1971.

10

MSFC modified a contract with Chrysler Corporation to authorize additional work in the Saturn IB program. Chrysler was the prime contractor for the first stage of the Saturn IB, which was assembled at the Michoud Assembly Facility in New Orleans. Under the current modification, the company would maintain nine Saturn IB boosters in storage. Three of the nine vehicles were for the Skylab Program and would be launched in 1973. Those three, plus a fourth that would serve as a backup, would be maintained and modified as necessary under terms of this contract. Prelaunch checkout of the Skylab vehicles would also be accomplished under this modification. The period of performance was from 1 January 1971 to 15 August 1973. Six of the vehicles were located at the Michoud Facility; the other three were at MSFC in Huntsville.

MSFC Contracts Office, MOD MICH-425 to Contract NAS 8-4016 Schedule 1, 10 March 1971.

10

Agreement was reached between KSC and MSFC that the Centers would perform the Skylab cluster design verification tests at KSC and integrate these tests with basic prelaunch cluster integrated system checkout activities. In this way the

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development Center would be provided adequate participation, knowledge, and data to ensure that cluster design verification was accomplished and that requirements and objectives of both the development Centers and the launch operation Centers would be satisfied.

MSFC/KSC Memorandum of Understanding for Skylab Cluster Integrated System Tests, 10 March 1971; letter, Thomas W. Morgan, KSC, to Manager, Skylab Program Office, MSFC, 16 March 1971.

11 NASA Hq issued guidelines for the EREP program. Among the guidelines offered were the following:

- Projected cost overruns would be reviewed to determine whether they could be reduced by acceptable changes in the work package.
- The contingency for each contracted effort would be held to 10 percent.
- The Skylab Program Director would be notified of any change which exceeded $50 000.
- Consideration would be given by MSC and MSFC to the establishment of an inter-Center EREP management team.

Letter, William C. Schneider, NASA Hq, to Managers, Skylab Program, MSC and MSFC, "EREP Costs," 11 March 1971.

11 Orbital Workshop vibration test objectives, test article status, test facility preparation status, and test schedules were reviewed by MSFC and MSC during a test readiness review prior to a Skylab OWS vibration test at MSC. The review board concluded, upon resolution of one test constraint, that the initial run could proceed on schedule on 19 March.

Memorandum ES6-3/71-027, R. E. Vale, 18 March 1971.

15 An inter-Center agreement defining the policies, procedures, and responsibilities for planning and conducting experiment integration activities at module contractors' test sites was approved by Skylab Program Managers Kenneth S. Kleinknecht (MSC) and Leland F. Belew (MSFC).

MSCM 8010, *Program Management Guide,* 15 March 1971.

15 A Skylab trainer meeting with representatives from MSC and MSFC reviewed the delivery schedule for the major Skylab trainer modules and experiment trainers, the schedule for initial acceptance, and the training hardware acceptance data package requirements. Delivery dates were reviewed, and a delivery schedule established. It was agreed that MSC would develop a list of trainer hardware, identify trainer systems, and develop the trainer acceptance checkout procedures. The following Skylab training modules would be delivered to MSC: OWS one-g trainer; airlock one-g trainer; airlock zero-g trainer; airlock neutral buoyancy

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trainer; airlock one-g support stand; neutral buoyancy deployment assembly; MDA trainer; ATM one-g trainer; ATM zero-g trainer; and ATM neutral buoyancy trainer.

"Minutes of Skylab Trainer Review," 16 April 1971.

17

MSC completed a study for the use of uncommitted flight hardware from the Apollo and Skylab programs. The study was limited to low-Earth-orbit manned missions to be flown prior to the start of Space Shuttle operations in the late 1970s. Based on various considerations, the study recommended three missions: two Earth resources surveys and the Apollo-Soyuz mission. A further study would be made to determine a specific mission for the fourth available spacecraft.

MSC, "Post-Skylab Missions Summary Report," 17 March 1971; letter, Robert R. Gilruth, MSC, to Dale D. Myers, NASA Hq, 25 March 1971.

26

A joint MSFC–MSC–Martin Marietta meeting was held at Denver to discuss Earth resources experiments package testing at Martin Marietta. A test program with appropriate delivery dates was established compatible with the experiment integration requirements test specification.

MSFC, "Weekly Activity Report," 1 April 1971; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 2 April 1971.

26

NASA Hq issued a directive which enabled the Skylab Program Director to communicate mission objectives and mission requirements to the implementing Centers and offices. It provided the basic plan identifying programwide objectives and requirements, listed key operational documents, and stated responsibilities pertaining to the key documents. Objectives and requirements for each Skylab mission were also included, as well as detailed instructions for planning and performing the Skylab experiments.

Skylab Program Directive No. 43A, "Operations Directive," 26 March 1971; "Weekly Progress and Program Summary for the Administrator—Skylab Program," 2 April 1971.

29–30

A Skylab subsystem and experiment review was held at MSC with representatives from NASA Hq, KSC, MSFC, and MSC. Items discussed included the Earth resources experiment package, integrated testing at KSC, and the problem of contamination.

MSC, "Weekly Activity Report," 2 April 1971; letters, A. C. Bond, MSC, to Deputy Associate Administrator for Manned Space Flight, "Skylab Subsystem Review," 13 April 1971; C. W. Mathews, NASA Hq, to R. R. Gilruth, MSC, and K. H. Debus, KSC, "Skylabs Subsystems Reviews," 22 February 1971; E. F. M. Rees, MSFC, to C. W. Mathews, 11 March 1971.

30

Dale D. Myers, NASA Associate Administrator for Manned Space Flight, testifying before the Senate Committee on Aeronautical and Space Sciences, said that in

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the Skylab Program three separate three-man Skylab flight crews would be selected during the coming year. Scientist astronauts would be included and would perform about 50 experiments in various disciplines. Twenty of these would be in the life sciences, to determine how human beings adjust and perform under conditions of prolonged space flight, up to two months' duration. The scientist astronauts would also operate the Skylab Earth resources experiment package in the second space flight phase of NASA's Earth resources program. These observations would be in conjunction with and complementary to those of the automated Earth Resources Test Satellite (ERTS) to be launched in 1972.

U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *NASA Authorization for Fiscal Year 1972: Hearings on S. 720*, 92d Cong., 1st sess., 1971, pp. 140–141, 146.

During the Month

McDonnell Douglas, Huntington Beach, conducted a 90-day experiment with four volunteer crewmen confined in a space station simulator. The purpose of the space station simulation was to provide an artificial environment in which man could live and work with minimal stress and compromise to a normal existence. Test objectives were met. Medical and physiological data accumulated during the test would serve as an effective control in future experiments on the long-term effects of confinement and exposure to an elevated carbon dioxide partial pressure atmosphere that would probably be encountered in a long-duration space flight.

John Hall (90-day crewman), "A Summer Trip to Nowhere—90 Days in Space," McDonnell Douglas Paper WD 1591, March 1971.

April

1

A food heating tray critical design review was conducted at Whirlpool Corporation. Concern was expressed about the material used to cover the tray deck. Whirlpool was directed to determine the impact in design, schedule, and cost to change the tray deck and tray lid liner to micarta.

MSC, "Weekly Activity Report," 9 April 1971; MSFC, "Weekly Activity Report," 1 April 1971.

9

Martin Marietta, in conjunction with The Boeing Company, was performing sneak circuit analyses of the AM, OWS, MDA, ATM, CSM, electrical support equipment, and instrument unit. Work would be completed in December 1972, with a final report in January 1973. Prior work under Apollo identified 91 sneak circuits. With the greater complexity of Skylab, the effort was considered necessary to successful performance of the electrical system.

Sneak circuits were electrical anomolies that would occur as a result of abnormal (unplanned) combinations of commands and switch/relay operations and timing and ambiguous labeling. They were not component failures/malfunctions.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 9 April 1971.

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12

Space engineers and astronauts studied Skylab Workshop storage facilities in a review at MSFC. Astronauts taking part performed Workshop activation procedures, reviewing each compartment's storage areas and running through deactivation procedures.

MSFC Skylab Office, PM-SL-SW-508-71, "Final Review Board Minutes of the Crew Compartment Storage Review," 7 May 1971.

13

NASA published a Skylab Launch Readiness and Delivery Schedule which moved the scheduled Skylab launch date from 1 November 1972 to 30 April 1973.

NASA Hq Schedule, 13 April 1971.

15

Proposed Skylab rescue mission profile requirements were:

- The trajectory planning for a rescue mission would be the same as the nominal Skylab mission.
- Nominal mission duration from launch to recovery would be limited to five days.
- The orbital assembly would maneuver to provide acquisition light support for the rescue CSM.
- The rescue CSM would be capable of rendezvous without very-high-frequency ranging.
- Landing and recovery would be planned for the primary landing area; transfer of the crew from the MDA to the CSM would be in shirt sleeves with no extravehicular activity.
- The KSC rescue launch response time would vary from 10 to 45½ days, depending on the transpired time into the normal checkout flow.

"Weekly Progress and Program Summary Report for the Administrator—Skylab Program," 15 April 1971.

16

Following the results of a review of Skylab windows by MSC, a presentation was made at MSFC. During the presentation, MSC made the following recommendations.

- Fracture mechanics analyses should be made of all annealed windows.
- Fused silica should be replaced by tempered glass in the OWS wardroom.
- Airlock module windows should be vented inside the cluster.
- The astronaut viewing port should be redesigned.
- All windows should be proof-tested.

Memorandum for record, W. H. Mann, MSFC, "MSC Presentation on Skylab Window Review," 5 May 1971.

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April
19 A meeting was held at McDonnell Douglas to discuss plans for the Skylab backup hardware. Representatives from NASA Hq, MSC, KSC, MSFC, McDonnell Douglas, and Martin Marietta attended. Initial plans were formulated for the flow and testing of backup hardware to meet a 10-month launch turnaround after Skylab 1, 2, or 3.

MSFC, "Weekly Activity Report," 29 April 1971.

23 MSC was reviewing the design of all Skylab pressure vessels associated with experiments/subsystems for which MSC had direct responsibility. The review would lead to a single listing of all hazardous pressure vessels, along with appropriate configuration, analysis, and test data that would allow evaluation from the fracture mechanics viewpoint.

Letter, Kenneth S. Kleinknecht, MSC, to Manager, Skylab Program, MSFC, "Skylab Pressure Vessels," 23 April 1971.

27 A technical design review on the Skylab fire extinguishers was held at the Southwest Research Institute. No major problems were encountered. The flight units would be changed before installation—around launch minus 60 days—to limit any possible emulsion degradations.

MSC, "Skylab Program Office Weekly Activity Report," 27 April 1971; "Weekly Progress and Program Summary for the Administrator—Skylab Program," 14 May 1971.

27–28 A review of the coolanol system of the AM was held at McDonnell Douglas. Representatives from KSC, MSFC, MSC, and NASA Hq attended. It was agreed that MSFC would implement a 100-percent government inspection of all coolanol line assemblies and installations; astronaut repair or tightening of nuts was not feasible, since less than 15 percent of the internal fittings were accessible; recommendations against the use of leak tracers would be made; additional surveys and reviews would be made of vendor facilities, requirements, and procedures.

MSFC, "Weekly Activity Report," 6 May 1971.

29 A Skylab rescue kit preliminary requirements review was held at MSC. It was determined that the rescue kit could be installed in one shift, that suits would be worn for reentry, and that the center couch would be ballasted for launch. Studies were being conducted to determine the feasibility of jettisoning disabled CSM from the axial port.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 7 May 1971.

May
1 After a simulated 144-day Skylab mission, the reaction control system engines were fired at the White Sands Test Facility, to deplete the propellant supply

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module in a backup deorbit propulsive mode. The firing was made without problems. Depletion of both oxidizer and fuel occurred at about the same time.

Letters, William C. Schneider, NASA Hq, to Associate Administrator for the Office of Manned Space Flight, "Skylab RCS Test Program at White Sands Test Facility," 5 May 1971; William C. Schneider to Kenneth S. Kleinknecht, MSC, 10 May 1971.

3

NASA Hq approved an external TV system for Skylab. The system would use experiment T027 (Apollo telescope mount contamination measurement) photometer extendable boom to extend a television camera and motorized lens system through either of the scientific airlocks in the Workshop. The addition of the camera on the T027 boom would permit observations of targets of scientific interest, Earth, extravehicular operations, and operations of various spacecraft assemblies. The previously baselined Skylab color television system would permit observation of experiments and crew activities and provide virtually unlimited internal coverage.

MSFC, "Skylab Program Manager's Monthly Review," 3 May 1971.

7

In the past, NASA policy was to release all air-to-ground voice communications to the news media in real time, or as close to real time as practicable. However, because of the long duration and the medical research aspects of the Skylab Program missions, deviations would be made to this policy to allow flight crews to speak privately with their families and on a regular daily basis with the Flight Surgeon.

Letters, Kenneth S. Kleinknecht, MSC, to Director, Skylab Program, "Private Air-to-Ground Voice Communication," 7 May 1971; William C. Schneider to Manager, Skylab Program, MSC, "Skylab Air-to-Ground Communications," 18 June 1971.

7 and 21

An atmospheric leak locator was developed by J. T. Sawyer, MSFC. The concept, which is based on vacuum sensing, was developed after Martin Marietta classified 120 potential atmospheric leak locations in the OWS, MDA, and AM due to such factors as cable penetrations. Martin Marietta submitted a study to MSFC that determined the adapters that would be required for the device to sense leakage at various types of cluster penetration points.

"Weekly Progress and Problem Summary Reports for the Administrator—Skylab Program," 7 May 1971 and 21 May 1971.

9

A full-scale flight hardware meteoroid shield deployment test was performed on the Workshop flight article. The shield did not deploy fully and took longer than nominal for the deployment. However, it was concluded that the deployment would have been successful if performed in orbit. All components of the shield had previously passed development tests.

MSFC, "Weekly Activity Report," 13 May 1971; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 14 May 1971.

1971 May 19 — A mission analysis simulation technique was designed to evaluate and optimize the Earth resources experiment package program. Factors influencing available opportunities such as orbital parameters, solar lighting at the target, and systems limitations were incorporated in the simulation and analyzed to determine their effect. The United States was considered as the prime target. Optimization for various mission parameters, such as orbital inclination, launch time, and launch date were included. A 50° inclined circular orbit at 435-km altitude was analyzed in depth.

NASA TM X-64598, E. H. Bauer and B. S. Perrine, Jr., MSFC, "An Evaluation of Earth Resources Observation Opportunities from an Orbiting Satellite," 19 May 1971.

21 — A discussion on Apollo-Skylab inflight contamination measurements was held with representatives from NASA Hq, MSC, and MSFC. Decisions were made to take the following actions:

- Apollo 15 would use available Apollo equipment for photographic coverage of liquid venting.
- Apollo 16 and 17 would examine existing capabilities for potential contributions to contamination knowledge. However, efforts for additional contamination instrumentation would be discontinued because of cost and launch schedule impact.

"Weekly Progress and Problem Summary Report for the Administrator—Skylab Program," 27 May 1971; letter, Leland F. Belew, MSFC, to Managers, Apollo Spacecraft Program and Skylab Program, MSC, "Apollo 15 Motion Camera Coverage of a Liquid Venting to Space," 5 April 1971; memorandum, William C. Schneider, NASA Hq, to NASA Directors of Apollo and Skylab Programs, "Apollo-Skylab Contamination Measurements," 17 May 1971; TWX, Leland F. Belew to John H. Disher, NASA Hq, Kenneth S. Kleinknecht, J. A. McDivitt, and R. W. Kubicki, MSC, "Contamination Measurements on Apollo," 13 May 1971.

25 — MSC initiated a plan for Principal Investigators of Skylab experiments to view Apollo 15, 16, or 17 mission operations. This would permit them to obtain necessary exposure to MSC operational procedures before initiation of the mission operations phase of Skylab.

Letter, Kenneth S. Kleinknecht, MSC, to William C. Schneider, 25 May 1971.

26 — An Orbital Workshop design and development status review was conducted at McDonnell Douglas. Incorporation of the cation absorber into the water feed system was discussed. The purpose of this absorber was to remove the metal ions released into the water by the iodine depletion reaction. Hydrogen and potassium exchange resins were tested. The potassium type was selected to minimize the acidity and corrosivity of the effluent. Final location of the absorber had not been definitely determined, but preliminary procedures for deactivation were established. Test results on iodine depletion in the OWS water system were also reviewed. These results supported an earlier view that the iodine

Activity at the McDonnell Douglas facility at Huntington Beach as work progressed on the Orbital Workshop flight unit.

depletion rate in the system could be dealt with satisfactorily. The onboard system would provide the capability of replacing the depleted iodine, if it became necessary, by reinjecting a concentrated iodine solution directly into the water tanks and mixing, sampling, and testing the resultant mixture.

1971 May

MSC, "Skylab Program Office Weekly Status Report," 16 June 1971.

An airlock module review of crew-station-related changes was held at McDonnell Douglas. Some subsystem changes were identified: one for McDonnell Douglas/MSFC on the AM tape recorder overloading the converters; another for MSFC to identify a configuration management method for intermodule trainer hardware.

26–27

MSC, "Skylab Program Office Weekly Activity Report," 4 June 1971.

Robert C. Hock was appointed Manager, KSC Apollo-Skylab Programs, succeeding Thomas W. Morgan. Morgan's reassignment as Vice Commander of the Air Force Space and Missile Systems Organization, Los Angeles, had been announced previously by the Air Force.

28

KSC Announcement, "Mr. Robert C. Hock Named Manager, Apollo-Skylab Programs, KSC," 28 May 1971; letter, Kurt H. Debus, KSC, to Robert R. Gilruth, MSC, 1 June 1971.

MSC published a document on the trajectory and attitude control sequence of events, data flow, and real-time decision logic for the manned Skylab launch

28

1971 May — phase aborts. Purpose was to ensure compatibility of all related MSC, other NASA Centers, and supporting contractor activities.

MSC Internal Note (MSC–04318), "Preliminary Manned Skylab Launch Abort Mission Techniques," 28 May 1971.

June 3 — The Medical Research and Operations Directorate at MSC ordered five U.S. Army self-contained, transportable, mobile units to be used as a mobile facility to support Skylab preflight medical operations and experiment requirements. The facility would be set up and activated at MSC to support Skylab preflight activities and would be flown to the recovery site for use on board the recovery ship to support the immediate postflight medical requirements.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 3 June 1971.

3–4 — Representatives from Ames Research Center, Arkon Scientific Laboratories, and MSC met at Ames to initiate action required to develop a carbon monoxide sensor for the Skylab Program. A two-phase program for developing the sensor was approved. The first phase was for a unit to be used during the Skylab medical experiments altitude test; the second was for flight and backup sensors for Skylab.

Memorandum for record, E. S. Harris and M. W. Lippitt, Jr., MSC, "Skylab Carbon Monoxide Sensor Coordination Meeting," 10 June 1971; letter, H. Mark, Ames Research Center, to Robert R. Gilruth, MSC, 21 July 1971.

4 — The OWS dynamic test article was offloaded from the barge *Orion* at MSFC where installation of strain gauges and other modifications necessary to support a structural test program were being made. The dynamic test article was shipped from MSC on 23 May following completion of the Phase I vibro-acoustic test program.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 27 May 1971; MSFC, "Weekly Activity Reports," 10 and 16 June 1971; MSFC, *Project Logistics Office Marine Operating Log*, 3 June 1971.

7 — The MDA dynamic test article was completed at Martin Marietta on 3 June, well ahead of the contractual delivery date. Following an acceptance review of the dynamic test article, it was flown by *Guppy* aircraft to MSC where it was prepared for stacking and testing.

"Skylab Program Engineering Weekly Status Report," 9 June 1971; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 21 May 1971; MSFC, "Weekly Activity Report," 10 June 1971.

6–7 — In a start toward building orbital space stations, the Soviet Union's manned *Soyuz 11* linked with the space laboratory *Salyut 1*, launched two weeks earlier,

1971 June

and three cosmonauts from *Soyuz 11* went aboard the Salyut. The combined craft formed a vehicle 18.2 m long, 3.6 m in diameter, and weighing 20.4 metric tons (22.5 U.S. tons). The Russian news agency Tass declared that "a Soviet manned orbital scientific station is functioning." The linkup climaxed a chase through space lasting more than 25 hours. *Salyut 1* was launched 19 April and *Soyuz 11* on 6 June for the 7 June linkup. The three cosmonauts aboard were Viktor Patsayev, Vladislav Volkov, and Georgy Dobrovolsky.

Associated Press, *Huntsville Times*, 7 June 1971, p. 1.

8

A Skylab weight teleconference was held with representatives from NASA Hq, KSC, MSFC, and MSC participating. During the conference, a weight control limit of 86 000 kg was imposed.

TWX, William C. Schneider, NASA Hq, to Leland F. Belew, MSFC, Kenneth S. Kleinknecht, MSC, and R. C. Hock, KSC, "Weights Telecon on June 8, 1971," 10 June 1971; "Skylab Program Engineering Weekly Status Report," 16 June 1971.

9

During a Manned Space Flight Management Council Meeting at MSFC, it was decided to retain a 10-month reaction time requirement for a backup Workshop launch. To accomplish this schedule, the backup OWS, MDA, AM, and payload shroud would be delivered to KSC upon completion of manufacture and manufacturing verification. Acceptance testing would be performed at KSC.

TWXs, William C. Schneider, NASA Hq, to Leland F. Belew, MSFC, Kenneth S. Kleinknecht, MSC, R. C. Hock, KSC, et al., "Skylab Workshop Backup Hardware," 23 June 1971; William C. Schneider to Leland F. Belew, Kenneth S. Kleinknecht, and R. C. Hock, "Skylab Workshop Backup Hardware," 7 July 1971.

14

MSC was requested to provide preliminary assessment of the technical feasibility of Earth resources technology satellite (ERTS) and EREP proposals and to support evaluation panels that were being organized to review ERTS and EREP proposals. Between 11 March and 14 June, MSC had evaluated 239 proposals and submitted reports on them to Headquarters.

Letters, Dale D. Myers, NASA Hq, to Robert R. Gilruth, MSC, 11 March 1971; Robert R. Gilruth to Dale D. Myers, 7 May 1971; J. M. DeNoyer, NASA Hq, to MSC Director of Science and Applications, "Additional Guidelines for OMSF Center Involvement in EREP Proposal Evaluation and Implementation," 3 June 1971; Robert R. Gilruth to Dale D. Myers, 14 June 1971; TWX, William C. Schneider, NASA Hq, to Skylab Program Managers, MSC and MSFC, 11 June 1971.

14–17

In an exchange of letters between MSFC and MSC, agreement was reached for the maximum use of MSC's existing facilities for MSFC's manned altitude chamber tests.

Letters, C. A. Berry, MSC, to G. D. Hopson, MSFC, 14 June 1971; W. R. Lucas, MSFC, to C. C. Kraft, Jr., MSC, 17 June 1971.

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June
16

John L. Disher, Deputy Director of the NASA Skylab Program, approved a configuration control board change which would provide the capability to switch control of the Skylab vehicle back to the instrument unit after the initial transfer to the Apollo telescope mount digital computer control. The current configuration would preclude a switchboard and prevent the use of the IU control system should problems arise during the first critical hours of active ATM DC control. Concern over the inability to make the switchback was constantly expressed by MSC because unexpected previously unidentifiable failures occurred during actual flight in every computing system used—e.g., lunar module guidance computer, command computer IU, real-time computer complex, and the Gemini computer.

Letters, Kenneth S. Kleinknecht, MSC, to William C. Schneider, NASA Hq, "ATMDC to IU Switchback Capability," 25 March 1971; William C. Schneider to Skylab Program Managers, MSC and MSFC, "ATMDC to IU Switchback," 13 April 1971; memorandum, F. S. Roberts, NASA Hq, to Dist., "Minutes of Level I CCB Meeting," 16 June 1973; memorandum for file, John H. Disher, NASA Hq, "ATMDC to IU Switchback," 17 June 1971.

17

The Office of the Comptroller General prepared a report on the analysis of estimated cost changes for the Skylab Program. The system used by NASA to cost the program, as well as the rationale for the changes, was contained in the report.

Letter, E. B. Staats, U.S. Comptroller General, to J. C. Fletcher, NASA Hq, 17 June 1971.

17

An optical efficiency problem was reported in the Naval Research Laboratory ATM flight instrument at Ball Brothers Research Corporation. A failure analysis review attended by experts from Bausch & Lomb, Ft. Belvoir, Virginia, Goddard Space Flight Center, Naval Research Laboratory, and MSC concluded that failure was due to the "Purple Plague," an aluminum coating overcoating on gold. An alert would be released by Goddard for dissemination throughout NASA and the Air Force to preclude further use of this particular method of coating optics.

"Weekly Progress and Problem Summaries for the Administrator—Skylab Program," 27 May and 17 June 1971; MSFC, "Weekly Activity Reports," 26 May and 3 June 1971.

17

Vibration testing was successfully completed on the ATM vibration unit at MSFC. Following testing, the unit was prepared for shipment to MSC where it would be used in the payload assembly vibroacoustic test.

MSFC, "Skylab Program Office Weekly Activity Report," 22 June 1971.

24

A study indicated that if the Skylab airlock could not be used for a normal extravehicular activity, contingency modes were possible. One would be a

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June

two-man EVA to the ATM using oxygen, water, and electrical umbilical connections in the structural transition section of the airlock. Another possibility would be a one-man EVA from the CM. Selection of a contingency EVA mode would depend on the failure that prevented the nominal operation.

W. W. Hough, "Contingency EVA on Skylab, Case 620," Bellcomm Study, 24 June 1971.

25

Authority to proceed on the calibration rocket program was given by NASA to determine the amount of degradation of Harvard College Observatory and Naval Research Laboratory experiment data to be expected during the Skylab mission. Degradation due to decrease in mirror reflectivity, changes in photographic film sensitivity, gamma and background fogging, and aging of filters and gratings could cause misinterpretation of the solar data. To improve data evaluation, sounding rocket launchings during the mission were proposed, to carry instruments similar to those in the ATM and calibrated to a known light source. These instruments would be pointed to some of the same solar areas as were the ATM and the returned data would be compared to the ATM data.

Letter, William C. Schneider, NASA Hq, to Kenneth S. Kleinknecht, MSC, et al., 25 June 1971.

June 29–

July 1

The astronaut life support assembly first-article configuration inspection was conducted at AiResearch Division, Garrett Corporation. No major problem areas that could affect the hardware design were noted. First-article acceptance testing was completed. The only problem of significance that had appeared during the testing was excessive leakage of the high-pressure oxygen regulator in the secondary oxygen package. AiResearch replaced the regulator before completion of acceptance testing on this unit. The astronaut life support assembly appeared to be in satisfactory condition.

MSC, "Skylab Program Office Weekly Activity Report," 6 July 1971.

June

30

George M. Low, NASA Deputy Administrator, expressed regrets over the deaths of three cosmonauts, Georgy Dobrovolsky, Vladislav Volkov, and Viktor Patsayev. Low speculated that Russia's worst space tragedy was caused by failure of the spacecraft. He said that he did not anticipate any changes in the Skylab Program because of the accident. The accident occurred as the three cosmonauts were returning to Earth in *Soyuz 11* from a record of nearly 24 days in space in the world's first manned orbital space laboratory.

NASA Activities, 15 July 1971, p. 107.

July

7

The Spacecraft Acoustic Test Laboratory of the Vibration and Acoustic Test Facility at MSC was modified on a temporary basis to accommodate specific test requirements for the Orbital Workshop and payload assembly. However, because

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of the exceptional quality of the Facility's performance, it would appear desirable to maintain the Facility in an operational status to provide acoustical test facilities for the Space Shuttle and space station base programs.

Letter, Robert R. Gilruth, MSC, to Dale D. Myers, NASA Hq, 7 July 1971.

8–9

The final Skylab subsystem review was conducted in Washington. These reviews, which began 17 November 1970, were an in-depth look at the Skylab subsystems by NASA top management. NASA Hq set the requirement for these following the *Apollo 13* Accident Review Board recommendation to ensure that the Skylab mission had adequate safety and reliability in its development. All formal action items from the previous reviews were closed out at the meeting.

"Skylab Subsystem Review Action Item Response," 8 July 1971; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 15 July 1971; letter, A. C. Bond, MSC, to Deputy Associate Administrator of Manned Space Flight, "Skylab Subsystem Review, July 8 and 9, 1971," 29 July 1971.

14

An Orbital Workshop wardroom window design review was held at McDonnell Douglas. McDonnell Douglas presented a design concept for a tempered-glass protective interior shield for the wardroom window. MSFC representatives discussed the possibility of adding a pressure plate to protect the window from internal damage and to limit the delta pressure across the glazings.

MSC, "Skylab Program Office Weekly Report," 23 July 1971.

Work is shown in progress as the fixed airlock payload shroud flight unit nose cone is mounted following installation of electrical, ordnance, and air conditioning components at the McDonnell Douglas plant, Huntington Beach.

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July
15

Representatives from NASA Hq and MSFC attended a briefing at the Goddard Space Flight Center on contamination problems in unmanned spacecraft. Causes and cures for inflight contamination effects such as unwanted light scattering, ice formation, and high-voltage corona were discussed. The discussions were based on experiences with the Orbiting Astronomical Observatory, Orbiting Solar Observatory, and Nimbus programs. Suggestions for preventing similar contamination problems on Skylab were discussed.

"Weekly Progress and Problem Summary for the Administrator—Skylab Program," 15 July 1971; letter, Leland F. Belew, MSFC, to Managers of Apollo and Skylab Programs, MSC, "Background and Justification for Apollo 16 Skylab Data Request," 10 September 1971.

16

The official Skylab launch and mission designations were announced:

Acceptable for use outside NASA and for nonoperational NASA use	*Acceptable for operational use*	
	Launch	*Mission*
Workshop launch	SL–1	SL–1/SL–2
First manned visit	SL–2	
Second manned visit	SL–3	SL–3
Third manned visit	SL–4	SL–4

Memoranda, Dale D. Myers, NASA Hq, to Assistant Executive Secretary, "Naming of the Skylab Missions," 7 May 1971; George M. Low, NASA Hq, to Associate Administrator for Manned Space Flight, "Naming of Skylab Missions," 18 May 1971; Dale D. Myers to George M. Low, "Naming of Skylab Missions," 7 June 1971; William C. Schneider, NASA Hq, to Public Affairs Officer for Manned Space Flight, "Naming of Skylab Missions," 16 July 1971; letter, William C. Schneider to Dist., "Skylab Launch and Mission Designations," 1 July 1971.

16

NASA approved the award to The Boeing Company of a contract modification for systems engineering and integration work on the Saturn V launch vehicle. The modification would extend Boeing's integration work through 31 December 1972. The basic contract began in September 1964. Included in the modification was work on requirements for Saturn V vehicles that would launch the remaining Apollo lunar exploration missions (Apollo 15, 16, and 17) and the Skylab Program's Saturn Workshop. Boeing's systems engineering and integration work at the time of this modification award included requirements and documentation for presettings for onboard computers that determined launch events, propellant loadings for all three vehicle stages, vehicle structural integrity, expected heating environments, range safety, tracking and communication data, and postflight reconstruction of launch data. Boeing was also MSFC's contractor for manufacture and testing of the first (S–IC) stage of the Saturn V.

MSFC Contract Office MOD 492 to Contract NAS 8–4608, Schedule 11, 16 July 1971.

1971 July 20 — An airlock module management meeting was held at McDonnell Douglas. Electrical fabrication and coolant loop design problems were in the process of being solved. A seven-day workweek was being continued to meet schedules.

"Skylab Program Engineering Weekly Status Report," 27 July 1971; MSFC, "Weekly Activity Report," 28 July 1971; "Weekly Progress and Problem Summary," 29 July 1971.

27 — A study was made to determine if the *Super Guppy* aircraft was capable of flying the combined airlock-multiple docking adapter and ground support equipment from St. Louis to KSC. The study revealed that the *Guppy* capabilities were exceeded by over 1800 kg. McDonnell Douglas and MSFC were considering shipment by barge. This would, however, delay delivery by 10 days.

"Weekly Progress and Problem Summary," 29 July 1971; "Skylab Program Engineering Weekly Status Report," 27 July 1971.

27 — The U.S. Geological Survey submitted to NASA a formal investigative proposal defining studies to be accomplished using photography acquired with the Earth terrain camera on Skylab missions. MSC and MSFC would review the proposal to ensure compatibility of the requirements as outlined.

Letter, William C. Schneider, NASA Hq, to Kenneth S. Kleinknecht, MSC, 27 July 1971.

August 2 — In response to specific queries concerning the Skylab biomedical experiments program, the following response was made:

- Flight schedules and long lead times would make it virtually impossible for an additional investigator to meet schedule requirements, if the flight hardware required an interface with the spacecraft.
- Self-contained biomedical experiments that did not require such an interface would still be considered.
- Biomedical experiment proposals should be submitted to Director of Life Sciences, NASA Office of Manned Space Flight, Washington, DC.
- Proposals should be submitted on NASA Form 1346, "Experiment Proposal for Manned Space Flight."

Letters, Walter F. Mondale, U.S. Senate, to Robert R. Gilruth, MSC, 15 July 1971; Robert R. Gilruth to Walter F. Mondale, 2 August 1971.

5 — MSC surveyed equipment and experiments aboard Apollo 16 and 17 which might make contamination measurements useful to Skylab. In addition to command module cameras, Apollo 16 would carry a mass spectrometer and Apollo 17 would carry a far-ultraviolet spectrometer and an infrared scanning radiometer. These might be able to provide contamination data.

"Skylab Program Office Weekly Progress and Problem Summary," 5 August 1971.

1971

August

6

George M. Low recommended:

- Periodic examination of deviations from planned test flow for all flight hardware to ensure that only a minimum number of deviations from the use of flight hardware in tests be permitted.
- Periodic review of the changes requested by users (flight crew and flight operations personnel) that were turned down, to ensure that when viewed as a total package the "turn downs" were still valid.
- Periodic meetings with flight crews in which they could express their overall views concerning the Skylab Program.

Recommendations were made following a program discussion with astronauts.

Memorandum for the record, George M. Low, NASA Hq, "Skylab Discussion with Pete Conrad," 6 August 1971.

The acoustics portion of the vibroacoustic test at MSC began on the Skylab payload assembly which consisted of the airlock, multiple docking adapter, and payload shroud test articles.

MSC, *Schedules and Status Summary Report,* 31 August 1971.

11

Proposals were made at an OSSA-sponsored meeting at Goddard Space Flight Center on methods for managing ERTS and EREP programs. One proposal was that both ERTS and EREP contracts be managed by NASA Centers on a regional basis because of the scope and magnitude of the programs. However, MSC felt that, since the overall program management and operational responsibility belonged to MSC, it should be responsible for all the major contracts associated with EREP.

Letters, Robert R. Gilruth, MSC, to Dale D. Myers, NASA Hq, 11 August 1971; Dale D. Myers to Robert R. Gilruth, 22 September 1971.

11

An in-resident Orbital Workshop test team was established at McDonnell Douglas, Huntington Beach, by MSFC. The team's purpose was to provide timely programmatic and technical interface with, and response to, the contractor in matters relating to hardware design, development, qualification, manufacture, and checkout. William K. Simmons, Jr., MSFC Orbital Workshop Project Manager, was appointed leader of the team whose members represented the various MSFC technical disciplines. Because of the significant number of MSC operational and hardware interfaces with the Workshop, MSC assigned James C. Shows and Richard H. Truly as members of the team.

Letter, Leland F. Belew, MSFC, to MDAC–W, 11 August 1971; George C. Marshall Space Flight Center Charter, MM1142.2, "Orbital Workshop Task Team," 11 August 1971.

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August

The American Institute of Aeronautics and Astronautics devoted a major portion of the June issue of their journal to articles on the Skylab Program.

19

Letter, William C. Schneider, NASA Hq, to Members of the Skylab Scientific Investigations Team, 19 August 1971.

23

Concern was expressed that the material to be used for the top of food trays in the Skylab wardroom was still not selected six weeks after a decision was made to change the material. Subsequently, it was reported that a material, polyamide, had been selected by food tray contractor Whirlpool Corporation and that efforts were underway to procure the material.

MSC, Skylab Program Office Manager's Staff Meeting, K. S. Kleinknecht, MSC, 23 August 1971.

27

Missions still under consideration for the immediate post-Skylab period included the following:

- An independent CSM mission for Earth observations.
- An independent CSM mission for rendezvous and docking with the U.S.S.R. Salyut spacecraft.
- A combination of the above.
- Use of the Skylab backup CSM to conduct a cooperative docking with the Salyut vehicle and thereafter carry out a fourth visit to Skylab. This mission would occur approximately 18 months after the launch of Skylab.
- A second Skylab supported by two 90-day CSMs and a rescue vehicle.

Letter, P. E. Culbertson, NASA Hq, to R. A. Berglund, MSC, 27 August 1971.

30

A study was conducted at MSFC on the effects of various pitch attitudes at the time of the Skylab payload shroud jettison on the possibility that the shroud would collide with the Skylab at a later date. Based on the study, a 10-degree attitude error constraint on a 90-degree-pitch (nose down) shroud separation attitude was recommended to preclude such a collision.

Letter, B. S. Perrine, Jr., MSFC, to Dist., "Effect of the Skylab/Shroud Recontact Analysis," 30 August 1971.

31

A review of the Orbital Workshop waste management subsystem was held at McDonnell Douglas. Recent design changes to the urine sample tray were accepted. A test was established, at the request of MSC, which would subject the production system hardware to flight conditions for a period of 56 days.

MSFC, "Weekly Activity Report," 1 September 1971.

31

A Skylab food subsystem management plan was agreed to by Charles A. Berry, M.D., MSC Director of Medical Research and Operations; Maxime A. Faget,

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August

MSC Director of Engineering and Development; and Kenneth S. Kleinknecht, MSC Skylab Program Manager. In the plan, the Medical Research and Operations Directorate would provide the technical management for the Government-contractor team in planning, development, procurement, and integration of the food subsystem, including ancillary equipment, within constraints and guidelines of the Skylab Program.

MSCM 8010, *Program Management Guide*, 31 August 1971.

September

8–30

Cold weather environment tests began at the Climatic Laboratory, Eglin Air Force Base, Florida, on the performance of the Skylab command module postlanding and recovery systems. Because Skylab flights would be launched on a 50-degree inclination, the spacecraft would pass over regions of the Earth considerably colder than experienced before. Tests would determine the cold weather limitations of the crew and command module should an emergency or major system malfunction force the spacecraft to land in these areas.

MSC News Release 71–70, 17 September 1971; Kenneth S. Kleinknecht, MSC, "Manned Space Flight Program Status Review," 6 October 1971.

13

Skylab crewmen would wear soft suits on reentry for both regular and rescue missions in order to provide stowage space for maximum data return. All available stowage space in the command module would be needed for film, experiment samples and specimens, flight data files, life support equipment, and supplies.

Note, William C. Schneider, NASA Hq, to Dale D. Myers, NASA Hq, 13 September 1971.

13–17

A multiple docking adapter crew compartment storage review was held at Martin Marietta. Representatives from NASA Hq, KSC, MSFC, MSC, and Martin Marietta attended. It was anticipated that three or four review item discrepancies, which would cause only minor impact, would be submitted on the MDA.

Immediately following the MDA crew compartment stowage review, the MDA one-g trainer final acceptance review was held.

MSFC, "Weekly Activity Report," 21 September 1971; "Minutes of the MDA 1–G Trainer Pre-Shipment Acceptance Review," 15–17 September 1971.

14

An Apollo telescope mount final acceptance review for the ATM one-g and zero-g trainers was held at MSFC. Representatives from MSC, MSFC, Martin Marietta, and Brown Engineering Company attended. The trainers were scheduled for shipment, with an arrival date at MSC of 12 October.

Letter, Leland F. Belew, MSFC, to Manager, Skylab Program, MSC, "ATM Trainer Acceptance," 22 October 1971; "Minutes of Skylab Acceptance MSC/MSFC," A. R. Morse, MSFC, and T. U. McElmurry, MSC, 14 September 1971.

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September

15 James C. Fletcher, NASA Administrator, described planned Skylab mission medical research in an address before the Utah State Medical Association: " . . . we will be looking far with a strong impact on the future of manned space flight during the remainder of this century." Major questions as yet unanswered after Gemini and Apollo flights were the causes of moderate loss of weight by astronauts early in flight, moderate cardiovascular deconditioning, moderate loss of exercise capacity, and minimal loss of bone density. Medical results from Gemini and Apollo missions had shown: "1. There were no major surprises. 2. As of now, we see no reason why man cannot live and work effectively in space for a long period of time. 3. Man seems to adapt to space flight more easily than he does to Earth's environment after returning from space."

James C. Fletcher, NASA Hq, address before the Utah State Medical Association, 15 September 1971.

15 An inter-Center agreement was approved by Skylab Program Managers Kenneth S. Kleinknecht (MSC), Robert C. Hock (KSC), and Leland F. Belew (MSFC) covering the use and control of acceptance checkout equipment-spacecraft for the checkout of Skylab 1 payloads.

KSC Management Instruction 1058.2A, 15 September 1971.

23 A contract for the construction of an Apollo telescope mount clean room at KSC was awarded to the Holloway Corporation.

KSC, "Weekly Progress Report," 1 October 1971.

23 A policy letter which identified the essential roles and responsibilities of Skylab Center organizations and Principal Investigators in the development of Skylab experiments was published by NASA Hq.

Letter, William C. Schneider to Skylab Program Managers, MSFC, MSC, and KSC, and Directors, Ames Research Center and LaRC, "Skylab Policy Relative to the Relationship and Responsibilities Between Skylab Principal Investigators and Skylab Center Organizations," 23 September 1971; "Skylab Program Engineering Weekly Status Report," 29 September 1971.

24 The Skylab payload shroud (nose cone) was accepted by MSFC from McDonnell Douglas Astronautics Company. The shroud, 18.2 m long and 6.7 m in diameter, weighed almost 12 000 kg and was the first major piece of Skylab hardware to be delivered to NASA.

NASA Hq News Release 71–182, 22 September 1971; MSFC, "Schedules and Status Summary," 30 September 1971.

27 NASA announced assignment of Robert O. Aller, Manager of Space Station Operations, Space Station Task Force of Office of Manned Space Flight, to the

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September

Skylab Program Office as Director of Operations. Aller would be responsible for coordination and development of operationally related program and mission planning activities.

NASA Hq, "Weekly Bulletin."

September 29–October 1

The crew compartment stowage review for the airlock module was held at the McDonnell Douglas facility in St. Louis. Several crewmen attended the review.

MSFC, "Skylab Weekly Activity Report," 5 October 1971.

30

Corrective measures were being incorporated into the Apollo telescope mount as a result of the prototype thermal/vacuum test being performed in the MSC Space Environmental Simulation Laboratory September–December 1971. A number of anomalies unidentified in previous component system or subsystem tests were identified. Unlocated, the anomalies could have had serious impacts on ATM orbital operations.

Letter, Eugene H. Cagle, MSFC, to James C. McLane, Jr., MSC, 7 March 1972.

October 5

An OWS shower design review was completed at MSFC. Representatives from NASA Hq, MSC, KSC, MSFC, and McDonnell Douglas attended. Although the design appeared acceptable, programmatic problems such as stowage, program requirements, and the McDonnell Douglas installation schedule were evidenced.

MSFC, "Weekly Activity Report," 14 October 1971; letter, Leland F. Belew, MSFC, to Director, Skylab Program, NASA Hq, "Skylab Whole Body Shower," 19 October 1971.

5–6

During an Advanced Applications flight experiments (AAFE) review at Langley, Principal Investigators gave interim status reports on experiments already in the AAFE Program. Representatives from NASA, other Government agencies, and participating universities and industries attended. Reports were divided into the following areas: Earth-resources survey; communications; meteorology; navigation/traffic control; applications technology; and geodesy, Earth physics, and physical oceanography.

"Interim Progress Reports AAFE P.I. Review," 5–6 October 1971.

6–18

Training mockups of several components of the Skylab spacecraft arrived at MSC. The Orbital Workshop and the Apollo telescope mount arrived aboard the NASA barge *Orion*. The shipment also included the multiple docking adapter exterior shell and a portion of the airlock module mockup. The AM one-g trainer had arrived previously at MSC on a contingent of six trucks. The trainers and hardware were scheduled for use by MSC in training prospective Skylab crewmen for missions.

1971

MSFC, "Skylab Weekly Activity Report," 26 October 1971; MSC, "Weekly Activity Report," 15 October 1971.

October

8 Personnel and equipment from other countries were being utilized in the Skylab Program. K. Pounds (United Kingdom), M. Oda (Japan), and M. C. Pande (India) were endorsed as ground-based observers in connection with the ATM. Proposals for participation in Earth resources were anticipated from Canada, Argentina, Chile, India, Iran, Japan, Thailand, Belgium, France, Germany, Greece, Switzerland, and the United Kingdom.

Numerous small articles of equipment such as zippers and lenses were obtained from England, Switzerland, Germany, and Monaco. Cameras were obtained from Sweden and Japan. Glass for the multispectral photography window came from Japan. Rockets used for ATM calibration flights were obtained from Canada.

Memorandum, William C. Schneider, NASA Hq, to R. Littlefield, NASA Hq, "International Contributions to Skylab Program," 8 October 1971.

8 Over 700 requests to participate in EREP and ERTS experiments were received by NASA; 280 required EREP data or both ERTS and EREP data. Of these, 150 were selected for inclusion in an EREP mission compatibility study being conducted at MSC. A list of the tentative investigations included proposers from 28 states and 12 countries. About one-third of the investigators were from Federal or state governments, one-third from universities, and one-third from industry and foreign governments.

Memorandum, Dale D. Myers, NASA Hq, to the Administrator, "Earth Resources Experiment Package (EREP) Investigation," 8 October 1971.

8 A formal certification program was being instituted at TRW and McDonnell Douglas to ensure that the technicians, inspectors, and engineers involved in setting adjustments and clearances, installing ordnance, or stacking the array after each deployment in the development and qualification of the solar array system was properly certified. Backup personnel would also be trained and certified to ensure a continuity of expertise.

Letter, William C. Schneider, NASA Hq, to Skylab Program Manager, MSFC, "Solar Array System," 8 October 1971.

20 To provide protection against system failure from the SL–1 launch through the first 56-day mission, it would be necessary to retain prelaunch preparation and launch capability through completion of the second manned mission. The elapsed time from the SL–1 launch through the second manned mission would be about 5 months.

Memorandum for record, John H. Disher, NASA Hq, 20 October 1971.

1971
November

ERTS and EREP investigations were assigned to Goddard Space Flight Center and MSC for negotiations and award of contracts by NASA Hq. In general, the ERTS investigations were assigned to Goddard, the EREP investigations to MSC. At the same time, general guidelines were established for all ERTS/EREP proposals. 1

Letter, Dale D. Myers and J. E. Naugle, NASA Hq, to Robert R. Gilruth, MSC, "Guidelines for ERTS and Skylab EREP Investigations," 1 November 1971.

2–4

A Skylab rescue vehicle preliminary design review was held at North American Rockwell. The anticipated reentry mode for the rescue vehicle would be with the crewmen suited, thus providing additional return stowage volume for program-critical items. North American would define the return volume and loading available, while MSC would identify the returnable program-critical items. The rescue command and service modules would be designed for both suited and unsuited reentry and for axial and radial docking. The rescue kit would include provisions for the return of five men.

MSC, "Skylab Program Office Weekly Activity Report," 12 November 1971.

10

The Skylab menu, in addition to being the most palatable menu carried into space, was also designed to meet the requirements and objectives of an important series of medical investigations. Whirlpool Corporation was under contract to produce the approximately 20 000 man-meal equivalents for the Skylab Program. The food system was designed to maintain a calorie level of between 2000 and 2800 calories and to provide the minimum dietary allowances of protein, fat, carbohydrate, minerals, and vitamins recommended by the National Academy of Sciences.

MSC Project Document 72-2049, 10 November 1971; MSC News Release 72-155; memorandum, C. A. Berry, MSC, to Chairman, Facilities Review Board, "Interim Food Bonded Stowage Facility," 14 October 1971.

10–12

A test and checkout requirements specifications documents review was conducted at MSFC.

- The test requirements for the OWS, AM, MDA, and test and checkout requirements specifications documents were agreed to.
- An approach to define the all-systems test sequence was tentatively agreed to by MSFC and KSC.
- OWS, AM/MDA, and integrated test and checkout requirements specifications documents would be republished, with distribution scheduled for mid-December 1971.

"Skylab Program Engineering Weekly Status Report," 17 November 1971.

11

An acceptance review of the ATM experiment training hardware was held at MSFC. MSC representatives participated in the review. Following the review,

1971
November

the hardware was shipped to MSC for crew familiarization in preparation for a multiple docking adapter crew compartment fit and function review.

MSFC, "Weekly Activity Report," 10 November 1971.

11

A test readiness review for the payload assembly high-force vibration test was held at MSC. The review board concluded that the facility-test article was ready for test. The main objective of the test would be verification of the payload shroud primary and secondary structural integrity.

MSC, "Skylab Program Office Weekly Activity Report," 19 November 1971.

15

NASA Hq announced formation of a Manned Space Flight Team to conduct a midterm review of the Skylab Program. The objectives were to assess the validity of the Skylab Program plan in terms of scope of work planned and its relation to schedules and resources; validate the runout cost with a new estimate of resources required to completion; and make management and technical recommendations as required. The Team was scheduled to complete its work in late December 1971. A report would be made to the Manned Space Flight Management Council in January 1972.

Letter, Dale D. Myers, NASA Hq, to Robert R. Gilruth, MSC, 15 November 1971; memorandum, William C. Schneider, NASA Hq, to Kenneth S. Kleinknecht, MSC, Leland F. Belew and R. G. Smith, MSFC, and R. C. Hock, KSC, "Skylab Mid-Term Review Task Team," 24 November 1971; letter, William C. Schneider to Kenneth S. Kleinknecht, 24 November 1971; plan, J. P. Field, Jr., NASA Hq, "Skylab Mid-Term Review Plan," 23 November 1971.

23

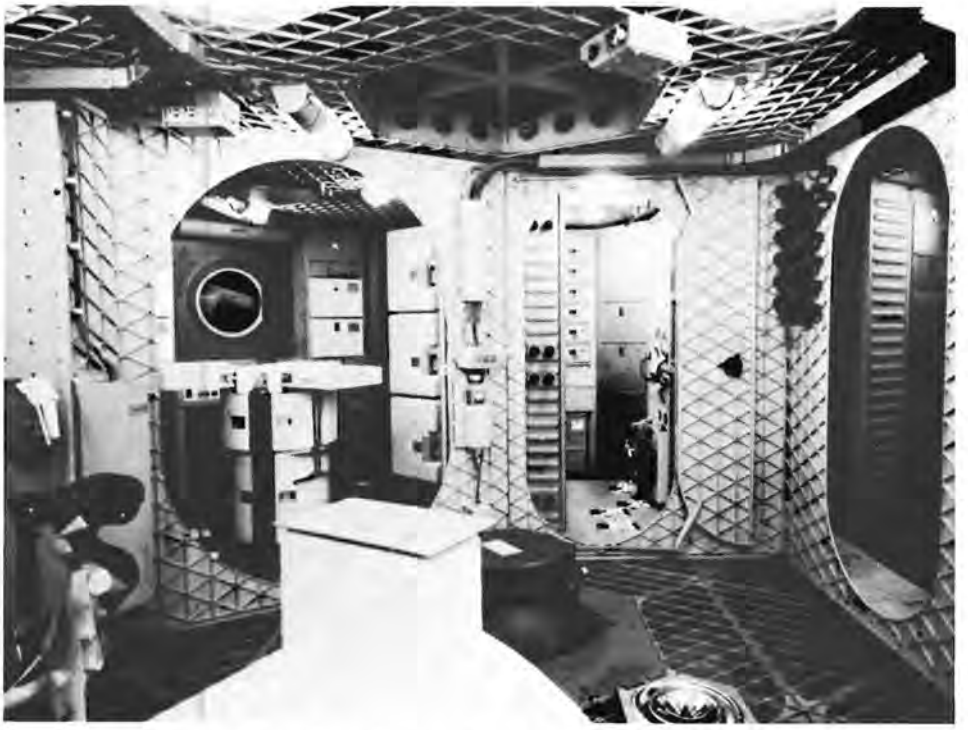
The MDA/EREP systems integration testing was completed at Martin Marietta. The testing included all individual sensors, EREP systems functional verification tests, and EREP simulated data pass verification tests. Test data were under evaluation.

MSC, "Skylab Program Office Weekly Activity Report," 3 December 1971; MSFC, "Weekly Activity Report," 29 November 1971.

26

MSFC awarded Chrysler's Space Division a contract modification for additional work on Saturn IB launch vehicle booster stages. The contract extension would run through 31 January 1974. The additional work was to refurbish four S-IB booster stages that would be used in the Skylab Program in 1973. The fourth vehicle (SA-209) would be assigned as a backup. All four stages had been in storage for several years. The major portion of the work would be removing the stages from storage, preparing them for delivery to KSC, and providing launch support to them throughout the Skylab launch readiness period, which would end in early 1974. Most of the work would be done at the Michoud Assembly Facility in New Orleans, but some work would be done at MSFC.

MSFC Contracts Office MOD MICH 465 to Contract NAS 8-4016, Schedule I, 26 November 1971.



The overall interior of the crew quarters area in the Skylab High Fidelity mockup, at McDonnell Douglas, Huntington Beach, where the Workshop was fabricated. The sleep compartment is at the right, waste management compartment in the center, and the wardroom at left.

1971

November

29

MSFC amended a contract with General Electric Company to allow modifications for support of the Skylab Program. The contract change would be completed by 1 April 1972. The new work included the manufacture and delivery of modification kits for the reconfiguration of ground support equipment at KSC's Launch Complex 39 to provide a Saturn IB launch capability for Skylab.

MSFC Contracts Office, MOD 49 and MOD 51 to Contract NAS 8–25155, 29 November 1971.

November 30–

December 1

A customer acceptance readiness review of the OWS food heating tray was held at Whirlpool Corporation, Benton Harbor, Michigan. No significant problems were encountered. Previous problems of heat transfer and possible flammability were solved.

MSC, "Skylab Program Office Weekly Activity Report," 3 and 10 December 1971.

December

6

NASA Hq established procedures for documenting the existence of significant technical problems in flight hardware and associated ground support equipment and for providing technical support for their resolution for each Skylab mission from initiation of integrated systems tests through mission completion.

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December

Skylab Program Directive No. 56, "Technical Support for Resolving Significant Technical Problems From Initiation of Integrated System Test Through Mission Completion," 6 December 1971.

7–10

A Skylab MDA crew compartment fit and function review was held at Martin Marietta to familiarize astronauts with MDA equipment and storage problems. The review was conducted in four parts: a bench review, a vertical upper platform review, a vertical lower platform review, and a horizontal configuration review.

MSFC, "Weekly Activity Report," 8 December 1971; MSC, "Skylab Program Office Weekly Activity Report," 17 December 1971; letter, William C. Schneider, NASA Hq, to Managers, Skylab Program, MSC and MSFC, Manager, Apollo-Skylab Program, KSC, "Verification of Crew Equipment Interfaces," 29 December 1971; memorandum, R. O. Aller, NASA Hq, to Director, Skylab Program, "Contractor Crew Compartment Fit and Function Tests," 17 December 1971.

8

Apollo experience was utilized in the design and development of the Skylab water system which consisted of

- Ten 272-kg storage tanks
- A chiller and three water dispensers for drinking water
- A heater and two water dispensers for food reconstitution
- A heater and water dispenser for personal hygiene
- A portable water container and fixed and flexible plumbing with quick disconnect fittings

Memorandum, William C. Schneider, NASA Hq, to NASA Deputy Administrator, "Apollo Lunar Module Water System Problems as Related to the Design of the Skylab Water System," 8 December 1971.

9

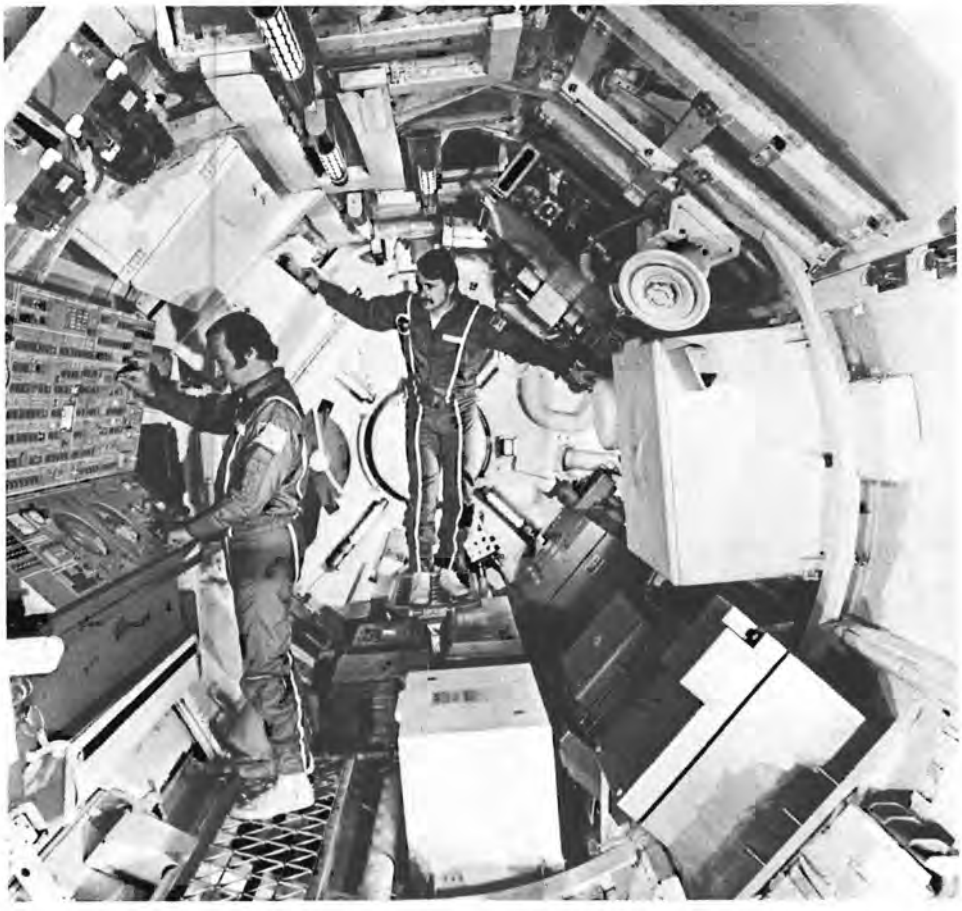
NASA Hq defined the responsibility for preparation and coordination of test procedures which involved crew participation in factory module test and checkout operations. Essentially, this required that not later than 12 weeks prior to anticipated testing MSC should provide a crew integration plan and negotiation should take place between MSFC and MSC on the degree of crew participation in the test and checkout operations.

Appendix A to Skylab Program Directive No. 26, "Intercenter Responsibilities for Support and Preparation of KSC Test and Checkout Plans and Procedures, and Coordination of Factory Test Procedures with Crew Involvement," 9 December 1971.

15

An MSFC–MSC agreement was approved detailing responsibilities for Skylab flight crew training in the neutral buoyancy simulator at MSFC. The agreement was approved by Kenneth S. Kleinknecht, MSC Skylab Program Manager, and Leland F. Belew, MSFC Skylab Program Manager. Charles A. Berry, Maxime A. Faget, and Donald K. Slayton, all of MSC, concurred.

MSCM 8010, *Program Management Guide*, 15 December 1971.



At top, Stefanie Smith, associate engineer in crew systems at Martin Marietta's Denver facility, shows equipment location to astronaut William R. Pogue during a NASA acceptance checkout of the multiple docking adapter. Above, two Martin engineers simulate astronaut activities in a full-scale training mockup of the multiple docking adapter before the unit was shipped to MSC for astronaut training.

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15 The prototype of the Skylab ATM was returned to MSFC from MSC aboard the *Super Guppy* aircraft. At MSFC, the ATM was placed in a clean room in the Quality and Reliability Assurance Laboratory for a system checkout. It would next undergo vibration testing in the Astronautics Laboratory and then would be refurbished to serve as a backup for the flight model. While at MSC, the ATM prototype, which was assembled at MSFC, had been subjected to space conditions in a large chamber used for testing the Apollo spacecraft.

MSFC Project Logistics Office, *Flight Operating Log*, 15 December 1971.

17 A committee was established to conduct an operational readiness inspection of the Skylab medical experiments altitude test facility. The MSC Crew Systems Division's 6-m-diameter altitude chamber was modified to perform the test. The readiness inspection would serve to certify the operational readiness of the facility for the June 1972 manned testing.

Memorandum, Robert R. Gilruth, MSC, to Dist., "Operational Readiness Inspection of the MSC Skylab Medical Experiments Altitude Test Facility," 17 December 1971.

17–21 MSFC accepted the flight multiple docking adapter from Martin Marietta, Denver. It was then flown by *Super Guppy* to McDonnell Douglas in St. Louis, where it would be mated to the airlock module.

NASA News Release 71–241, "Skylab Docking Unit Accepted," 17 December 1971; MSFC Project Logistics Office, *Flight Operating Log*, 17 December 1971.

23 Discussions on the feasibility and the possible benefits and problems pertaining to the use and benefits of an amateur radio transmitter-receiver by the Skylab crew in their off-duty time were conducted over the past several months. Based on the discussions, it was concluded that the disadvantages outweighed the advantages of its installation and use.

Letters, P. I. Klein, AMSAT, to William C. Schneider, NASA Hq, "Skylarc Mission for Skylab-A," 11 September 1971; William C. Schneider to Managers, Skylab Program, MSFC and MSC, "Amateur Radio on Skylab," 2 December 1971; Kenneth S. Kleinknecht, MSC, to Director, Skylab Program, "Skylab Amateur Radio Communications," 14 December 1971; Leland F. Belew, MSFC, to Director, Skylab Program, "Amateur Radio on Skylab," 23 December 1971; notes, Dale D. Myers, NASA Hq, to William C. Schneider, "Ham Radio Activity for Skylab," 20 November 1971; William C. Schneider to Dale D. Myers, "Ham Radio Activity for Skylab," 30 November 1971.

During the Month The Skylab Program was reviewed by a Skylab midterm task team. Among the findings were the following: Although there was little margin left in the schedule for contingencies, there were no known reasons why the launch date of 30 April 1973 could not be met. Planned resources were sufficient to support the program on the established schedule. A comprehensive and systematic program of reviews, tests, and analyses had been performed to produce high confidence in reliable and

After acceptance by MSFC, the multiple docking adapter flight article was readied for shipment from Martin Marietta's Denver facility to the McDonnell Douglas plant at St. Louis to be mated with the airlock module.

safe technical performance. A greater number of formal detailed program level plans and inter-Center agreements were required in Skylab than in earlier programs because of complexities of technical organizational interfaces. Limitations on travel funds created problems. There was some concern regarding the Earth resources experiment package where costs exceeded the original plan. Technical problems remained, and Principal Investigators had not been selected.

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Letters, William C. Schneider, NASA Hq, to Kenneth S. Kleinknecht, Christopher C. Kraft, Jr., and S. A. Sjoberg, MSC, "Skylab Mid-Term Review Task Team Program Directors Summary Working Notes," 28 February 1972; draft, Kenneth S. Kleinknecht, MSC, "Skylab Program Mid-Term Review," 1 December 1971; "Skylab Mid-Term Review Workshop Project Problem Summary," December 1971; "Skylab Mid-Term Review Workshop Status Schedule Status," December 1971.

The National Science Teachers Association had received more than 15 000 applications for participation in the NASA Skylab Student Project, NASA announced. The Association was managing the project to stimulate interest in science and technology by promoting participation by U.S. students in grades 9 to 12 in experiments, demonstrations, or activities to be performed by astronauts during 1973 Skylab missions. NASA would select 25 proposals on the basis of compatibility with Skylab requirements. Selectees and their teachers would attend a Skylab Educational Conference and award presentations at KSC at Skylab launch time. MSFC would build the required hardware in consultation with students. Regional and national selectees would be announced in April.

1972

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3

NASA News Release 72-1, 3 January 1972.

NASA Hq issued a revised directive providing work authorization for the Skylab Program to the Centers. The directive provided flight numbers and objectives, assigned the launch vehicles and command and service modules to be used, and designated the launch complexes to be utilized. It also listed the controlled milestones for Skylab and planned launch dates. The milestones included delivery of major flight, test, and training hardware; delivery of other major items such as ground support equipment; key reviews; completion of key tests; facility operational readiness; and launch readiness. The planned launch dates were: 30 April

3

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1973 for SL–1; 1 May 1973 for SL–2; 30 July 1973 for SL–3; and 28 October 1973 for SL–4.

Skylab Program Directive No. 4F, Director, Skylab Program, to Dist., "Skylab Program Work Authorization," 3 January 1972.

4

The OWS water chiller which had been redesigned was undergoing tests at AiResearch Corporation. The reason for the redesign was that nickel ion generation exceeded that allowable in the specifications. At an OWS water system review on 20 November 1971, the probability of exceeding the nickel ion concentration was discussed, and a decision was made not to consider an increase in the allowable nickel concentration. In September 1971 McDonnell Douglas tests indicated that considerably higher numbers of nickel ions were being released from the water chiller.

During many water subsystem meetings, nickel ion generation of the entire OWS water system, not just the chiller, had been considered a major problem. It was indicated that with the exception of the water system components installed in the wardroom table (including the chiller), the OWS water system ion generation would be controlled with an ion exchange resin, and the redesign of the chiller would correct the problem. This would permit the water supply to meet specifications throughout Skylab 1, 2, 3, and 4.

Letter, Leland F. Belew, MSFC, to Kenneth S. Kleinknecht, MSC, "Skylab Drinking Water Nickel Content," 4 January 1972.

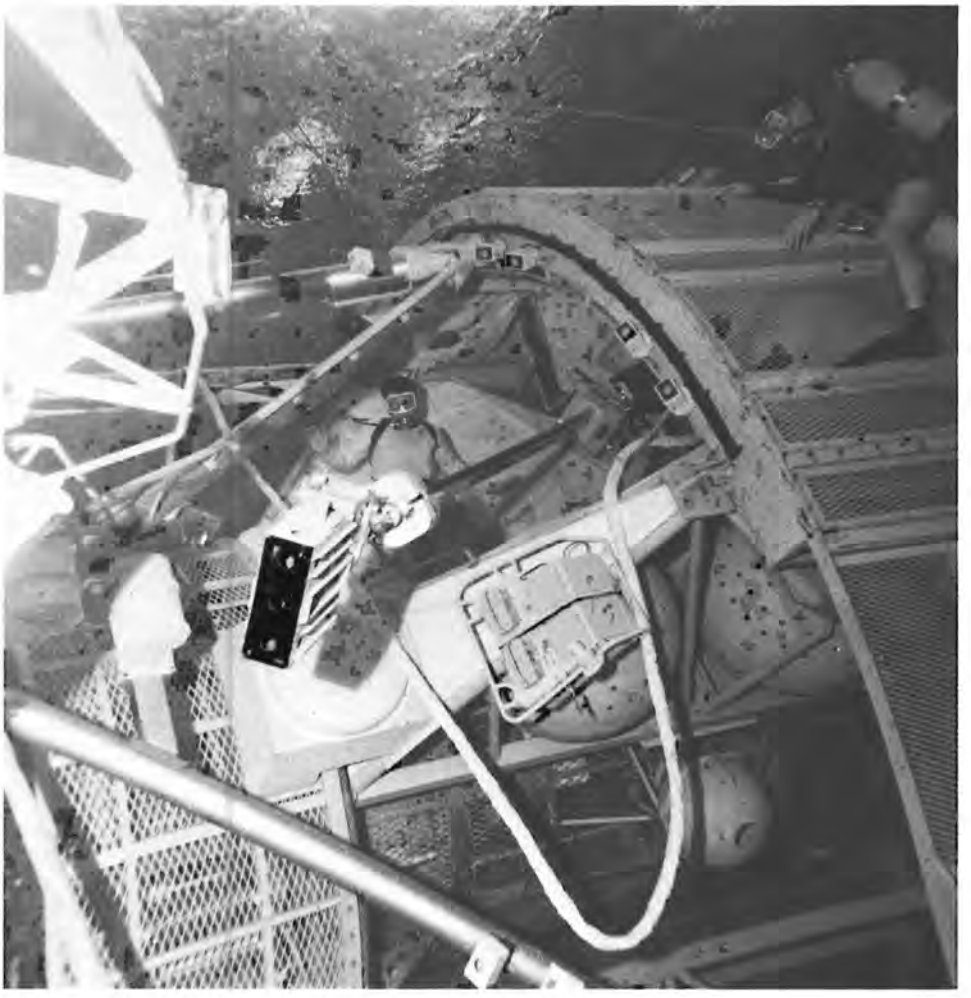
6

Skylab Managers William C. Schneider (NASA Hq), Robert C. Hock (KSC), Leland F. Belew (MSFC), and Kenneth S. Kleinknecht (MSC) met at MSFC to resolve the problems associated with the OWS test operations at McDonnell Douglas. Kleinknecht had previously expressed concern about the difficulties in getting the first article—both OWS and experiments—through factory acceptance; the effects of a tight OWS checkout operation; and the need for a multi-Center (MSFC–KSC–MSC) contractor team to complete the OWS factory checkout, integration of Government-furnished equipment and other stowage, and verification of man and machine interfaces with astronauts and their support people. Actions taken at the meeting ensured a tightening of discipline and resulted in progress in eliminating the areas of concern.

Letter, Kenneth S. Kleinknecht to Leland F. Belew *et al.*, 3 January 1972; memorandum for record, William C. Schneider, 11 January 1972; letter, William C. Schneider to Dale D. Myers, Associate Administrator for Manned Space Flight, 14 February 1972; memorandum, Dale D. Myers to George M. Low, Deputy Administrator, 16 February 1972; letter, Kenneth S. Kleinknecht to Leland F. Belew, 12 April 1972; memorandum, William C. Schneider to Dale D. Myers, 4 May 1972.

11

MSC proposed that SL–1 should be flown at an altitude of 435 km and that the orbit should be controlled by removing any insertion dispersions and drag effects with burns of the SL–2 CSM reaction control system after that spacecraft had



Activities at MSFC on 5 January 1972 during a simulation of film retrieval from the Apollo telescope mount in the MSFC Neutral Buoyancy Tank.

rendezvoused and docked with SL–1. A controlled, repeating orbit would satisfy requirements common to many Earth resources experiment proposals. In addition, multiple passes over fixed targets would increase the probability of successfully obtaining data which otherwise might be lost because of cloud cover or equipment malfunctions. It was estimated, after a study lasting several months, that implementation of a controlled orbit would enhance the probability of success of such experiments by between 25 and 50 percent. The study had also shown that the proposal was feasible with regard to hardware, operations, and the crew. **1972** **January**

Letter, Kenneth S. Kleinknecht, MSC, to Manager, Skylab Program, MSFC, "Controlled Repeating Orbit for Skylab," 11 January 1972.

The NASA Manned Space Flight Management Council agreed to retain the currently planned Skylab launch-readiness date of 30 April 1973 and to assign no **11–12**

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more experiments or other efforts requiring changes in hardware, flight plans, or training.

MSF Management Council Minutes, 31 January 1972.

12 Representatives of MSC and MSFC discussed the needs for Skylab flight communications systems/ground performance operations data and the possibility of compatibility testing to develop data. Among the decisions reached were the following: flight and ground systems performance and compatibility testing would be conducted using the MSC Manned Space Flight Network station and test facilities; MSC and MSFC would jointly develop the necessary test plans; both Centers would participate in the test and the data evaluation; and MSC and MSFC would jointly review existing systems performance data and current test plans against operational data requirements.

Letter, S. R. Reinartz, MSFC, to C. E. Charlesworth, MSC, 18 January 1972.

13 Leland F. Belew reported that the airlock module flight article systems tests were nearly completed. The AM had been moved from the test area on 10 January to begin the mating operation with the ATM deployment assembly and the fixed airlock shroud. The multiple docking adapter had completed shell leakage tests and was undergoing radiator leakage tests. Special illumination tests and TV camera/video recorder tests began 10 January at McDonnell Douglas. Personnel from MSC, MSFC, and NASA Hq were observing the testing.

TWX, Leland F. Belew, MSFC, to William C. Schneider, NASA Hq, 13 January 1972.

18 NASA Hq approved addition of a video tape recorder to the Skylab TV system. A presentation had been given at MSFC to Dale D. Myers, Associate Administrator for Manned Space Flight, and William C. Schneider, NASA Skylab Program Director. The addition of the recorder would provide increased flexibility and the capability for more TV coverage. Playback would be controlled from the ground.

Configuration Change Board Directive 800–72–0111, 10 February 1972.

19 A Skylab crew news conference, with prime and backup crewmen, was held at MSC. Astronaut Charles Conrad, Jr., said preparations were on schedule for an April 1973 launch. Contractor checkouts and tests of hardware were expected to be completed for delivery to KSC in July. Skylab would carry some 20 000 pieces of stowed equipment on board to provide life support for nine men for 140 days. "So it all goes up at one time, and we've got a great deal of work to do, not only to learn how to operate this vehicle but also all the experiments in it. It became apparent that we could not be 100-percent cross-trained as we had been in

Apollo, so we've . . . defined some areas for each guy to become expert in. . . . That allowed us to balance out the training hours. Right now . . . we have some 2000 training hours per man defined. We've been working on the basic training for the past year . . . [and] our training hardware . . . [is] going to be available to us for training . . . about February 1." The commander would have overall responsibility for the mission and would be a command and service modules expert. The science pilot would be expert in all medical equipment and in the Apollo telescope mount and its associated hardware. The pilot would be expert in Orbital Workshop systems and electrical systems. Remaining experiments would be divided among crew members according to availability and choice.

1972 January

Prime crewmen for the first mission were Charles Conrad, Jr., Joseph P. Kerwin, and Paul J. Weitz; second mission, Alan L. Bean, Owen K. Garriott, and Jack R. Lousma; third mission, Gerald P. Carr, Edward G. Gibson, and William R. Pogue. Backup crews were Russell L. Schweickart, F. Story Musgrave, and Bruce McCandless II, first mission; Vance D. Brand, William B. Lenoir, and Don L. Lind, both second and third missions. Kerwin, Garriott, Gibson, Musgrave, and Lenoir were scientist astronauts; the other Skylab crew members were pilot astronauts.

NASA News Release 72–12, 19 January 1972; Test Skylab Crew Press Conference, 19 January 1972.

20

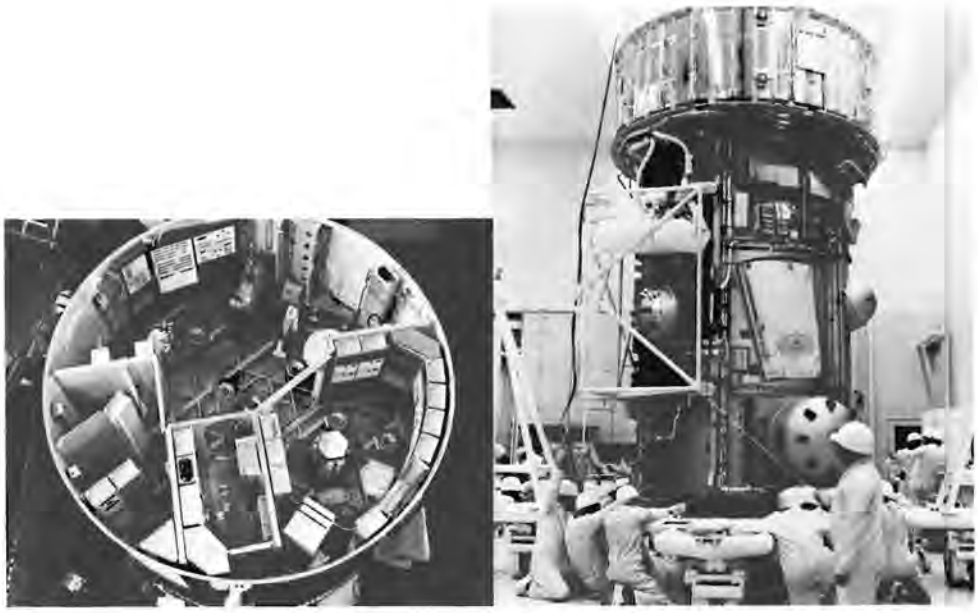
An ad hoc Earth resources experiment package investigations office was established at MSC. O. Glenn Smith was given the additional duty assignment as Manager of the EREP investigations office. The office was assigned responsibility for conducting and managing the contracting phase of Skylab EREP investigations.

MSC Announcement 72–10, 20 January 1972.

27

Skylab Program Director William C. Schneider told the Skylab Managers at MSFC, MSC, and KSC that "at the last meeting of the Management Council it became apparent that the Council was not aware of our recent activities and current planning for contamination control on Skylab." Schneider said that a presentation had been scheduled to update the Council on the subject for the meeting to be held in Washington 7–8 March. He asked that MSFC assume the lead role in developing and delivering the presentation, with MSC and KSC assisting. The following areas were to be covered: MSFC—background, requirements, cluster hardware, and ground test program; MSC—command and service modules, Earth resources experiments package, and operational plans; and KSC—prelaunch contamination control plans.

Letter, William C. Schneider to MSFC, MSC and KSC, "Contamination Presentation for Management Council," 27 January 1972.



Left, the crew quarters area of the Skylab Orbital Workshop training model, which had been shipped from MSFC to MSC to be used for Skylab mission crew in flight simulation exercises. Right, the airlock module flight article is shown in a clean room at the McDonnell Douglas facility at St. Louis before being mated with the multiple docking adapter. The airlock module provided a pressurized passageway between the multiple docking adapter and the Orbital Workshop.

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28

Trace contamination tests were scheduled to be made on the OWS during transportation to KSC. MSC would provide a toxicologist to accompany the OWS to supervise sampling, storage of exposed charcoal, and return of the charcoal to the Analytical Research Laboratories for analysis. Analytical Research Laboratories, under contract to MSC, had completed an AM/MDA trace contaminant analysis that would be compared with that of the OWS. A carbon monoxide analyzer would also be provided by MSC. A carbon monoxide monitor was in the development stage for potential use on the OWS. The test would be conducted during the Skylab medical experiment altitude tests; if these tests indicated that carbon monoxide was being generated within Skylab, a flight monitor would be furnished.

Letter, Kenneth S. Kleinknecht, MSC, to Leland F. Belew, MSFC, "Trace Contaminant Diagnostics on the OWS (Orbital Workshop)," 28 January 1972.

February

1

MSFC and MSC completed a Memorandum of Agreement with the National Oceanic and Atmospheric Administration (NOAA) for support contracts for Skylab. The contract would include both ATM and crew radiation monitoring support in the areas concerning the solar network and Mission Control Center Operations. ATM support performed by the National Oceanic and Atmospheric Administration as required by MSFC and MSC would be contracted for by MSC, with that Center providing the technical monitor for the contract and

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technical direction during the mission simulation and inflight operations phases. Requirements would include a variety of solar data on current solar conditions and predicted solar conditions. These data would ensure effective scheduling of ATM experiments and ATM data for Principal Investigators in the form of photographs, line drawings, etc., to support their detailed analyses of solar activity.

The crew radiation monitoring support would be contracted by MSC, with all technical direction provided by the MSC technical monitor. These activities would include management and operation of facilities for acquisition and transmission of solar data for crew radiation monitoring during simulations and inflight operations; a 24-hour solar watch and photographic record; and monitoring of current and future radiation environments to provide an assessment of the biological effect on the flight crew.

Letter, Leland F. Belew, MSFC, to MSC, Manager, Skylab Program, "National Oceanic & Atmospheric Administration (NOAA) Support Contract for Skylab," 1 February 1972, with memorandum of agreement, "National Oceanic and Atmospheric Administration Support to the Skylab Program," signed by Leland F. Belew and Kenneth S. Kleinknecht, MSC, undated.

1

NASA invited research scientists to submit proposals for Skylab experiments studying use of weightlessness. Experiments would use weightlessness in space to develop improved techniques for preparing biological materials and for studying crystal growth, solidification, and other aspects of nonorganic substances. One invitation was for electrophoresis—motion of charged particles through fluid while under the influence of an electrical field. Use of this technique on ground was hampered by effects of heat convection in fluid and sedimentation. A second invitation was for investigation of solidification effects, crystal growth, and other phenomena in weightless materials and close observation of them as they cooled and solidified. First experiments could be flown on Skylab missions begininng in 1973.

NASA News Release 72–22, 1 February 1972.

3

The Apollo telescope mount flight unit was being readied for a three-month, post-manufacturing checkout at MSFC. The ATM would be moved in May from the Quality and Reliability Assurance Laboratory to the Astronautics Laboratory for vibration tests and would be delivered to MSC 1 June for thermal and vacuum tests. The ATM would be launched on the first Skylab mission in 1973.

MSFC News Release 72–8; MSC News Release 72–32, 3 February 1972.

4

Contamination control, a continuing problem in the space program, was the subject of a letter from Skylab Director William C. Schneider to MSFC, MSC, and KSC Skylab Program Managers. He pointed out that this problem had received considerable attention, particularly in two areas: (1) cleanliness of major modules during manufacture and before launch; and (2) contamination control of the

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cluster during orbital operations, particularly of the man-related induced environment.

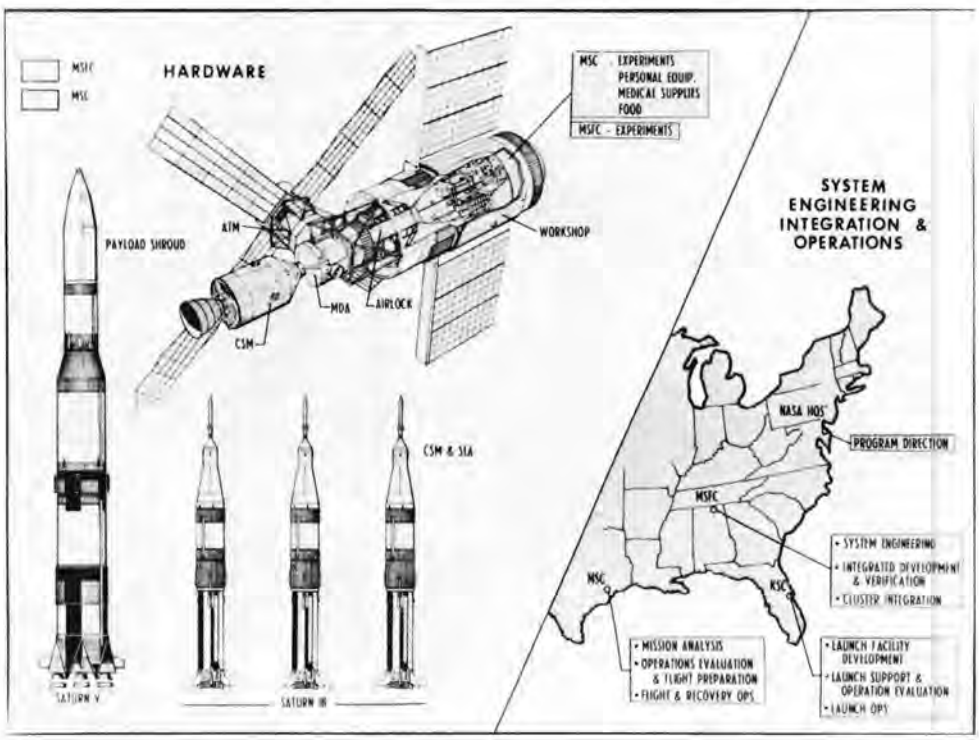
Schneider said, ". . . the anomalous behavior of two experiments on *Apollo 15* substantiates the need for efforts of the foregoing nature and indicates to me the need for increased emphasis on contamination aspects of Skylab experiments. . . ."

He added that a special effort should be directed toward assessment and elimination of contamination possibilities in Skylab experiments to increase confidence in the ability of all experiments to function successfully. Schneider considered it necessary that all experiments be critically reviewed for susceptibility to malfunction from contamination either in the experiment itself or in its operating environment. He further felt that a contamination "audit" of the manufacturing, transportation, and installation procedures used for each experiment should be conducted; the experiment cleanliness status should be determined; and acceptable (and realistic) contamination tolerance levels for experiment operation should be established.

Schneider suggested that those objectives were identical to those of the Skylab systems operational compatibility review and would provide an appropriate and timely mechanism to accomplish the audit.

Letter, William C. Schneider, NASA Hq, to MSFC, MSC, and KSC, "Contamination 'Audit' of Skylab Experiments," 4 February 1972.

Skylab management responsibilities.



1972
February
14

MSC developed a Skylab flight management team plan that provided for coordinated management guidance for sustained mission periods, was flexible, and was capable of adjusting to varying mission and management situations. The proposed team would be composed of NASA management officials having primary responsibility for the overall conduct of flight: the Skylab Program Director; the MSC, KSC, and MSFC Skylab Program Offices; the Director of Flight Operations; and the Director of Flight Crew Operations. The NASA Skylab Program Director or his designee, who would be at MSC during the eight-month mission period, would serve as the senior Headquarters official at the Mission Control Center, chairing the flight management team meetings and coordinating decisions with other Headquarters' offices to ensure that their requirements were met.

Letter, Christopher C. Kraft, Jr., MSC, to Dale D. Myers, NASA Hq, 14 February 1972.

15

William C. Schneider (NASA Hq) issued a directive that listed the directorates within the NASA Hq Skylab Program Office and spelled out the specific responsibilities of each. The Skylab organization was composed of directorates for project integration; program budget and control; reliability, quality, and safety; engineering; and operations.

Skylab Program Directive No. 57, "Functions and Responsibilities of the Headquarters Skylab Program Office," 15 February 1972.

15

Evaluation of events and redesign resulting from the May 1971 OWS–1 meteoroid shield deployment test indicated that a successful "mechanical separation and deployment" must be demonstrated prior to shipment of the flight article to KSC. This retest would verify flight readiness of redesigned shield mechanisms and would be considered a vital part of the OWS–1 acceptance test. A pin-release panel would be used for this purpose after appropriate "walk-through" procedures were exercised and prior to the planned "ordnance deployment."

All three of these activities were to be performed at McDonnell Douglas prior to shipment of the flight article from Huntington Beach, and after arrival at KSC. "Walk-through" was defined as a simple verification that no mechanical binding of any linkage would occur upon installation of the meteoroid shield. "Mechanical separation and deployment" was defined as a hands-off automatic deployment, with the shield rigged to less than flight loads, and a test that could be performed repeatedly without panel replacement. "Ordnance deployment" would represent the ultimate deployment verification. A separate ordnance panel with primary and backup expandable tubes would be required, and the deployment would be fully automatic and remotely controlled.

Letters, William K. Simmons, Jr., MSFC, to F. J. Sanders, McDonnell Douglas, "Orbital Workshop Meteoroid Shield Development," 15 February 1972; Karl L. Heimburg, MSFC, to L. F. Belew, MSFC, "Orbital Workshop and Backup OWS Meteoroid Deployment Verification Test Recommendations," 4 February 1972.

1972

February

18 Vibration testing began on the Apollo telescope mount prototype at MSFC. After vibration testing, the prototype would be disassembled and refurbished. It would then become the backup ATM flight unit.

MSFC, "Skylab Program Office Weekly Activity Report," 22 February 1972.

22 NASA Skylab Program Director William C. Schneider outlined the program's progress in testimony during the House Committee on Science and Astronautics' Subcommittee on Manned Space Flight hearings on NASA's Fiscal Year 1973 authorization bill: "During the coming fiscal year testing and checkout will be completed and operation of Skylab will have started. Within 2 years, the first Skylab . . . will have become part of history, having contributed new knowledge in many fields."

Skylab offered "an earth observation capability never before available" to U.S. manned spacecraft. During the eight-month mission, Skylab would fly over the entire United States, except Alaska, much of Europe, all of Africa, Australia, and China, and almost all of South America—covering 75 percent of Earth's surface and passing over each point every five days. By the end of 1971, 288 investigations requiring Skylab data had been submitted—249 U.S. and 39 foreign. Of these, 164 had been identified for further study. Skylab was the "first manned space flight program designed specifically to carry activities and equipment explicitly aimed at improving man's life on earth. It will contribute significantly to the increase of knowledge of pure science and is also an experimental space station; a forerunner of permanent space stations of the future." Earth-oriented sensors would test technology for synoptic surveys of many environmental and ecological factors and give preliminary data for management of ecological systems. Solar and astronomical observations and other science experiments would expand knowledge of the solar system, universe, and near-Earth space. Biomedical experiments would inform how man's well being and ability to function were affected by living in space.

U.S. Congress, House, Subcommittee on Manned Space Flight of the Committee on Science and Astronautics, *1973 NASA Authorization: Hearings on H.R. 12824*, 92d Cong., 2d sess., Feb.–March 1972, pp. 168, 176, 179–180.

25 MSC sent letters to approximately 160 potential EREP investigators to obtain clarification and supplemental information on the experiments. From the information, MSC would make recommendations to NASA Hq regarding the overall size of the EREP investigation program, as well as specific investigations and supporting rationale.

Letter, Christopher C. Kraft, Jr., MSC, to Charles W. Mathews, NASA Hq, 25 February 1972.

28 Concern about crew exercise during Skylab led to a proposed crew exercise program for quantitating the amount and level of personal exercise performed by the crewmen during the 30 minutes a day set aside for personal exercise.

Letter, Christopher C. Kraft, Jr., MSC, to Dale D. Myers, NASA Hq, 28 February 1972.

1972

February

March

A Skylab stowage hardware review was held at MSFC. Plans for the stowage of flight crew equipment were presented by MSFC, MSC, and KSC. Factory close-out stowage and long-term stowage without retest were established as acceptable ground rules. Maximum practical factory flight stowage would reduce the testing and stowage efforts at KSC. Crew verification of stowage hardware would be accomplished during systems test or formal crew compartment fit and function reviews at the manufacturers and KSC. 1

Letter, William C. Schneider, NASA Hq, to Managers, Skylab Program, MSFC and MSC, and Manager, Apollo-Skylab Programs, KSC, "Skylab Stowage Hardware," 20 March 1972.

The AM/MDA flight units were hardmated at McDonnell Douglas, St. Louis. The units would remain mated through checkout, delivery to KSC, launch, and mission. 5

MSFC, "Skylab Program Office Weekly Activity Report," 7 March 1972.

The NASA Skylab Program Office approved the formation of a Scientific Airlock Working Group, designating MSC the lead Center, with full support from MSFC. Organization of the working group had been discussed at a scientific AM/Principal Investigator meeting at MSC 3 February and again during a T025 experiment (coronagraph contamination measurements) telephone conference 28 February. As approved, MSC would appoint a chairman and MSFC a cochairman. The group would define and optimize flight operation requirements and would assist in defining the joint operation requirements of experiments in which data from one instrument complemented data obtained from a second or third instrument. Meetings would be held as appropriate, but at regular intervals. The chairman and cochairman would coordinate the activities of the working group with their appropriate Center elements. 6

TWX, William C. Schneider, NASA Hq, to Kenneth S. Kleinknecht, MSC, 6 March 1972.

The Skylab rescue mission was a definite NASA commitment. The hardware, procedures, documentation, and training would need to be available immediately after the launch of Skylab 2 for a potential rescue mission. To accomplish this requirement, the rescue mission would be treated as a separate mission in the Skylab Program. The rescue mission would be established as a standing agenda item for major boards and panels, and its status would be reviewed on a regular basis with other missions. 7

Memorandum, Kenneth S. Kleinknecht, MSC, to Dist., "Skylab Rescue Mission (SL-R)," 7 March 1972.

1972
March
13

While the CSM was docked with the OWS, the systems would generally be powered down except for the communication and thermal control systems. The thermal control system, which was expanded by additional thermostat controlled heaters, would maintain temperatures above the freezing point for components, propellants, and propellant lines. While docked to the OWS, one side of the CSM would be in sunlight, the other in the shade. Insulation and a heat reflecting thermal control paint were added to the side that would be exposed to sunlight; the heaters would help in controlling the temperature on the shaded side. Temperatures on the cold side of the spacecraft were expected to approach 200 K (−100°F).

North American Rockwell News Release SP–10, "Skylab Program Apollo Command/Service Modules," 13 March 1972.

13

Efforts required for the development of long-lead-time software items were initiated in the postmanufacturing checkout of the backup Skylab. Directives were being issued for development of the test and checkout requirements specification document, which would be the first milestone required in the development of any acceptance checkout equipment software. An acceptance checkout equipment software requirements document would then be developed from the test and checkout specification document. It was estimated that for a backup OWS/AM/MDA to meet the launch turnaround time of 10 months, acceptance checkout equipment would probably be required to be ready in May 1973.

Letters, Kenneth S. Kleinknecht, MSC, to Leland F. Belew, NASA Hq, 25 February 1972; Leland F. Belew to Kenneth S. Kleinknecht, 13 March 1972.

17

An inter-Center agreement that defined the MSC–MSFC–KSC responsibilities in integrating flight crew equipment into KSC tests, checkout, and launch activities was approved by Skylab Program Managers Robert C. Hock (KSC), Leland F. Belew (MSFC), Kenneth S. Kleinknecht (MSC), and James A. McDivitt, also of MSC. The agreement defined flight crew equipment as Government-furnished equipment which would be stowed or carried by the flight crew into the spacecraft.

MSCM 8010, *Program Management Guide*, 17 March 1972; KSC Management Issuance 1050.2/AA, Ch. 2.

20

A personal hygiene task team, established for the purpose of reviewing all personal hygiene activities within the Skylab Program with regard to their medical adequacies and effectiveness, completed the review. The system was found to be acceptable. However, the team recommended that a stick deodorant, an item in the individual personal hygiene kits, be deleted because of its outgassing and flammability problems.

Memorandum, R. S. Johnston, MSC, to Director, MSC, and Manager, Skylab Program, MSC, "MR&OD Review of Skylab Personal Hygiene Equipment," 20 March 1972.

1972
March
21

NASA announced opportunities to fly new materials science and manufacturing experiments in space. Proposals would be received no later than 30 March. Tentative plans called for the proposals to be evaluated and recommendations for their selection or rejection made by 1 May. Experiments recommended for Skylab would then be submitted to the Manned Space Flight Experiments Board for final evaluation in mid-May. A directive for implementation of the selected experiments would be issued during the first week in June.

Letter, Dale D. Myers, NASA Hq, to Christopher C. Kraft, Jr., MSC, 21 March 1972.

22

MSC initiated a series of planning meetings for the Skylab extravehicular activities. Meetings would be held at MSC on the fourth Thursday of each month with representatives from MSC, MSFC, McDonnell Douglas, and Martin Marietta. The purpose of the meetings would be to establish and coordinate Skylab EVA operational requirements and constraints, review EVA hardware and verify its operational suitability, obtain an agreement on recommended flight activities and mission guidelines, identify and resolve operational problem areas, and compile comments on EVA crew procedures and operational planning.

Letters, Kenneth S. Kleinknecht, MSC, to Leland F. Belew, MSFC, 15 February 1972; Leland F. Belew to Kenneth S. Kleinknecht, 22 March 1972.

27–28

Preliminary design reviews on the Skylab video tape recorder were held at MSC and MSFC. The most significant items discussed were flammability and outgassing, capability for recording Earth resources experiments package data, and interleaving the audio with the video. MSFC agreed to furnish an old video tape recorder engineering model for use in flammability and outgassing tests.

TWX, Leland F. Belew, MSFC, to Kenneth S. Kleinknecht, MSC, 5 April 1972.

April
5

A Skylab medical experiments altitude test (SMEAT) operations management committee was established to review progress of the test during the test period, assess real-time problems as they occurred, track open problems and corrective actions, approve and direct changes in test protocol or policy, release progress reports, meet with news media, and review and approve the daily report to the Director, MSC.

SMEAT, a ground-based simulation test, was intended primarily to obtain and evaluate baseline medical data on the medical experiments scheduled for Skylab, including studies of the cardiovascular system, the expenditure of energy to do measured work, and food and nutritional investigations. The test crew of three astronauts, R. L. Crippen, W. E. Thornton, and K. J. Bobko, would also engage in a full schedule of activities of work, eating, leisure, recreation, and sleep comparable to the Skylab schedule during their 56 days in the 6-m-diameter test chamber designed to simulate the Skylab OWS atmosphere. The test was scheduled to begin 26 July 1972.

1972

April

Memorandum for record, R. S. Johnston, MSC, 24 April 1972; SMEAT Press Conference, MSC, 23 June 1972, MSC News Releases 72-135, 23 June 1972, and 72-170, 2 August 1972; newsletter, William C. Schneider, NASA Hq, to Dist., "Skylab Program News," 31 May 1972; letter, R. S. Johnston to Principal Investigators, "Skylab Medical Experiment Newsletter," 7 April 1972.

6 NASA and the National Science Teachers Association announced selection of 25 finalists in a Skylab Student Project to propose flight experiments and demonstrations for performance aboard Skylab in 1973. NASA had announced the selection of the Association for management and operation of the Skylab Student Project in September 1971. Purpose of the project was to stimulate interest in science and technology by directly involving students in space research.

Since the project's inception, more than 15 000 applications for participation had been received from throughout the United States and overseas. Finalists' proposals had been selected from these entries. The project, which had been initiated in the spring of 1971 by the NASA Administrator, involved students in grades 9 to 13.

Letters, William C. Schneider, NASA Hq, to Leland F. Belew, MSFC, Kenneth S. Kleinknecht, MSC, Thomas W. Morgan, KSC, "Skylab Educational Program," 3 May 1971; William C. Schneider to Leland F. Belew, "Skylab Student Project," 2 November 1971; Dale D. Myers, NASA Hq, to Robert R. Gilruth, MSC, "Skylab Student Project," 16 November 1971; memoranda, Dale D. Myers to the NASA Administrator, "High School Student Participation in the Skylab Missions," 18 August 1971; B. P. Brown, NASA Hq, to Dist., "Minutes Skylab Educational Program Team Meeting," 14 July 1971; William C. Schneider to Directors of Life Sciences, Physics, Astronomy, and Earth Observation Programs, "Review of Proposed Skylab Student Project Investigations," 17 and 21 March 1972; NASA News Releases 71-189, 28 September 1971; 72-1, 3 January 1972; and 72-71, 6 April 1972; TWX, William C. Schneider to Leland F. Belew, Kenneth S. Kleinknecht, and Thomas W. Morgan, "Skylab Student Project Final Selection," 7 March 1972; "Weekly Progress and Problem Summary for the Administrator—Skylab Program," 17 June 1971; newsletter, William C. Schneider to Dist., "Skylab Program News," 31 May 1972.

12 MSC was authorized to procure EREP aircraft sensors for use in the Earth-resources aircraft program in support of underflight activities for Skylab EREP investigations.

Memorandum, Dale D. Myers, NASA Hq, to Associate Administrator for Applications, "Funding Support for Aircraft Sensors and Skylab Underflights," 12 April 1972.

13–14 At the NASA Manned Space Flight Management Council meeting, the Skylab Program Director and the Center Program Managers presented a comprehensive review on the Skylab status. The participants agreed that every possible effort would be made to maintain the 30 April 1973 launch readiness date for the Skylab Workshop.

"Minutes, MSF Management Council meeting," 17 April 1972.

14 During an Orbital Workshop meteoroid shield test at MSFC, it was discovered that in one hinge section of the foldout panel, nine of the 15 torsion springs were

installed in such a manner that they were only 50-percent effective in action to assist shield deployment. Action was initiated to ensure proper spring action. 1972 April

Letter, W. K. Simmons, Jr., MSFC, to F. J. Sanders, McDonnell Douglas, "Orbital Workshop Meteoroid Shield Folded Panel Springs," 17 May 1972.

MSFC, KSC, and MSC performed studies which identified the cost and reliability tradeoffs on planned one- and two-week slips between the launches of SL–1 and SL–2. An analysis of the studies identified significant cost and reliability penalties that would be incurred if the SL–2 mission were slipped, reconfirmed the desirability of getting the CSM docked to the Orbital Workshop as soon as possible after launch of SL–1, and recommended against extending the launch interval between SL–1 and SL–2. Launch plans called for a 1-day interval between the two launches. 21

Memorandum, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Cost and Reliability Tradeoffs Associated With Varying the Interval of the Skylab-1 and Skylab-2 Missions," 21 April 1972.

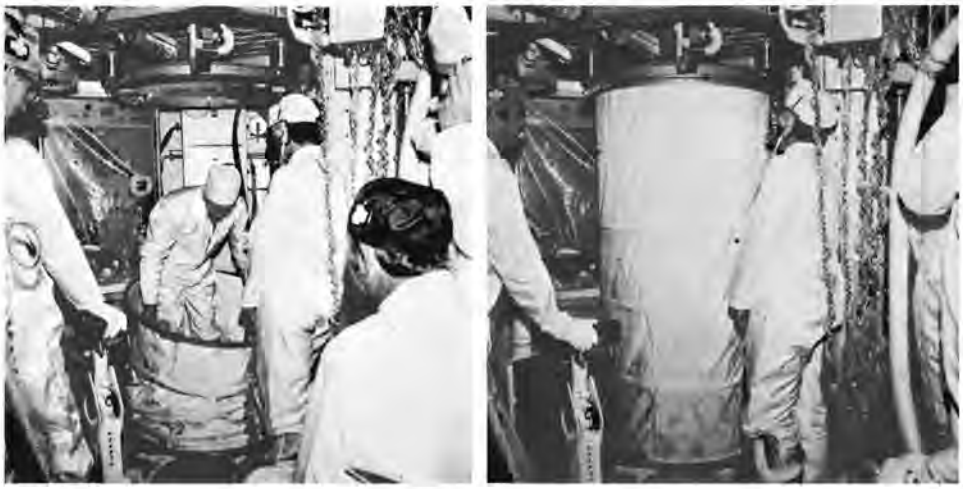
A telecon among the Skylab Program Managers (MSC and MSFC), Apollo-Skylab Program Manager (KSC), and the Director, Skylab Program (NASA Hq) was held to discuss AM/MDA/EREP testing. It was agreed that the AM/MDA checkout through simulated flight and altitude chamber testing would be conducted at McDonnell Douglas as rapidly as possible. EREP bench testing would also be conducted at McDonnell Douglas to verify EREP operations. Following the AM/MDA altitude chamber test and the EREP bench testing and before delivery to KSC, an integrated AM/MDA/EREP system test and checkout would be conducted. Delivery to KSC was scheduled for 30 September 1972. 25

Letter, William C. Schneider, NASA Hq, to Managers, Skylab Program, MSC and MSFC, and Manager, Apollo-Skylab, KSC, "AM/MDA–EREP," 3 May 1972; TWX, Leland F. Belew, MSFC, to William C. Schneider, Kenneth S. Kleinknecht, MSC, C. K. Williams, MSC, and R. C. Hock, KSC, "Airlock/MDA/EREP Agreements," 1 May 1972; MSFC, "Weekly Activity Report," 4 May 1972; letter, Leland F. Belew to Manager, Skylab Program, MSC, "EREP Integrated Bench Testing at MDAC–E," 18 May 1972.

A compact shower assembly for use on Skylab Earth-orbital missions was designed and built at MSFC. The shower remained stored on the floor when not in use. Astronauts would step inside a ring on the floor and raise a fireproof beta cloth curtain on a hoop and attach it to the ceiling. A flexible hose with push-button shower nozzle could spray 2.8 liters of water from the personal hygiene tank during each bath. Used water would be vacuumed from the shower enclosure into a disposable bag and deposited in the waste tank. 30

MSFC News Release 72–38, 3 May 1972.

Recently, one employee was killed and another seriously injured while operating a gas-tight storage battery power supply at the MSC Water Immersion Facility. During the Month



Provisions were made so that each Skylab astronaut could take a shower every week. MSFC designed and built a shower assembly to be stored as a compact unit in the crew quarters area of the workshop. At the left is a demonstration of the manner in which an astronaut would step inside a ring mounted on the floor and raise the 109-cm-diameter hoop to form the shower area. The extended curtain is then attached to the ceiling (right), and the shower is ready for use.

1972

April

An Accident Investigation Board determined the cause of the accident and recommended corrective actions to help preclude such accidents in the future. The facility was used for astronaut training.

Accident Investigation Report of the Water Immersion Facility Battery Box Explosion, April 1972; letter, Christopher C. Kraft, Jr., MSC, to Dist., same subject, 26 June 1972.

May

1

An evaluation of the protection available to flight crews from hazards associated with electrical shock from powered equipment and from buildup of static charges was conducted. The evaluation consisted of a Skylab systems operations compatibilities assessment review of the requirements used to implement electrical shock protection and confirmation of contractor efforts to ensure implementation of requirements. Assessment of the review activities indicated that the requirements for protection against shock and static charge had been met.

Letter, Leland F. Belew, MSFC, to Manager, Skylab Program, MSC, "Electroshock Protection," 1 May 1972.

4

A suit-drying crew station and design review was held at McDonnell Douglas. Representatives from MSC and MSFC attended. Basic design and operational procedures for equipment stowage, suit drying, and desiccant canister drying were found to be generally acceptable. However, the launch storage configuration for the desiccant canisters and provisions for maintaining a dryness level while suits were stored in the command module between use were not completely resolved.

1972
May

The objective was to maintain a 50-percent relative humidity level within the astronaut suits during inflight storage to prevent a potential fungal contamination.

Letters, S. D. McIntyre, MSFC, to Dist., "Suit Drying Crew Station and Design Review Minutes," 9 May 1972; S. D. McIntyre to Dist., "Minutes to Suit Drying Modification Review at MDAC," 13 April 1972; Leland F. Belew, MSFC, to Manager, Skylab Program, MSC, "Orbital Workshop Suit Drying Provisions," 22 March 1972; note, Leland F. Belew to E. F. M. Rees, MSFC, "Suit Drying Station Status," 26 May 1972.

8

NASA Hq issued a revised policy for Skylab scientific investigations. The basic concept of the policy, which was issued on 4 October 1971, remained unchanged. However, two significant phrases, "proprietary rights" and "exclusive use of data," were eliminated by the revision.

Letter, William C. Schneider, NASA Hq, to MSFC, MSC, KSC, Ames Research Center, and LaRC, "Skylab Policy for Scientific Investigations (Revision A)," 8 May 1972.

8–12

NASA officials met at MSFC with the 25 national winners of the Skylab Student Project competition to discuss design of the experiments and demonstrations. During the week, each of the students and their teachers met with their NASA advisors and participated in preliminary design reviews. An informal dinner was held on 10 May with the 25 winners, their teacher-sponsors and chaperones, local officials, and the news media participating. During the visit the students also toured MSFC laboratories and the Alabama Space and Rocket Center.

TWX, Leland F. Belew, MSFC, to MSC Manager, Skylab Program, "Dinner Speaker for Student Project Preliminary Design Review Activities," 1 May 1972; newsletter, William C. Schneider, NASA Hq, to Dist., "Skylab Program News," 31 May 1972.

9

A meeting was held at MSFC to discuss Skylab data retention and retrieval plans. Representatives from NASA Hq, MSC, KSC, Goddard Space Flight Center, and MSFC attended. Items discussed included storage of original data, data storage and retrieval to meet the needs of primary experiment and systems data users, and provision of data to national data centers. It was agreed that

- MSFC would establish a storage and retrieval facility to handle original telemetry data.
- MSC would establish local data archives to accommodate storage and retrieval of all Skylab data for which MSC is responsible.
- KSC data retention policy for Skylab was similar to the Apollo policy.
- Goddard Space Flight Center preliminary space flight tracking and data network management plan for Skylab was compatible with the plans presented by MSC, KSC, and MSFC.

Letter, R. O. Aller, NASA Hq, to Dist., "Minutes of the Skylab Data Retention Meeting," 12 May 1972.

1972 May 11 — The Apollo telescope mount crew compartment fit and function review was conducted at MSFC. Skylab astronauts participated. ATM flight cameras and film cassettes were checked during the review.

MSFC, "Skylab Weekly Activity Report," 16 May 1972.

12 — A proposal by the University of Texas, through MSC, for use of a Skylab external gas analyzer was disapproved. The mass spectrometer, which would provide a capability to determine the composition and pressure of the external gaseous environment, would augment planned contamination monitoring. However, it was felt the cost and program impacts of the proposed mass spectrometer would outweigh its benefits; therefore, the decision was made not to develop the equipment.

Letters, William C. Schneider, NASA Hq, to Director, Skylab Program, MSC, "Skylab External Atmosphere Gas Analyzer," 24 April 1972; Leland F. Belew, MSFC, to Manager, Skylab Program, NASA Hq, "Skylab External Atmosphere Gas Analyzer," 12 May 1972.

17 — The following dates and locations were established for Skylab design certification reviews:

Design Certification Review	*Date*	*Location*
Launch vehicle 513/206	8–9 June 1972	MSFC
Command and service modules	25–26 July 1972	NASA Hq
MSC experiments	10–11 Aug. 1972	MSC
MSFC experiments	14–15 Sept. 1972	MSFC
Mission/cluster (two parts)		
Operations	5–6 Oct. 1972	MSC
Cluster systems	10–12 Oct. 1972	MSFC
Launch complex/launch vehicle-ground support equipment	January 1973	——

All center DCR plans and activities would be scheduled to comply with the above dates.

Letter, William C. Schneider, NASA Hq, to Managers, Skylab Program and Saturn Program, MSFC, Manager, Skylab Program, MSC, and Manager, Apollo-Skylab Programs, KSC, "Establishment of Design Certification Reviews Schedule," 17 May 1972.

18 — An engineering walkaround inspection team for the Skylab modules was established. Inspection would provide MSC and MSFC program personnel with first-hand knowledge of the workmanship condition of the modules immediately before shipment. Inspections would be performed, as nearly as possible, immediately before compartment sealing, but after the hardware was stored. Walkaround inspection would be made of the OWS and AM/MDA. Team personnel were

skilled in the electrical, mechanical, materials, and quality/reliability/safety disciplines. 1972 May

Letters, Kenneth S. Kleinknecht, MSC, to Leland F. Belew, MSFC, 5 April 1972; Leland F. Belew to Kenneth S. Kleinknecht, 18 May 1972.

26 An Orbital Workshop crew compartment fit and function test was conducted with representatives from MSC, MSFC, and McDonnell Douglas participating. Ninety percent of the crew compartment fit and function hardware items were satisfactorily reviewed. Problems identified by the crew included numerous mechanical problems in the urine collection system, tools breaking, snaps debonding, and velcro debonding.

MSFC, "Weekly Activity Report," 1 June 1972; memorandum, E. L. Field, MSFC, "OWS Crew Compartment Fit and Function Test," 2 June 1972; MSFC, "Weekly Activity Report," 8 June 1972.

31 NASA announced completion of major preflight verification test of Skylab Workshop at the McDonnell Douglas Huntington Beach plant. Two teams of six astronauts performed checkout activities in two, six-hour shifts daily for three days, activating the Workshop to demonstrate that it could support all activities planned for missions. The test was one of the last two major tests for the Workshop, which was 14.6 m long, 6.7 m in diameter, and scheduled for launch in early 1973. A flight demonstration would be conducted before the spacecraft was shipped to KSC during the summer.

NASA News Release 72-117, 31 May 1972; MSC News Release 72-122, 2 June 1972.

June 1 Rising costs for the ATM experiments were attributed to a number of factors. Principal among these was the delay in launch time of over four and one-half years. The ATM development began in 1965 and was scheduled for launch in 1968. The long delay in launch time meant that the Principal Investigators, their in-house staffs, and their contractors had to be supported for the additional four years. Other factors which contributed to the cost increase were new state-of-the-art developments for which NASA or the Principal Investigators had no previous experience.

Memorandum, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Space Science Board Comments Regarding High Costs of ATM Experiments Due to Man-Rating," 1 June 1972.

6 The AM/MDA crew compartment fit and function test was completed at McDonnell Douglas, St. Louis. During the test, astronauts activated the AM/MDA to demonstrate that the modules would support all activities planned for the Skylab mission. The crewmen worked with the experiments installed and stowed hardware to verify that mechanical and electrical functions were as intended, and verified that on-orbit operations could be performed as planned.

1972

MSFC News Release 72–72, 12 June 1972; MSFC, "Skylab Weekly Activity Report," 13 June 1972.

June

7–8 A Skylab launch vehicle design certification review board met at MSFC. Representatives from NASA Hq, KSC, MSC, MSFC, North American Rockwell's Rocketdyne Division, Chrysler Corporation, The Boeing Company, McDonnell Douglas, North American Rockwell, IBM, and General Electric attended the review. Purpose of the design certification review was to examine the adequacy of the launch vehicles used for SL–1 and SL–2. Changes required on the Saturn V and Saturn IB were examined to determine overall vehicle capabilities in meeting SL–1 and SL–2 mission requirements. From its findings, and subject to closeout of open work items, the board certified the launch vehicles for SL–1 and SL–2 missions.

Letter, William C. Schneider, NASA Hq, to Dist., "Skylab Launch Vehicle Design Certification Review," 3 July 1972; "Minutes of Launch Vehicle Design Certification Review."

9 Award of a contract to Itek Corporation, Optical Systems Division, for three multispectral camera systems was announced by MSC. Cameras would be used on MSC's Earth resources aircraft in conjunction with Skylab missions. The airborne multispectral photographic system would obtain photos from altitudes of 378 km. Each photo would show more than 12 800 km^2 of the Earth's surface. Photos would be used in assessing urban and metropolitan growth and land use patterns and in inventorying crop, range land, and forest resources.

MSC News Release 72–130, 9 June 1972.

18 An MSC–KSC subagreement defining the responsibilities and the inter-Center participation and coordination necessary for test and checkout for preparation and launch of the Skylab Program CSM was approved by Robert C. Hock, KSC Skylab Program Manager, and Kenneth S. Kleinknecht, MSC Skylab Program Manager.

MSCM 8010, *Program Management Guide,* 18 June 1972.

21 A Skylab CSM design certification review board met at MSC. Representatives from NASA Hq, MSFC, KSC, MSC, and North American Rockwell attended. G. B. Merrick (North American) reviewed the program status and the various milestone reviews in support of the Skylab CSM program. Descriptions of the CSM modifications required for Skylab were presented. Following the presentations, the board concurred in accepting the design of the Skylab CSMs as capable of supporting the Skylab Program.

"Minutes, Design Certification Review Skylab CSM Phase II," 7 July 1972; "Skylab DCR CSM Certification," 14 July 1972.

1972

June

The Apollo telescope mount flight unit was delivered to MSC for thermal vacuum testing. A configuration turnover review was conducted before the delivery.

23

MSFC, "Skylab Program Office Weekly Activity Report," 27 June 1972.

July

6

NASA Hq issued instructions which defined requirements and responsibilities on postacceptance changes to Skylab flight hardware, experiments, and stowage items. The instructions established procedures for initiating, authorizing, implementing, and documenting postacceptance changes at the development site, integration site, or launch site.

Skylab Program Directive No. 58, "Post-Acceptance Change Control," 6 July 1972.

7

Experiments proposed by 19 high school students from 16 states were selected for the Skylab Program. The experiments were from the 25 national winners selected by the National Science Teachers Association in April 1972. The other six proposed investigations were not selected for flight because their performance was incompatible with the Skylab environment or because the equipment required would involve a development program that could not be accommodated within the Skylab schedule. The Skylab Student Project was endorsed by the Associate Administrator for Manned Space Flight and by the Manned Space Flight Experiments Board.

Memorandum, William C. Schneider, NASA Hq, to Executive Secretary, MSFEB, "Skylab Student Project," 7 July 1972; NASA Hq News Release, "Student Experiments Selected for Skylab," 20 July 1972; TWX, William C. Schneider to Managers, Skylab Program, MSFC and MSC, and Manager, Apollo-Skylab Programs, KSC, "Skylab Student Project," 28 July 1972.

12

Key personnel in the Skylab Program from NASA Hq, MSC, KSC, and MSFC participated in a telecon on design certification reviews (DCRs). Purpose was to discuss a revised DCR approach that would reduce costs without major sacrifices of DCR objectives. A concensus was reached on necessary actions to be taken on the DCR scheduling and procedures.

Memorandum for record, John H. Disher, NASA Hq, "DCR Approach," 12 July 1972; memorandum, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "DCR Approach," 20 July 1972.

14

Responsibility for hardware for the Earth resources experiment package was transferred to the Skylab Experiments Project Office in the Engineering and Development Directorate, MSC. Responsibility for EREP has been assigned to the Science and Applications Directorate since 1970, but now the program had reached the stage of delivering hardware for integration and operation in the Skylab Program.

MSC Announcement 72-106, 14 July 1972.

1972

July

17 A Skylab vibration and acoustics test program which began at MSC in January 1971 was completed. The 18-month test program was characterized by extreme complexity requiring highly innovative testing techniques. It was the first time that an extensive test operation was conducted with a computer-controlled system. All components of the Skylab payload assembly were involved in the test program. The complete assembly, as it would be at launch, underwent vibration and acoustic tests. Then the cone and shroud were removed, the ATM deployed, and the CSM joined to the MDA for tests with the assembly positioned as it would be in Earth orbit.

MSFC News Release 72–87, "Skylab Vibration and Acoustics Tests End," 17 July 1972; MSFC, "Weekly Activity Report," 2 August 1972; letter, E. F. M. Rees, MSFC, to Christopher C. Kraft, Jr., MSC, 2 August 1972.

17 An Orbital Workshop all-systems test began on 17 July 1972 and was completed on 7 August 1972 at McDonnell Douglas' Huntington Beach Vehicle Checkout Laboratory. Following the test, which lasted 309 hours, a meeting was held to verify that the OWS all-systems test had been successfully completed. At the conclusion of the meeting, it was agreed that pending closeout of the test anomalies, all test requirements had been satisfied.

TWX, F. J. Sanders, McDonnell Douglas, to MSFC, MSC, NASA Hq, and KSC, "Flash Report, OW–1 All Systems Test," 11 August 1972.

18–19 The first command and service modules designed for the Skylab Program were delivered by North American Rockwell. The CSM arrived at KSC via the *Super Guppy* aircraft. Upon arrival, the CSM, which would be launched on SL–2, was installed in the Operations and Checkout Building to begin its checkout procedure.

Newsletter, William C. Schneider, NASA Hq, to Dist., "Skylab Program News," 22 August 1972.

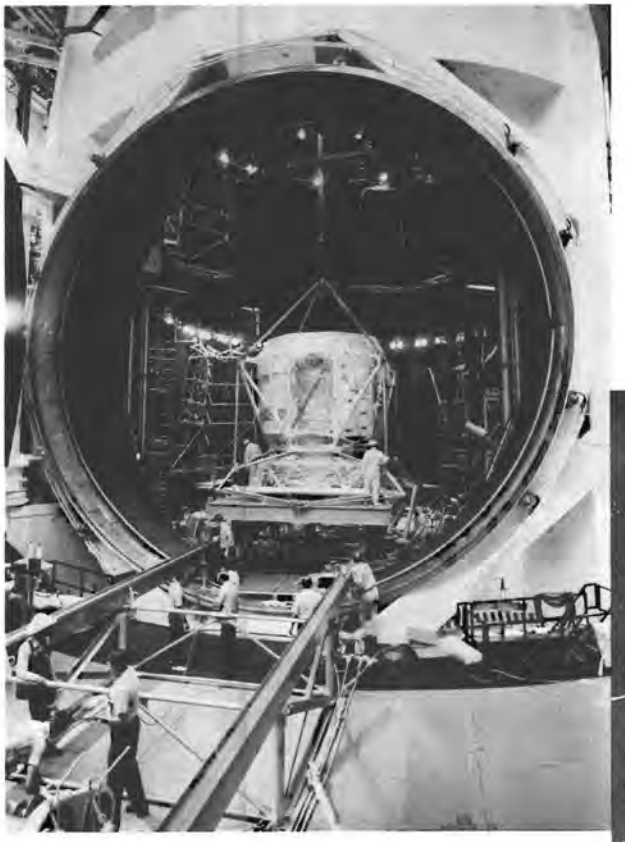
August

1 A recommendation was made during an Agency budget review to abolish two systems at KSC which were used primarily to support MSC for Apollo. The two systems were the Apollo launch data system and the countdown and status transmit system. MSC concurred in the deletion of the first of these immediately following Apollo 17. MSC also concurred in deletion of the second one if a meaningful cost reduction would be realized, even though the Center considered the countdown and status transmit system a desirable capability.

Letter, Christopher C. Kraft, Jr., MSC, to Kurt H. Debus, KSC, 23 August 1972.

3 AM/MDA simulated flight tests and altitude chamber tests were completed at McDonnell Douglas with the flight crew participating. During the altitude test, the flight crew operated the systems as they would during an actual flight.

MSC, "Skylab Weekly Activity Report," 11 August 1972.



Above, the Apollo telescope mount flight article is shown being placed in the Space Environment Simulation Laboratory chamber at MSC for extensive thermal vacuum testing to verify its ability to withstand the harsh environment of space.

Astronauts selected for Skylab missions are shown below being assisted by scuba divers during training in the MSFC Neutral Buoyancy Tank. They are preparing for mission extravehicular activity in which they will install and retrieve Apollo telescope mount film and thermal control coatings (experiment) from the airlock module.

Astronauts Robert L. Crippen, William E. Thornton, and Karol J. Bobko receive moral support and best wishes from, left to right, Royce Hawkins, Kenneth S. Kleinknecht, Sigurd A. Sjoberg, and James Correale before entering the 20-foot altitude chamber at MSC to participate in a 56-day Skylab Medical Experiments Altitude Test. The test, which started 26 July 1972, was designed to obtain medical data and evaluate medical experiment equipment planned for use in the Skylab program.

1972

August

The Skylab Program Offices at NASA Hq and MSFC were reorganized to meet the changing phase of Skylab activities.

3

Memorandum, William C. Schneider, NASA Hq, to Managers, Apollo and Skylab Programs, KSC, MSC, and MSFC, "ML Organization Realignment," 3 August 1972; MSFC Charter No. 88, MM 1142.2, 3 August 1972.

8

MSFC was conducting a series of manned tests in an altitude chamber to evaluate the Skylab environmental control system. Crew comfort under simulated space conditions was being emphasized. Tests were being conducted with chamber pressure at sea level and reduced to 34.5 kilonewtons per sq m (5 psi, absolute), the pressure normally found at an altitude of 8200 m. This was the internal pressure level at which the Skylab was to operate in space.

NASA News Release 72–162, "Skylab Tests," 8 August 1972.

8–10

Critical design reviews were conducted at MSFC for student experiments for which hardware development was approved. Representatives from KSC, MSFC, NASA Hq, and MSC attended the reviews, as well as the student investigators whose experiments were involved. Results of the reviews were satisfactory.

Letter, Leland F. Belew, MSFC, to Addressees, "Skylab Student Project Critical Design Reviews," 13 July 1972; MSFC, "Weekly Activity Report," 17 August 1972.

9

The Skylab upgraded TV camera final design review was held at MSC. The review covered in detail the electrical and mechanical design, as well as selected manufacturing, test, and reliability aspects. Emphasis was placed on previous and current problem areas and solutions and on specific questions and discussion subjects raised by Center and contractor attendees. Two design problems received particular attention: camera hangup during retrieval into the scientific airlock and lens adjustment binding during external low-temperature camera operation. Both problems were in the process of being resolved.

MSC, "Skylab Weekly Activity Report," 18 August 1972.

10

A meeting was held at Goddard Space Flight Center to discuss the possibility of establishing an emergency mission control center for Skylab at Goddard. Personnel from MSC and Goddard attended the meeting. The main point of discussion centered around the desire to establish an emergency center at little or no cost to the two Centers.

Memorandum for record, R. O. Britner, Goddard Space Flight Center, "Skylab Emergency Mission Control," 18 August 1972.

10

MSC Skylab Program Manager Kenneth S. Kleinknecht said there was no basic requirement for including wine in the Skylab menu. In vetoing its use he said that the beverage was not necessary for nourishment or to provide a balanced

diet; it was not a fully developed menu item and would involve an unnecessary expense; it would aggravate a minor galley stowage problem; its use would invalidate the experimental results of Experiment M071, mineral balance; and it would result in adverse criticism for the Skylab Program.

Memoranda, Kenneth S. Kleinknecht to Director, MSC, "Skylab Menu," 10 August 1972; Dale D. Myers, NASA Hq, to Deputy Administrator, "Use of Sherry on Skylab," 30 August 1972.

11 NASA Hq published instructions which outlined the basic duties, responsibilities, and procedures to be followed in implementing a Skylab mission contingency review.

OMSF, "Skylab Mission Contingency Review Plan"; letter of transmittal, William C. Schneider, NASA Hq, to MSC, MSFC, KSC, GSFC, and Patrick Air Force Base, "Mission Contingency Review Plan," 11 August 1972.

18 The Saturn IB first stage for the Skylab 2 launch arrived at KSC aboard the NASA barge *Orion* and was immediately offloaded for processing in the Vehicle Assembly Building (VAB). Following preliminary checkout in the VAB transfer aisle, the S–IB 206 first stage would be erected atop the 39-m-tall pedestal on Mobile Launcher 1 on 31 August.

KSC News Release 246–72, 22 August 1972.

18 A design certification review of MSC Skylab Government-furnished equipment was held at MSC. Representatives from NASA Hq, MSFC, MSC, Martin Marietta, and The Boeing Company attended. Items of equipment covered included Orbital Workshop food and food trays, biomedical instrumentation, the carbon dioxide dew point monitor, the inflight medical support system, Skylab mobile laboratories, and radiation monitoring equipment.

"Minutes of Meeting, Design Certification Review, Phase II," 18 August 1972.

20 A Skylab Program safety analysis report was being prepared by NASA Hq for submittal to the Administrator at the time of the flight readiness review. The report would provide a compilation of the risks associated with Skylab flights, the manner in which they had been accommodated, and the rationale for acceptance of the remaining risks.

Letter, William C. Schneider, NASA Hq, to Managers, Skylab Program, KSC, MSC, and MSFC, "Safety Analysis Report for Skylab," 20 August 1972.

22 A Skylab Advisory Group was established at Headquarters for the purpose of effecting maximum scientific and technological output from the Skylab Program. The Group, whose membership consisted of the Directors of the Earth Observations, Life Sciences, Advanced Manned Missions, Space Technology, and Physics

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August

and Astronomy Offices, would meet on a regular weekly schedule with the Skylab Program Director during the Skylab missions.

Newsletter, William C. Schneider, NASA Hq, to Dist., "Skylab Program News," 22 August 1972.

25

Twenty-four Skylab suits were delivered by the space suit manufacturer, International Latex Corporation; five were ready for delivery, nine were in the manufacturing process, and material for the remaining three had been procured.

Letter, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Skylab Spacesuit Situation," 25 August 1972.

29

MSC Director Christopher C. Kraft, Jr., Deputy Director Sigurd A. Sjoberg, Director of Life Sciences Richard S. Johnston, Director of Flight Crew Operations Donald K. Slayton, MSC Skylab Program Manager Kenneth S. Kleinknecht, and members of the Skylab medical experiments altitude tests (SMEAT) team met to review the status of the test program. The team recommended that the test be continued for its full duration of 56 days. Personnel at the meeting felt that the 56 days of physiological baseline data and the additional hardware and procedural evaluation which could be performed in the additional three weeks would outweigh any gain from an early termination of the SMEAT program. In addition, early termination would shorten certain evaluations requiring other test programs to be conducted. The consensus was that SMEAT should proceed to its full duration. The MSC Director approved the recommendation. Half of the maximum 56 test days were completed with the crew in excellent health and spirits. The crew and test teams were still performing to the preestablished time lines and schedules with little or no deviations. The test showed that even though Skylab equipment was built in the same manner as equipment for other space programs and was thoroughly tested in qualification and acceptance tests, when the equipment and crew were brought together in a flight environment, problems developed that could not be discovered in other ways. One of the more significant problems thus far was with an instrument called the metabolic analyzer, designed in part to measure oxygen consumed and carbon dioxide produced. The instrument had not been working as it should before the test, but it was hoped that enough engineering data could be generated during the test to correct the problems. The test also provided a means of bringing together a flight operations, medical, and crew procedures team and giving them some indication of the problems they might experience in working out their procedures in a flight environment.

"SMEAT Four-Week Status Report," 23 August 1972; memorandum for record, R. S. Johnston, 1 September 1972.

September

1

Six mobile laboratories were being designed for postflight conduct of the Skylab medical experiments. The laboratories would remain at MSC in a semioperational state until just prior to mission termination. An elapsed time of 17 hours would be required to fly the laboratories on a C-5A aircraft from MSC to one of

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four Pacific islands in the splashdown area. A one-hour elapsed time from splashdown to laboratory entrance for the flight crew was established by experimenters as necessary to obtain experimental data before readaptation changed the degree of deconditioning caused by extended exposure of the crew to zero-g.

Letter, Kenneth S. Kleinknecht and R. S. Johnston, MSC, to NASA Skylab Program Director, "Skylab Mobile Laboratories," 1 September 1972.

1

An MSC team was conducting tests with the rescue mission configured Skylab command module at KSC. Purpose of the test was to evaluate the equipment, techniques, and procedures involved in the egress required by a five-man command module loading. Navy and Air Force helicopters were participating in the test.

KSC, "Weekly Progress Report," 1 September 1972.

6–7

A special ceremony at McDonnell Douglas, Huntington Beach, marked completion of the OWS, the main section of the Skylab space station. The OWS, with a volume equivalent to that of a five-room house, was being readied for shipment to Cape Kennedy aboard the USNS *Point Barrow*. The trip would take 13 days.

Officials present at the Orbital Workshop turnover at McDonnell Douglas, Huntington Beach, included, left to right, Willis B. Shapley, NASA Deputy Associate Administrator; Casper Weinberger, Director of the Office of Management and Budget; James C. Fletcher, NASA Administrator; Eberhard F. M. Rees, MSFC Director; Walter F. Burke, McDonnell Douglas; and Dale D. Myers, NASA Associate Administrator for Manned Space Flight.

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September

Casper Weinberger, Director of the Office of Management and Budget, and James C. Fletcher, NASA Administrator, attended the completion ceremony. Among officials who attended were William C. Schneider, Skylab Program Director; Eberhard F. M. Rees, MSFC Director; Leland F. Belew, MSFC Skylab Program Director; William Simmons, Jr., MSFC Workshop Manager; Kenneth S. Kleinknecht, MSC Skylab Program Manager; Robert C. Hock, KSC Skylab Program Manager; and Walter J. Kapryan, Director of Kennedy Launch Operations.

Also attending were Walter F. Burke, President of McDonnell Douglas Astronautics Company; Raymond A. Pepping, Vice President-General Manager, Skylab; Fred J. Sanders, Program Manager Skylab/Orbital Workshop; E. T. Kisselberg, Program Manager-Skylab Airlock, and California Congressmen Alphonzo Bell and Barry Goldwater, Jr.

MSFC, "Skylab Program Office Weekly Activity Report," 12 September 1972; "Minutes of OWS-1 Pre-delivery Turnover Report Board Meeting," 6 September 1972; TWX, O. S. Tyson, MSFC, to Dist., "OWS-1 Shipment," 8 September 1972.

15 A Skylab Mission Operations design Certification review was held at MSC. Representatives from NASA Hq, MSFC, MSC, KSC, Goddard Space Flight Center, Lewis Research Center, North American Rockwell, and Martin Marietta attended. The agenda contained such items as mission characteristics affecting flight operations, flight control team structure, major unique mission tasks, flight crew training program, and manned safety assessment and operations. The design certification review board certified the adequacy of planning and preparations for all mission operational requirements for Skylab, based upon the findings of the review, and contingent upon the satisfactory closeout of the open items.

"Minutes of the Skylab Mission Operations DCR," 15 September 1972; letter, William C. Schneider, NASA Hq, to Dist., "Skylab Mission Operations Design Certification Review," 16 October 1972.

22 The Skylab Apollo telescope mount arrived at the KSC skid strip aboard a *Guppy* aircraft. The ATM, which had been at MSC since mid-July, was immediately moved to the Operations and Checkout Building in KSC's industrial area and placed in the cleanroom for intensive checkout. The ATM was scheduled to be moved in January 1973 to the Vehicle Assembly Building for mating with the OWS atop the two-stage Saturn V launch vehicle. The Skylab orbital assembly—consisting of the OWS, the ATM, and the AM/MDA—was scheduled to be launched from Pad A of Launch Complex 39 in late April 1973.

KSC News Release 270-72, 26 September 1972.

23 The Skylab 1 Orbital Workshop was offloaded from a NASA barge and moved into the transfer aisle of the Vehicle Assembly Building (VAB) at KSC. The OWS had arrived the preceding day (22 September) aboard the *Point Barrow* at

The Skylab 2 crew participated in a series of simulation exercises in the MSC Simulation and Astronaut Training Facility. The simulations, which ended 20 September 1972, included: above, Joseph P. Kerwin at the Apollo telescope mount console; right, Kerwin in the human vestibular function experiment (M131) chair with Paul J. Weitz recording the results at the right of the picture and Charles Conrad, Jr., in the background riding the bicycle ergometer; and, bottom right, Conrad installing film in the Earth Resources Experiment Package, located in the multiple docking adapter.

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Port Canaveral, where it was transferred to a smaller barge for the journey through the locks, up the Banana River, and through the access canal to the barge unloading area at the VAB. Following preliminary checkout, the OWS, with its 361.4 cu m of living and working area, was scheduled to be mated to the two-stage Saturn V launch vehicle on 28 September.

KSC News Release 270–72, 26 September 1972.

25

An Apollo telescope mount turnover review board meeting was held at MSFC with representatives from NASA Hq, KSC, MSC, and MSFC in attendance. There were no constraints to shipment from MSFC or KSC acceptance of the ATM. No action items were assigned.

"Minutes of Meeting," 25 September 1972; letter, R. Ise, MSFC, to Dist., "ATM Turnover Review Board Minutes," 11 October 1972.

26

A news conference was held at MSC on the Skylab medical evaluation altitude test, which had ended 20 September. The test had brought together a multidisciplinary team from the Life Sciences, the Flight Operations, and Flight Crew Operations Directorates in a dress rehearsal for the Skylab missions. The tests had exercised the procedures and the data management, reduction, and arrangement into format for use in making decisions that would be needed in the Skylab flights. Data to date indicated there would be no significant changes in the functioning of the human body in the environment of Skylab. Some hardware problems included the urine volume measuring system, the metabolic analyzer, the sleep monitoring system, and food packaging. None of these, however, posed any threat to the Skylab flight.

SMEAT press conference, 26 September 1972.

26

Agreements were reached between the Office of Applications and the Office of Manned Space Flight on the management and conduct of the EREP project assigned to Skylab. EREP was one element of an Earth resources survey program designed to demonstrate the feasibility of using remote sensing in the solution of resources problems. Other elements of the Earth resources survey program included ERTS, Earth resources aircraft program, ground truth studies, and supporting research and technology programs.

Memorandum of understanding for EREP management, Charles W. Mathews and Dale D. Myers, NASA Hq, 26 September 1972.

28

CSM 119 would be utilized in a dual role: as a spacecraft rescue vehicle for the Skylab Program and later for the Apollo-Soyuz Test Project. However, CSM 111 would continue to be the primary Apollo-Soyuz Test Project spacecraft.

Letter, Christopher C. Kraft, Jr., MSC, to Dale D. Myers, NASA Hq, 28 September

The multiple docking adapter, a major experiment control center for the nation's first manned space station, moves through the air suspended from a crane during tests at the Martin Marietta facility at Denver. The pier of the space station, it contains two ports where Apollo command modules can dock. In the picture at left, engineers are shown testing the 7000 electrical connections and 9.3 km of wiring before the unit was flown to the McDonnell Douglas plant in St. Louis for mating and tests with the airlock module. —Martin Marietta photo.

1972; memorandum, Dale D. Myers to Christopher C. Kraft, Jr., "Storage and Utilization of Apollo Command and Service Modules," 30 October 1972.

September

28

Representatives of MSFC, MSC, McDonnell Douglas, and Martin Marietta attended an AM/MDA engineering walkaround inspection in St. Louis. The general quality of the flight module was found to be acceptable.

Letter, J. A. Chambers, MSFC, and W. H. Douglas, MSC, to Managers, Skylab Program, MSC, KSC, and MSFC, "AM–MDA Engineering Walkaround Inspection," 25 October 1972.

October

2

An agreement was issued which defined the policy and responsibilities of KSC and MSC for the control of MSC-licensed radioactive material designated for launch support and flight at KSC. The agreement was approved by Kenneth S. Kleinknecht and O. G. Morris (MSC) and R. C. Hock (KSC).

"MSC/KSC Subagreement on Control of MSC-Licensed Radioactive Material for Apollo and Skylab Programs," 2 October 1972; letter, R. C. Hock to Dist., same subject, 2 October 1972.

2–3

A modules and experiments design certification review was convened at MSFC. Representatives from NASA Hq, MSC, MSFC, KSC, Ames Research Center, LaRC, Department of Defense, Department of Transportation, various NASA contractors, and Principal Investigators attended. Purpose of the review was to assess and certify that the design of the OWS, MDA, payload shroud, AM, and ATM met Skylab requirements for performance, reliability, and safety.

"Minutes of the MSFC Modules and Experiments Design Certification Review," 2–3 October 1972; letters, William C. Schneider, NASA Hq, to Dist., "Skylab MSFC Modules and Experiments Design Certification Review," 11 December 1972; Kenneth

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S. Kleinknecht, MSC, to Skylab Program Director, "Design Certification Status," 15 November 1972.

October

3–29

The first major test of the OWS—the meteoroid shield deployment—was started 3 October at KSC. Problems were encountered with improperly torqued deployment torsion bars and latch failure in the open position. One torsion bar was replaced and the others retorqued. The meteoroid shield was successfully deployed on 22 October when three out of four latches worked, and it was judged acceptable for flight. By 29 October all work had been completed, and the meteoroid shield was placed in flight configuration.

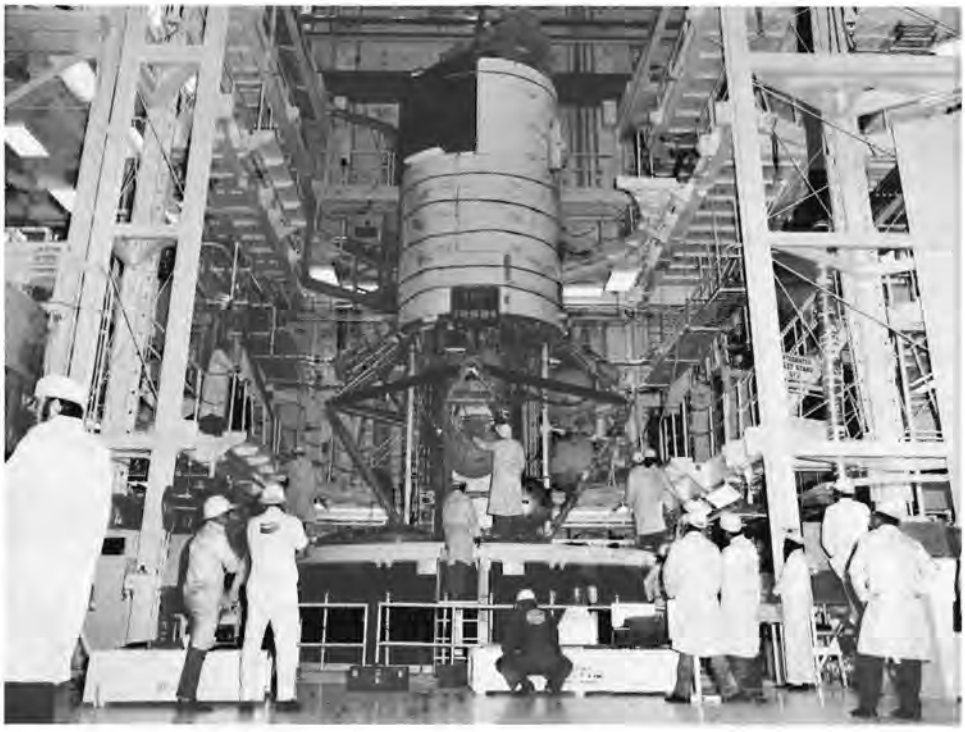
KSC, "Skylab 1 Post-Launch Report," 8 June 1973, p. 2–8.

6

NASA Hq authorized MSC to acquire a computer to perform data acquisition, monitoring, and storage of postflight medical experiments in the Skylab mobile laboratory.

Letters, Christopher C. Kraft, Jr., MSC, to Dale D. Myers, NASA Hq, 11 August 1972; M. K. Wible, NASA Hq, to MSC Director, "ADP Acquisition Plan for a Computer System to Monitor Post Flight Medical Data in the Skylab Mobile Laboratory," 6 October 1972; memorandum, G. M. Truszynski, NASA Hq, to Associate Administrator for Manned Space Flight, 5 October 1972.

The Skylab 1 airlock module and multiple docking adapter are moved to the work stand at Kennedy Space Center.



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October

Experience gained during the design and development of the Skylab Program showed that contamination and its control required considerable attention during development and test phases and during flight operations; therefore, it was recommended that the Space Shuttle Program give consideration to the establishment of a full-time group of qualified personnel to handle the subject of contamination. 10

Memorandum, William C. Schneider, NASA Hq, to Acting Director, Space Shuttle Program, "Contamination Control on Skylab as it relates to Shuttle," 10 October 1972.

A cluster communications compatibility meeting was held at MSC. Representatives from MSFC, Goddard Space Flight Center, and MSC attended. Purpose was to review the status of testing AM and ATM communications systems. AM audio and television systems were nearly complete. ATM telemetry and command systems were complete. 11

MSFC, "Weekly Activity Report," 24 October 1972; letter, Leland F. Belew, MSFC, to Director, Skylab Program, "Skylab Communications Operational and Compatibility Testing," 16 October 1972.

The test report on the Skylab medical evaluation altitude test which ended 20 September noted that potential hardware problems had been recognized, but that early recognition afforded time for analysis and resolution before use of the hardware in the Skylab missions. A higher degree of confidence had been gained in the ability of the medical hardware to support the Skylab objectives. Skylab flight control personnel and Principal Investigators participated in the test under simulated manned space flight network conditions to evaluate support required for actual missions and to note where improvement could be made. Safety, reliability, and quality assurance personnel were exposed as a team to the integrated performance of Skylab medical hardware and would develop their overall plan to support actual missions. 18

"SMEAT Test Report," 18 October 1972.

A Skylab cluster systems design certification review was conducted at MSFC with representatives from NASA Hq, MSFC, KSC, Lewis Research Center, and MSC. Contractor representatives included Martin Marietta, McDonnell Douglas, TRW, IBM, and Bendix Corporation. The review concluded the flight hardware and systems design certification effort which had begun earlier in the summer. All hardware was certified for flight with the closing out of identified open items. 19

"Minutes of the Cluster Systems DCR Held at MSFC," 19 October 1972; memorandum, William C. Schneider, NASA Hq, to Dist., "Skylab Cluster Systems Design Certification Review," 15 December 1972.

The multiple docking adapter backup flight unit was delivered to McDonnell Douglas following an acceptance review at Martin Marietta Corporation, Denver. 25

1972

October

The unit would be mated with the airlock backup flight unit and checked out to ensure readiness to support the Skylab 1 launch.

MSFC, "Skylab Weekly Activity Report," 31 October 1972.

The Skylab airlock module/multiple docking adapter is shown during offloading procedures at Cape Kennedy's Skid Strip, after arrival on the *Super Guppy* aircraft.

November

1

In the exchange of a series of letters which began earlier in the year, the directors of various NASA Centers agreed that some scientific and technical management functions for the EREP would be accomplished by Centers other than MSC.

Letters, Christopher C. Kraft, Jr., MSC, to H. Mark, Ames Research Center, E. F. M. Rees, MSFC, J. F. Clark, Goddard Space Flight Center, K. H. Debus, KSC, E. M. Cortright, LaRC, and B. Lundin, Lewis Research Center, 18 April 1972; E. F. M. Rees to C. C. Kraft, Jr., 1 May 1972; H. Mark to C. C. Kraft, Jr., 2 May 1972; J. F. Clark to C. C. Kraft, Jr., 12 May 1972; K. H. Debus to C. C. Kraft, Jr., 16 May 1972; E. M. Cortright to C. C. Kraft, Jr., 23 May 1972; B. Lundin to C. C. Kraft, Jr., 16 May 1972; C. C. Kraft, Jr., to E. M. Cortright, 1 November 1972; C. C. Kraft, Jr., to B. Lundin, 7 November 1972; C. C. Kraft, Jr., to H. Mark, 7 November 1972; C. C. Kraft, Jr., to K. H. Debus, 14 November 1972; E. F. M. Rees to C. C. Kraft, Jr., 1 December 1972; H. Mark to C. C. Kraft, Jr., 4 December 1972.

9

Representative examples of guidelines for the Skylab crews included:

- Eight hours of sleep a day simultaneously. This was based on an analysis of previous flight experience.
- A duty day between 6 a.m. and 10 p.m. either CST or CDT.

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November

• Simultaneous one-hour meal periods except for the noon meal when one crew member would be operating the ATM.

• One and a half hours a day per crew member for personal hygiene.

• Four to four and a half hours per crew member a day for equipment housekeeping.

• One day off in every seven; days off would be keyed to Earth-resources experiments package passes. No crew activities on off days except for housekeeping chores, flares, the mineral balance experiment, reentry simulations, debriefings, and passive experiments.

"Minutes, Manned Space Flight Management Council Meeting," 8–9 November 1972.

15

Restrictions were placed on the dissemination and use of certain Skylab telemetry data known as Skylab medical data. These restrictions were defined, and agreement was reached on the method of processing the data to conform to the restrictions imposed.

"MSC/MSFC Inter-Center Agreement on Skylab Medical Data," 15 November 1972.

17

The Skylab mission crew patches were approved by the Associate Administrator for Manned Space Flight.

• The patch for the first Skylab crew represented the silhouette of the Skylab cluster in front of the Earth with the eclipsed Sun behind the Earth.

• The patch for the second crew depicted the three major objectives of Skylab: study of the Sun, of the planet Earth, and of man himself.

• The patch for the third Skylab crew referred to the three major areas of investigation proposed in the mission and to the spirit of unification which the crew felt was an essential element in man's quest for understanding.

Letters, Christopher C. Kraft, Jr., MSC, to Dale D. Myers, NASA Hq, undated; Dale D. Myers to Christopher C. Kraft, Jr., 24 November 1972.

18

The Department of the Army agreed to extend the loan of six expandable medical units to NASA until January 1974. The units would be used to assist in maintaining the integrity of the Skylab medical experiments during the immediate postflight periods.

Letters, R. S. Johnston, MSC, to S. J. Turnbull, Department of the Army, 18 November 1972; S. J. Turnbull to R. S. Johnston, 5 December 1972.

21

NASA Hq published instructions defining the review procedure and requirements for the flight readiness review which would be conducted before each Skylab mission. Each review would cover the readiness assessment of the CSM, AM, MDA, ATM, OWS, payload shroud, launch vehicle, ground support equipment, launch complex, launch support, all operational elements, flight experiments, all

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November

software including computer programs, and all safety and emergency provisions and procedures. In short, the review would assess the suitability of a particular space vehicle for a scheduled flight mission assignment, as well as the readiness of the operational elements required to support the mission.

Skylab Program Directive No. 59, "Skylab Flight Readiness Reviews," 21 November 1972.

24

The Skylab debris situation was reviewed with emphasis on the S–IVB stages of Skylab 2, 3, and 4. It was decided that the S–IVB for these missions would be deorbited into the Pacific Ocean on an early revolution. The deorbit would be achieved by controlled venting of the S–IVB, dumping propellants through the main engine to provide sufficient retrovelocity for reentry. The capability to perform the deorbit would be evaluated and determined during flight; however, execution of the maneuver would be controlled from the ground. (The deorbit technique was the same used on early Earth-orbit Apollo missions.)

Memoranda, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Deorbit of SIVB Stages," 20 November 1972; Dale D. Myers, NASA Hq, to the Administrator, "Skylab Program, Deorbit of SIVB," 28 November 1972; TWX, William C. Schneider to Kenneth S. Kleinknecht, MSC, R. G. Smith and Leland F. Belew, MSFC, and R. C. Hock, KSC, "Deorbit of Skylab SIVBs," 28 November 1972.

30

In a number of instances in the Skylab Program, cost savings were obtained by accepting greater payload weights. Examples cited were

- The payload shroud, where a conservative estimate of savings at the expense of 5900 kg of payload was approximately $35 million.
- The gas storage system where a 2700-kg heavier payload resulted in an estimated savings of $5 million.
- Other structural elements, in addition to the payload shroud, accommodated 2200 kg of added payload weight for an additional savings of $35 million.

Memoranda, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Samples of Skylab Cost Savings at the Expense of Payload Weight," 30 November 1972 and 15 December 1972.

30

Nine Skylab astronauts completed a training session in the Space Environment Simulation Laboratory at MSC. Purpose of the session was to familiarize Skylab mission crews 3 and 4 with the intravehicular and extravehicular operation of the Skylab extravehicular mobility unit. Each of the astronauts participating in the training donned the Skylab life support assembly, entered the chamber B manlock, and evaluated his comfort level, flight checkout procedures, off-normal operations, and the pressure control unit caution and warning displays. The training was conducted in vacuum conditions.

"Space Environment Test Division Weekly Activity Report," 30 November–6 December 1972.

1972
December
7

Objection was voiced to a proposal that the Saturn V backup launch capability and all activities associated with it be terminated immediately following the first manned mission of Skylab. Reasons for the objection were

- NASA would be placed in the position of retaining a backup capability for the most reliable portions of Skylab and disposing of that capability for the most immature elements such as the Workshop and solar arrays.
- Cost of storing these elements at the factory during the missions would be small since flight support and postflight analysis would need to be retained until the spring of 1974.
- Without the backup capability, the possibility existed that the program could end up with no 28-day medical data, no science data, and no EREP data, just a $2.6-billion failure.

Letter, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Back-Up Saturn V," 7 December 1972; note, Dale D. Myers, NASA Hq, to William C. Schneider, "Back-Up Saturn V," 6 September 1972.

8

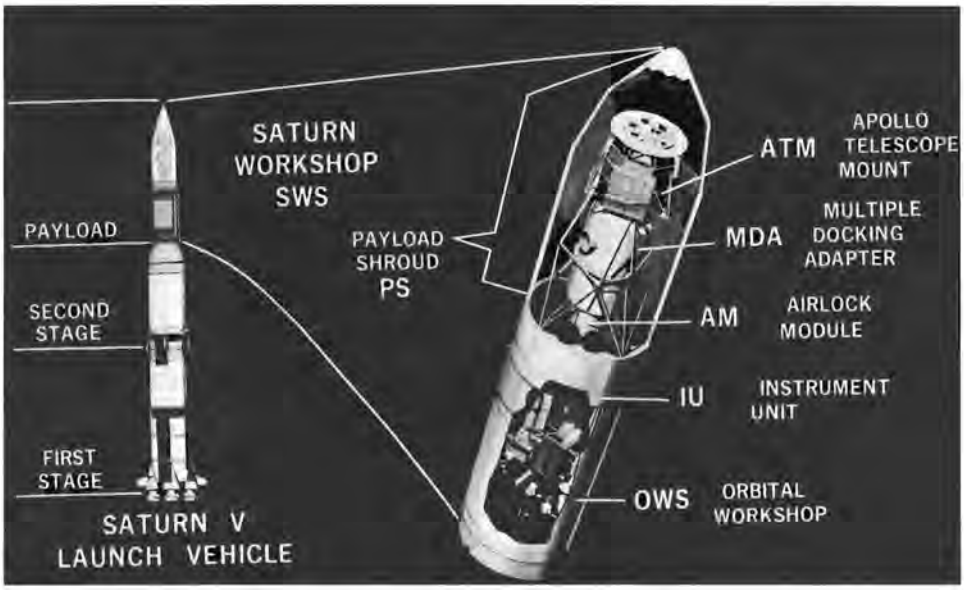
In spite of its small crew and limited number of missions, Skylab would be an impressive facility for research in orbit. More than 3500 astronaut-hours would be allocated to the performance of 270 separate scientific and technological investigations embracing almost every field capable of utilizing the unique properties of the orbital environment. These investigations would cover astronomy; remote sensing for forestry, agriculture, water resources, oceanography, meteorology, regional planning, geology, mineral resource prospecting, and cartography; medical and physiological studies of man; cosmic ray studies and x-ray and ultraviolet astronomy; and metallurgy and materials processing.

Memorandum, Dale D. Myers, NASA Hq, to the Administrator, "Scope of Skylab Experiment Program," 8 December 1972.

19

President Richard M. Nixon's statement on the U.S. space program following the splashdown of *Apollo 17* noted the role of Skylab: "The safe return of the command module America marks the end of one of the most significant chapters in the history of human endeavor. . . .

"The making of space history will continue, and this Nation means to play a major role in its making. Next spring, the Skylab will be put into orbit. It will be aimed not at advancing the exploration of deep space, but at gaining in space new knowledge for the improvement of life here on earth. It will help develop new methods of learning about the earth's environment and the earth's resources, and new methods of evaluating programs aimed at preserving and enhancing the resources of all the world. It will seek new knowledge about our own star, the Sun, and about its tremendous influence on our environment. Scientists aboard the Skylab will perform medical experiments aimed at a better knowledge of man's own physiology. Also, they will perform experiments aimed at developing new industrial processes utilizing the unique capabilities found in space. Skylab



Skylab unmanned launch configurations.

1972
December

will be our first manned space station. It will be in use for the better part of a year, permitting the economy of extended usage, and laying the groundwork for further space stations. . . ."

Presidential Documents, 25 December 1972, p. 1788.

20

Michael W. Whittle, a Royal Air Force medical officer, began a tour of duty with MSC as the first of several foreign aerospace doctors who would work with U.S. scientists on Skylab. It was anticipated that aerospace doctors from West Germany, Spain, and Sweden would receive similar assignments in the near future. The doctors would be financed by their respective countries at no expense to NASA.

Letters, A. W. Frutkin, NASA Hq, to A. Hocker, Director General, European Space Research Organization et al., 10 May 1972; A. W. Frutkin to W. Harbison, Royal Air Force Staff British Embassy, 20 December 1972.

26

NASA Hq published instructions which defined the Skylab portion of the NASA educational program. Subjects included in the program were video documentation; teacher services; lecture demonstrations, conferences, and speaker services; curriculum resources; slide and film presentations; youth programs; and adult programs.

Skylab Program Directive No. 60, "Skylab Education Program," 26 December 1972.

1973
January
4

The Aerospace Safety Advisory Panel, at the request of the NASA Administrator, undertook an extensive review of the Skylab Program. Priorities in the review were given to the activities and systems deemed to be most critical to crew safety

and mission success:

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January

- Contractor development and manufacture of Skylab modules and associated NASA management activities. (This included factfinding trips to principal contractor and NASA management Centers.)
- NASA management activities for the evaluation of design and hardware maturity and mission operations planning and preparation.

The Panel was satisfied with the technical management system for development and fabrication of the modules, spacecraft, and launch vehicles; the design and hardware acceptance reviews; and preparations for and execution of mission operations. They felt that the NASA/industry team was mature and that it was applying careful planning and responsible management to the hardware, software, and checkout operations. However, some mission operational areas, cluster change control, and integrated testing would require continued future emphasis. Some of these specific areas were contractor policies for joint operational activities; fire extinguishment and toxicity controls; and flammability of materials. Following the presentation of the written report, the Panel, by letter of 26 January 1973, was requested by George M. Low (NASA Hq) to continue the review and provide comments before each Skylab flight. This would include consideration of prelaunch activities, test, and checkout activities, mission preparations, and the areas identified in the study as warranting continued emphasis. The Panel would also review mission operations for each flight to assess the basis for confidence in mission operation for the next flight. In this area, the Panel conducted a comprehensive review of MSC operations activities on 12 and 13 March 1973.

Panel personnel were Carroll H. Dunn, chairman; Frank C. DiLuzio, Henry Reining, Jr., Bruce T. Lundin, John A. Hornbeck, and Harold M. Agnew, members; William A. Mrazek, consultant; and Gilbert L. Roth, Carl R. Praktish, V. Eileen Evans, staff.

Volume I, *Summary Report to the Administrator by the NASA Aerospace Safety Advisory Panel on the Skylab Program*, January 1973; letters, C. H. Dunn to J. C. Fletcher, NASA Hq, 4 January 1973; C. A. Berry, NASA Hq, to Director, Skylab Program, NASA Hq, "Skylab Between Mission Durations," 14 February 1973; memoranda, D. D. Myers, NASA Hq, to the Administrator, "Third Annual Report of the Aerospace Safety Advisory Panel," 27 June 1972; W. C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Comments on Third Report of the Aerospace Safety Advisory Panel," 26 June 1972; G. L. Roth to Manager, Skylab Program, MSC, "MSC Review," 14 February 1973; JSC (formerly MSC), "Skylab Program Office Weekly Activity Report," 16 March 1973.

10

At a Manned Space Flight Management Council meeting, William C. Schneider (NASA Hq) emphasized the mounting pressures from open work at KSC and the demanding schedule for integrated systems testing during February and March. As examples he cited the following areas:

- February ATM system verification
  AM/MDA/OWS end-to-end system test
  SL–2 (first manned Skylab launch) vehicle rollout to Pad B

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January

- March — Stowage and crew compartment fit and function review SL–1 and SL–2 flight readiness test

Summary of Action Items, Manned Space Flight Management Council, 10 January 1973.

15 — At a NASA general management review, Dale D. Myers summarized Skylab problems which were aggravated by a requirement to replace a control and display panel in the multiple docking adapter—one of the pacing program items. He told the general management review group that confidence in the ability to maintain an April launch date was slipping. Following the review, a decision was made to delay the launch of SL–1 and SL–2 until May 1973, with tentative launch dates of 14 and 15 May. An evaluation of launch intervals between SL–2 and SL–3 and between SL–3 and SL–4 was being made to determine if an approximate recovery date of 21 December 1973 could be maintained.

TWX, William C. Schneider, NASA Hq, to MSC, MSFC, KSC, and GSFC, "Skylab Planning," 22 January 1973; OMSF, "Summary of January Action Items," 10 February 1973; memorandum, Dale D. Myers, NASA Hq, to the Administrator, "Rescheduling of Skylab I Workshop Launch," 24 January 1973.

17–19 — A three-day mission planning simulation was conducted at MSC. Work was underway to resolve the problems identified during the simulation. Consideration was also being given to replacing the planned two-day on-orbit simulations with three-day simulations. A decision on this change would be reflected in a revised mission planning simulation schedule.

MSC, "Skylab Program Office Weekly Activity Report," 26 January 1973.

19 — MSFC began implementation of a plan for preparation and storage of unassigned Saturn hardware, phaseout of the Saturn V production capability, and amendment of the facility operations contract at the Michoud Assembly Facility for minimum surveillance of stored hardware.

Letter, E. F. M. Rees, MSFC, to Dale D. Myers, NASA Hq, "January Management Council Meeting," 19 January 1973.

19 — A design certification review was held at KSC. Primary and supporting Center responsibility was assigned for certain action items. Input from the supporting Center would be utilized by the Center having primary responsibility in generating the closeout information for the action. In the majority of the action items, KSC was assigned primary responsibility, with MSFC providing support.

Letters, William C. Schneider, NASA Hq, to MSFC, MSC, and KSC, "Launch Complex 39 Delta DCR and Integrated SWS and Launch Vehicle GSE/ESE DCR–Action Items," 30 January 1973; William C. Schneider to Dist., same title, 22 February 1973; William C. Schneider to Associate Administrator for Manned Space Flight, "DCR Action Items," 22 March 1973.

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January 19–February 2

KSC processing of SL–1 and SL–2 was progressing as planned. The Workshop and its associated modules were successfully stacked 29–31 January. No major problems were encountered in the SL–2 processing. Propellant loading and unloading, facilities, and ground support equipment tests were conducted on the Saturn IB launch vehicle at Pad B. Following tests, the vehicle was rolled back to the Vehicle Assembly Building. Prime and backup crews completed manned altitude chamber tests of the SL–2 command and service modules on 19 January, following which the spacecraft was moved to the Vehicle Assembly Building where it would be erected on the S–IB.

"Skylab Engineering Weekly Highlight Reports," 1, 8, and 16 February 1973; Manned Space Flight Management Council, "Summary of Proceedings," 14 February 1973.

22

An ATM calibration rocket systems launch was accomplished at the White Sands Test Facility in New Mexico. The launch was one of a series to qualify the calibration rocket program before the Skylab missions.

MSFC, "Skylab Weekly Activity Report," 23 January 1973.

24

An evaluation to determine the impact of changing the Skylab 1 and 2 launch dates indicated that the greatest impact was on the crew training activities. The evaluation indicated that the star charts aboard the Orbital Workshop were launch-date dependent. Changeout packages were being prepared for the star charts which would be carried in the command module. Changeout packages were also being prepared for the rendezvous book, the ATM systems checklist and data book, the flight plan, and the flight plan sequence for the activation and deactivation checklist.

MSC, "Skylab Program Office Weekly Activity Report," 2 February 1973; JSC, "Skylab Program Office Weekly Activity Report," 23 February 1973.

26

MSFC Director Eberhard F. M. Rees retired. He had served as Director since 1 March 1970. Rocco A. Petrone, NASA Apollo Program Director, became the new MSFC Director.

MSFC PAO; *Marshall Star,* 17 January 1973.

29–30

Checkout of the AM/MDA and ATM flight units was completed at KSC, and the units were mated to the launch vehicle.

MSFC, "Weekly Activity Report," 30 January 1973.

February 5

A customer acceptance readiness review for the Skylab television system was completed at Westinghouse Electric Corporation, Baltimore. The unit was being assigned to the qualification test program for testing.

MSC, "Skylab Program Office Weekly Activity Report," 9 February 1973.

The Apollo telescope mount is shown being moved from a clean room in the KSC Manned Spacecraft Operations Building. It was taken to the Vehicle Assembly Building and mated with other components of the Skylab Orbital Workshop cluster.

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February

12 The Manned Space Flight Management Council acting in the capacity of a design certification review board completed the following Skylab Program reviews:

Saturn launch vehicles	7–8	June 1972
Command and service modules and MSC experiments	10–11	Aug. 1972
Mission operations	15	Sept. 1972
MSFC modules and experiments	2–3	Oct. 1972
Cluster systems	19	Oct. 1972
Launch Complex 39 and integrated ground and electrical support equipment	19	Jan. 1973

The adequacy of the design performance requirements and verification programs for Skylab vehicles, spacecraft, modules, experiments, cluster systems, launch complex and ground support equipment, and mission operations planning were examined to certify that equipment and operational elements could safely accomplish the planned Skylab mission.

Memorandum, Dale D. Myers, NASA Hq, to the Administrator, "Skylab Design Certification Reviews," 12 February 1973.

14 At a Manned Space Flight Management Council meeting, William C. Schneider (NASA Hq) summarized the results of a Skylab study on launch interval options. The purpose of the study had been to assess the potential effect of reducing the interval between SL–2 and SL–3 by 5 days and between SL–3 and SL–4 by 10 days. The study indicated concern about launch abort lighting, night recovery, and circadian rhythm on SL–4 and about a reduction in the mission planning cycle between SL–3 recovery and SL–4 launch to 27 days. The Council accepted

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February

Schneider's recommendation to retain the previously scheduled launch intervals shown below. Planning would proceed on that basis.

Mission	*Launch*	*Recovery**
Skylab Workshop (SL–1)	May 14, 1973	——
First manned mission (SL–2)	May 15, 1973	June 12, 1973
Second manned mission (SL–3)	Aug. 8, 1973	Oct. 3, 1973
Third manned mission (SL–4)	Nov. 9, 1973	Jan. 4, 1974

*No nighttime recoveries were planned.

Manned Space Flight Management Council, "Summary of Proceedings," 14 February 1973; TWX, William C. Schneider to MSC, MSFC, KSC, and GSFC, "Skylab Planning," 16 February 1973.

15

The North American Rockwell Corporation and Rockwell Manufacturing Corporation merged to become Rockwell International Corporation.

Telecon, R. Newkirk, Historical Services and Consultants Co., to Lyle Burt, Rockwell International, 15 October 1974.

17

The Manned Spacecraft Center at Houston, Texas, was officially redesignated the Lyndon B. Johnson Space Center in honor of the late President.

MSC Announcement 73–34, 17 February 1973.

19

Astronaut Robert A. R. Parker was designated Skylab Program Scientist and would be responsible for ensuring that the inflight Skylab science requirements to be implemented by flight operations elements were compatible with NASA and Skylab program requirements. John R. Sevier served as Assistant Program Scientist. Parker was assigned to Skylab Program Manager Kenneth S. Kleinknecht and during actual mission operations would respond to the directions of the Skylab Program Director and the MSC and MSFC Skylab Program Managers.

MSC Announcement No. 73–32, "Key Personnel Assignment," 2 March 1973.

20

The OWS high-fidelity mockup arrived at MSFC from McDonnell Douglas, Huntington Beach. It was updated for use as a systems engineering mockup along with an AM/MDA and the ATM dynamic test articles, which were modified at MSFC for this use.

MSFC, "Weekly Activity Report," 27 February 1973.

22–23

A customer acceptance readiness review for Skylab flight food was held at Whirlpool Corporation in St. Joseph, Michigan. Items of OWS were accepted. However, the CSM flight and backup food were not accepted because of lack of

1973

February

stowage definition and the required stowage drawings in the data pack. This food would be accepted when the stowage arrangement in the CSM was defined.

JSC, "Skylab Program Office Weekly Activity Report," 2 March 1973.

February 27–May 25

The Skylab 2 spacecraft, mated to its launch vehicle, was transferred 27 February from the KSC Vehicle Assembly Building to Launch Complex 39B in preparation for launch. The SL–2 space vehicle consisted of the following major components: an S–IB (the first stage); an S–IVB (the second stage, which comprised the propulsion stages); an IU; a CSM; and an SLA. The next five paragraphs trace the SL–2 from the arrival of the component parts at KSC through liftoff.

The S–IVB stage had arrived at KSC on 24 June 1971 and was placed in storage until 17 April 1972. The CSM arrived on 19 July 1972 and was immediately moved into the Operations and Checkout Building for systems testing. The S–IB and the IU both arrived on 22 August 1972. On 5 September 1972 the S–IVB was mated to the S–IB. Three days later, 8 September 1972, the IU was mated to the S–IVB.

Since SL–2 was the first Saturn IB space vehicle to be launched from LC–39, it was necessary to verify the modified facilities and systems. Therefore, the SL–2,

The Skylab 4 crew is shown during preflight training in the Mission Training and Simulation Facility at JSC. Commander Gerald P. Carr, right, is seated at a simulator representing the control and display console of the Apollo telescope mount. Scientist-astronaut Edward G. Gibson is seated at the left, and William R. Pogue is in the left background.

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February

with a boilerplate spacecraft, was moved to LC–39B on 9 January 1973. The mobile service structure was positioned on 12 January 1973, and the fit, function, and facility systems tests required in support of the SL–2 launch were performed. The Propellant Loading All Systems Test was performed on 29 and 30 January, 1973. The SL–2 was then returned to the Vehicle Assembly Building.

On 9 February 1973 the SLA was mated to the CSM. The CSM/SLA was then moved to the Vehicle Assembly Building on 20 February 1973 and mated to the launch vehicle the following day. Transfer of the SL–2 to LC–39B was completed 27 February.

The space vehicle Flight Readiness Test was completed on 5 April 1973. The Countdown Demonstration Test began on 25 April 1973. At 8:00 a.m. EDT 9 May 1973, the launch countdown for SL–2 was started.

Because of the meteoroid shield anomaly and failure of the solar wings to deploy on the Workshop, the SL–2 launch was scrubbed on 14 May 1973 at T minus 14 hours 35 minutes (9:10 p.m. EDT 14 May), and scrub turnaround procedures started. The countdown clock was then held at T minus 59 hours until countdown resumed at 10:30 p.m. EDT 22 May 1973. SL–2 was successfully launched at 9:00 a.m. EDT on 25 May 1973 (see 25 May 1973 entry).

KSC, "Skylab 2 Post-Launch Report," 21 June 1973, pp. 7–1, 7–2.

28

During a news conference in Washington, Charles "Pete" Conrad, first manned Skylab mission commander, reviewed activities that would be conducted during the SL–2 mission.

NASA News Release, "Press Conference with Pete Conrad," 28 February 1973.

March

1

MSFC Director Rocco A. Petrone initiated an MSFC flight hardware integrity review at MSFC and contractors' facilities. The purpose of the review was to ensure integrity of MSFC-developed hardware by examining in-depth specifications, design and design changes, failures, and test results of critical hardware components and systems associated with the activation sequences. The review was scheduled to be completed before the MSFC preflight readiness review meeting in mid-April.

MSFC, "Weekly Activity Report," 20 March 1973.

8

Following two lightning strikes on *Apollo 12* while in flight and a strike on the launch umbilical tower while *Apollo 15* was on the launch pad, an intra-Center telecon with participation from NASA Hq, KSC, JSC, and MSFC was held to discuss previous studies on lightning. It was determined that analyses and corrective actions accomplished since the strikes on *Apollo 12* had reduced to a very low probability the chance of system damage to Skylab vehicles from lightning strikes.

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Memorandum for record, H. Wong, NASA Hq, "Lightning Strikes," 8 March 1973.

8 During a meeting of the Manned Space Flight Management Council, R. C. Hock (KSC) summarized the major test milestones completed and those remaining to be completed on SL–1 and SL–2 in order to meet the launch planning dates of 14 and 15 May 1973.

KSC Presentation Outline for MSF Management Council, 8 March 1973; Manned Space Flight Council, "Summary of Agreements and Action Items," 8–9 March 1973.

19 Consideration was being given to the feasibility of a second set of Skylab missions (designated Skylab-B) during the interval between the Apollo-Soyuz Test Project in 1975 and the start of Space Shuttle operations late in 1979. The inherent worth of a Skylab-B was recognized, but officials were reluctant to recommend it, on the premise that it would be unwise to allow it to delay or displace the development of the Space Shuttle and other programs already included in the FY 1974 budget.

Letter, James P. Fletcher, NASA Hq, to Lowell P. Weicker, Jr., U.S. Senate, 19 March 1973; note, William C. Schneider, NASA Hq, to Dale D. Myers, NASA Hq, "Skylab-B Planning," 15 March 1973; memorandum, William C. Schneider to Deputy Director, Budget and Program Analysis, "Request for Answer Regarding Skylab-B," 19 March 1973.

20 To reduce the possibility of fire hazards onboard spacecraft, NASA adopted a rigid materials selection and control program based on elimination of flammable materials and substitution of nonflammable or self-extinguishing materials wherever possible. Where this was not possible, flame propagation paths were eliminated. In addition, a two-gas system was adopted, fire sensors were added to the caution and warning system, fire extinguishers were installed in all elements of the Skylab cluster, and crews were trained in fire-fighting and evacuation methods.

Memorandum, Dale D. Myers, NASA Hq, to the Administrator, "Full-Scale Flammability Testing on Skylab," 20 March 1973.

25–30 The Skylab flight hardware successfully completed the first total mission operations sequence during the mission simulation and flight readiness test at KSC. The test included the SL–2 astronaut crew participation in the simulated launches of SL–1 and SL–2, mission activation and operation, deactivation, data dump, and powerdown.

KSC Skylab Spacecraft Integrated Daily Schedule, 30 March 1973.

28 The USNS *Vanguard,* a part of NASA's Space Flight Tracking and Data Network, departed Port Canaveral, Florida, for temporary duty at Mar del Plata, Argentina. The ship would provide a two-way flow of information and communication

A Martin Marietta aerospace test engineer, wired with heart-rate measuring electrodes and breathing through a metabolic analyzer hose, rides an ergometer, a device resembling a stationary bicycle, in a full-scale Orbital Workshop mockup. Martin Marietta designed and produced equipment for this experiment to enable physicians on the ground to measure oxygen consumption, body temperature, heart rate, and blood pressure during Skylab missions. The engineer on the right checks a display panel to see that the participating engineer does not exceed predetermined physical limits.—Martin Marietta photo.

Astronauts Charles Conrad, Jr., and Joseph P. Kerwin sample food in the wardroom of the Orbital Workshop during a crew station review (above). At the left, a Martin Marietta aerospace engineer checks the foot-controlled maneuvering unit in a full-scale mockup of the Skylab Orbital Workshop.—Martin Marietta photos.

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between Skylab and Mission Control Center in Houston via Goddard Space Flight Center. Upon completion of the Skylab Program, it would return to Port Canaveral. The *Vanguard* was originally designed to provide tracking and data acquisition for the Apollo flights. It played an important role in the Apollo Program.

GSFC News Release, "Vanguard Tracking Ship to Argentina for Skylab Support," 28 March 1973; Cocoa, Florida, *Today*, 28 March 1973, pp. 1B, 2B.

29

An agreement was published which provided for the optimum utilization of resources in programs and projects in which both JSC and MSFC had development roles. It would permit the direct application of each Center's institutional resources for the benefit of visiting members from the other Center.

"MSC (sic)/MSFC Inter-Center Agreement on Institutional Resources," 29 March 1973.

April 3

An ATM Naval Research Laboratory rocket calibration launch was unsuccessful due to two major discrepancies. The guidance system failed to work properly and the recovery system failed. The launch was a qualification test flight of the rocket vehicle, science package, and support equipment which would be flown during the manned Skylab mission to calibrate the Naval Research Laboratory instrument in the ATM. This calibration would establish the amount of misalignment or degradation of the optics, if any, in the ATM instrument due to the launch environment or contamination. Investigations were initiated to determine the causes of the failures.

Memorandum, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Skylab/ATM Calibration Rocket NRL Qualification Launch," 9 April 1973.

3

Studies were conducted to determine the feasibility of conducting a controlled deorbit of the Orbital Workshop. Three methods were considered: (1) using the CSM service propulsion system; (2) using the CSM reaction control system; and (3) implementing an S–II (Saturn V second stage) deorbit. The service propulsion system deorbit was assessed as not feasible; the reaction control system deorbit was considered technically feasible but, like the service propulsion system, it had an inherent program and crew safety risk associated with it. Implementation of an S–II deorbit would have serious time and cost impacts on the program. A 1970 study, which indicated that the probability of damage from the deorbiting Skylab was so small that changes which caused major impact in cost and schedule were not worth pursuing, was confirmed.

TWXs, William C. Schneider, NASA Hq, to MSFC and JSC, "OWS Deorbit," 2 March 1973; William C. Schneider to MSFC, JSC, and KSC, "SWS Deorbit," 30 March 1973; letter, Leland F. Belew and R. G. Smith, MSFC, to Director, Skylab Program, "SWS Deorbit," 12 March 1973; memoranda, William C. Schneider to Associate Administrator for Manned Space Flight, "SWS and S–II Deorbit," 3 April

1973; Dale D. Myers, NASA Hq, to Administrator, "Deorbit of Skylab Elements," 2 May 1973; Dale D. Myers to Administrator, "Workshop Deorbit," 23 June 1973.

1973

April

4–5

Reporters and commentators from the United States and several foreign countries attended a series of Skylab news briefings at MSFC. MSFC Director Rocco A. Petrone and MSFC Skylab Program Manager Leland F. Belew gave a general presentation on the program. They were followed by a series of presentations by specialists on the various systems, experiments, and research efforts connected with the Skylab missions. Tours of the high-fidelity mockup and the neutral buoyancy simulator were included during the two days.

MSFC PAO, *Marshall Star,* 11 April 1973.

5

The planning dates of 14 and 15 May 1973 were officially confirmed as the launch dates for SL–1 and SL–2, respectively. The launch planning date for SL–3 continued to be 8 August 1973; for SL–4, 9 November 1973.

TWX, William C. Schneider, NASA Hq, to JSC, MSFC, KSC, and GSFC, "Firm Launch Dates for SL–1 and SL–2," 5 April 1973.

13

A miniature, fast, analytical clinical laboratory developed by the Atomic Energy Commission's Oak Ridge National Laboratory for use on manned space stations was undergoing laboratory tests at JSC. It was expected that the new system would subsequently be used in clinical situations. The analyzer would provide a pediatrician with the capability of rapidly completing 12 simultaneous analyses of an infant through the use of only a drop of blood compared to as much as five cc's required by single analyzers. Tests would be performed in the doctor's office, with the results available within minutes. The same would apply for geriatric patients, emergency room patients, and accident victims where rapid multiple diagnoses with minimum blood samples were vital.

JSC News Release 73–37, "Analyzer Has Spinoff Potential," 13 April 1973.

16–19

Loading of the Apollo spacecraft's hypergolic propellants for a scheduled 15 May launch was completed at KSC. The next major milestone in preparing the Saturn IB/Apollo for launch would occur 23 April when the kerosene to fuel the Saturn IB booster's eight engines would be pumped aboard the first stage.

KSC News Release 75–73.

April 16–May 13

The Skylab 1 spacecraft on its launch vehicle was moved to Launch Complex 39, Pad A, on 16 April. The SL–1 space vehicle consisted of two launch vehicle stages, an instrument unit, and the three major payload modules of the Saturn Workshop (SWS). The two launch vehicle stages and IU (S–IC, S–II, and S–IU) were identical to the first and second launch vehicle stages of the Apollo Saturn V space vehicle. The SL–1 payload consisted of the Orbital Workshop

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April

(a converted S–IVB stage), airlock module/multiple docking adapter, Apollo telescope mount, payload shroud, nose cone, and experiments.

The S–II stage had been the first to arrive at KSC, on 1 April 1971, and was placed in storage. The stage underwent modifications for approximately one year. On 16 July 1972, the S–IC stage had arrived and was erected on Mobile Launcher 2 on 2 August. The S–II stage was mated to the S–IC stage on 20 September.

Both the ATM and the OWS arrived at KSC on 22 September 1972. The ATM was moved into the Operations and Checkout Building cleanroom, checked out, and moved to the Vertical Assembly Building. The OWS was moved to the Vertical Assembly Building and stacked on 29 September. On 26 October, the IU stage arrived at KSC; it was mated to the OWS on 1 November. The AM/MDA arrived at KSC on 6 October and was moved into the Operations and Checkout Building. Docking tests between the SL–2 CSM and the AM/MDA were conducted. The AM/MDA was flight-mated to the fixed airlock shroud (FAS) and docking adapter (DA), and on the following day the AM/MDA/FAS/DA was mated with the payload shroud. This section of the payload was then moved to the VAB and was mated to the OWS. The ATM was mated to the DA on 30 January 1973.

System testing began on the payload modules and the launch vehicle stages. Testing included both intra- and intermodule/stage testing, including SWS mission simulation flight readiness test and launch vehicle flight readiness test. The nose cone was installed on 8 April, and SL–1 transfer to Pad A was completed on 16 April.

High winds delayed the connection of environmental control system air and prevented internal access to the spacecraft until late on 17 April.

Skylab 1 countdown demonstration test started at T minus 123 hours at 7:00 p.m. EDT, 26 April. Final stowage of the ATM cameras and film in the MDA stowage locker and flight closeout of the MDA was completed on 27 April. Final closeout of the AM/MDA was completed on 1 May, and the EVA hatch was secured for flight.

Launch countdown began at 2:00 a.m. EDT, 9 May. A small amount of rain fell into the ATM area during a thunderstorm that day, but affected areas were temporarily covered. High winds prevented further weatherproofing of the payload shroud nose cap until 10 May. The Mobile Launcher 2 lightning mast was struck by lightning at 12:57 p.m. EDT on 9 May. Lightning retest operations on the launch vehicle and spacecraft were successfully completed. No anomalies attributed to the lightning were noted.

KSC, "Skylab 1 Post-Launch Report," 8 June 1973, pp. 7–1, 7–2.

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17

NASA Hq issued a policy instruction on accountability for experiment materials returned from the Skylab missions. The purposes of the instruction were to ensure the integrity of the experimental data in the returned material and to prevent loss, theft, or unauthorized use or disposition of such material.

Skylab Program Directive No. 61, "Skylab Policy on Accountability for Experiment Materiel Returned from the Skylab Missions," 17 April 1973.

17–20

The final NASA top management review and approval of the launch and mission readiness was completed in a flight readiness review at KSC. Items covered in the review ranged from modules and launch vehicles readiness to missions and operations support. Following the review, NASA Skylab Program Director William C. Schneider said, "We still have a few things to be closed out, but we have assured ourselves that the systems are all working with one or two minor open items and we're still ready to go for a 14 May launch of Skylab 1 and a 15 May launch of Skylab 2."

Transcript.

18

KSC and MSFC were directed by NASA Hq to implement a reduction in force of contractor personnel immediately following the launches of SL–1 and SL–2, but to maintain a sufficient complement for a backup launch capability through 30 September 1973.

TWX, William C. Schneider, NASA Hq, to KSC, MSFC, and JSC, "Post SL–1/2 Launch Manpower Planning," 18 April 1973.

25

Since the adjustment of the Skylab launch dates, KSC updated rescue response times. The new SL–R rescue response times are shown in the following table:

Days from SL Mission Launched	*Days to SL–R Ready for Launch*		
	SL–2	*SL–3*	*SL–4*
0	48½	48½	48½
7	41	41	41
14	36½	35	36
21	31½	31½	31½
28	25	27	26
35	——	21	19½
42	——	16½	15
49	——	15½	15
56	——	14	12½

Letter, R. C. Hock, KSC, to Dist., "Skylab Rescue," 25 April 1973.

Three astronauts examine equipment storage in the spacious interior of Skylab's multiple docking adapter during acceptance checkout of the flight article at the Martin Marietta facility in Denver. Left to right are William B. Lenoir, Paul J. Weitz, and Jack R. Lousma. The docking adapter served as a major experiment control center and the docking port for Skylab.—Martin Marietta photo.

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1 Individual and group behavioral evaluations, which were discontinued following the 14-day flight of *Gemini VII*, were being reinstituted for the Skylab flights because of the longer duration of the SL–2, 3, and 4 missions. Information obtained from these evaluations would provide additional data useful in future diversified crew selection and expected performance in future long-duration flights.

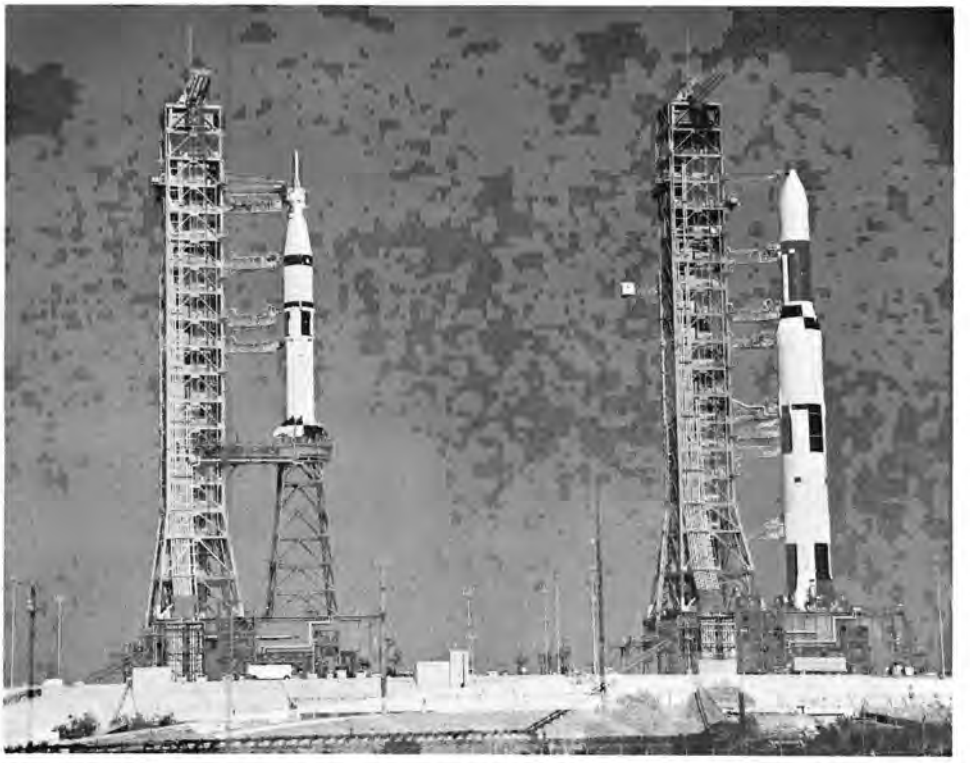
Letter, Dale D. Myers, NASA Hq, to Christopher C. Kraft, Jr., MSC, "Behavioral Evaluation of Skylab Crews," 1 May 1973.

3 Three types of private conversations were authorized for Skylab missions by the NASA Administrator: private phone calls from astronauts to their families once a week, conversations required by extreme operational emergency, and routine medical conversations. In the cases of operational emergency and medical conversations, bulletins would be issued to the news media. Bulletins or public announcements of crew member conversations with their families would not be made.

Memorandum, James C. Fletcher, NASA Hq, to the Associate Administrator for Manned Space Flight and the Assistant Administrator for Public Affairs, "Private Communications for Skylab," 3 May 1973; NASA News Release 73–110, "Fletcher Statement on Skylab Private Communications," 1 June 1973.

8 A fund of unsolicited cash contributions, which started in 1959 and contained $5548, would be used to defray the cost of equipment for student scientific experiments on Skylab. NASA was authorized by the Space Act of 1958 to accept unrestricted gifts.

NASA Hq News Release 73–98, "NASA Gift Fund Used for Skylab Student Experiments Program," 14 May 1973.



A double exposure of the Skylab 1 and Skylab 2 space vehicles, actually 2.4 km apart on their launch pads. The unmanned Skylab 1, at the right, was launched 14 May 1973 on the last Saturn V to be flown. *Skylab 2,* with the smaller Saturn IB perched on the "barstool" support tower, lofted astronauts to rendezvous with *Skylab 1* on 25 May 1973.

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Lightning struck the Skylab 1 launch umbilical tower near swing arm eight at 1:00 p.m. Lightning retest plans were satisfactorily completed on the AM, MDA, and ATM. No significant anomalies due to the lightning static were revealed.

"Skylab Engineering Weekly Status Report," 9 May 1973.

14

Skylab 1, the unmanned Orbital Workshop (OWS) was launched from KSC Launch Complex 39A at 1:30 p.m. EDT. (See item for 16 April–13 May for countdown detail.)

An unexpected telemetry indication of meteoroid shield deployment and solar array wing 2 beam fairing separation was received 1 minute and 3 seconds after liftoff. However, all other systems of the OWS appeared normal, and the OWS was inserted into a near-circular Earth orbit of approximately 435 km altitude.

The payload shroud was jettisoned, and the ATM with its solar array was deployed as planned during the first orbit. Deployment of the Workshop solar

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array and the meteoroid shield was not successful. Evaluation of the available data indicated that the following sequence of events and failures occurred:

Time from Liftoff (hr:min:sec)	*Event*
0:01:02.9	Meteoroid shield tension strap 2 separated.
0:01:03	Meteoroid shield tension strap 1 and 3 separated.
0:01:03	Solar array system wing 2 beam fairing separated.
0:01:30	Meteoroid shield temperatures went off-scale.
0:01:30	Partial deployment of meteoroid shield was indicated.
0:10:00	Thermal measurements on wing 2 solar array panels ranged from 345 K (161°F) to 389 K (240°F), rather than the expected temperature of about 300 K (80°F). Wing 1 temperatures remained normal.
0:55:55.9	Wing 1 beam fairing separated.

Solar array wing 1 was released, but there were indications that the wing had not fully deployed. Wing 2 was inoperative or had encountered structural failure. Temperature excursions in the OWS showed that the meteoroid shield was not affecting the temperatures as intended. The remainder of the planned Workshop system activation and deployment functions occurred as scheduled with transfer of attitude control from the instrument unit to the OWS approximately 4½ hours after liftoff.

The OWS was maneuvered into a solar inertial attitude, with the plane of the solar arrays normal to the Sun for maximum electric power generation. The OWS area temperature then rose above operating limits. The Workshop was subsequently pitched up toward the Sun at 13 hours into the flight to reduce the solar incidence angle on the OWS area. This attitude further reduced the power generation capability which had already been severely limited by the loss of the Workshop solar array wing 2 and the failure of wing 1 to deploy. A continuing adjustment of attitude was necessary to keep the power and temperature within acceptable limits. Constraints to maintain adequate heat in other critical areas of the Workshop and to optimize the operation of the attitude control system in an off-nominal mode added further complications. This delicate balance continued for approximately 10 days.

The electrical power available from the ATM solar array was further reduced by the requirement to cycle certain power regulator modules on and off to pre-

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vent the overheating caused by unplanned vehicle attitudes. Although considerably below the total design capability of approximately 8500 watts, the power was sufficient for the critical loads. Many components and systems were turned off or were cycled as required to remain within the power generation capability.

The high internal temperatures that were reached in the Workshop could have caused outgassing of some materials which would have been hazardous to the crew. Therefore, before crew arrival, the habitation area was depressurized and repressurized four times with nitrogen to purge the outgassing products. The final repressurization was with the proper oxygen/nitrogen mixture for the crew.

Maneuvering into and out of the various thermal control attitudes and maintaining attitude hold and control during several docking attempts caused a much larger use of the Workshop thruster propellant than predicted. Sufficient propellant remained, however, for the three manned missions.

JSC, *Skylab Mission Report First Visit,* JSC-08414, August 1973, pp. 2 and 4; JSC, "Skylab Program Office Weekly Activity Report," 18 May 1973.

22

A Skylab 1 Board of Investigation was established to investigate the anomalies that occurred during the launch and Earth orbit of SL-1. Bruce T. Lundin (Lewis Research Center) was named chairman of the Board.

Letter, James C. Fletcher, NASA Hq, to Bruce T. Lundin, "Skylab 1 Investigation Board," 22 May 1973; memorandum, James C. Fletcher to Associate Administrator for Manned Space Flight, "Investigation of Skylab 1 Anomalies," 22 May 1973; NASA Notice 1154, "Skylab 1 Investigation Board," 22 May 1973.

23

NASA Administrator James C. Fletcher briefed members of the Senate on the anomalies that occurred during liftoff and orbit of Skylab 1. Fletcher summarized as follows:

1. We encountered unexpected problems with the micrometeroid shield and the workshop solar arrays.

2. These problems led to overheating and reduced power.

3. We believe we can control the heating by one of several fixes executed by the crew of Skylab 2.

4. We will try to improve the power situation, but even if we can't, there is enough for nearly normal execution of the 28- and 56-day missions.

They are going to look at the condition of the solar panels. They are not going to spend too much time on that because we have enough power. If it looks like an easy thing to do, if one of the panels, which is missing here, is partially deployed and is hung up on something and all it needs is a little tug, we will put a loop of twine around the end of it, play it out so that we are well away from the panel in case it starts to deploy, and give a little tug on the twine. If it deploys, fine; but if it does not, we will go on without it.

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But we are not going to spend too much time on that fix. There are too many uncertainties and we do not really need the power.

5. We will be unable to carry out some 3 out of the planned 87 experiments. This is normal for almost any test of this complexity. Usually we aren't able to complete the large number of experiments that are planned. In this particular case we estimate that three of them will not be able to be carried out. Those are primarily the ones that would have come out of the airlock. If there is a sunshade over the airlock you can't do very many experiments from it.

The remaining experiments, in our judgment, fully warrant going ahead with the repair activity and then executing as much of the fully planned program as possible.

6. There will be no relaxation of safety considerations in the conduct of the replanned Skylab missions.

7. We have established a Skylab 1 investigation board whose findings will be reported to the committee as soon as available.

In closing, let us say that the crew, the Skylab team, and NASA management are cautiously confident—some more than others, but all are optimistic—that the Skylab 2 mission will be a historic one and that it will permit us to meet almost all of the major objectives of the Skylab program.

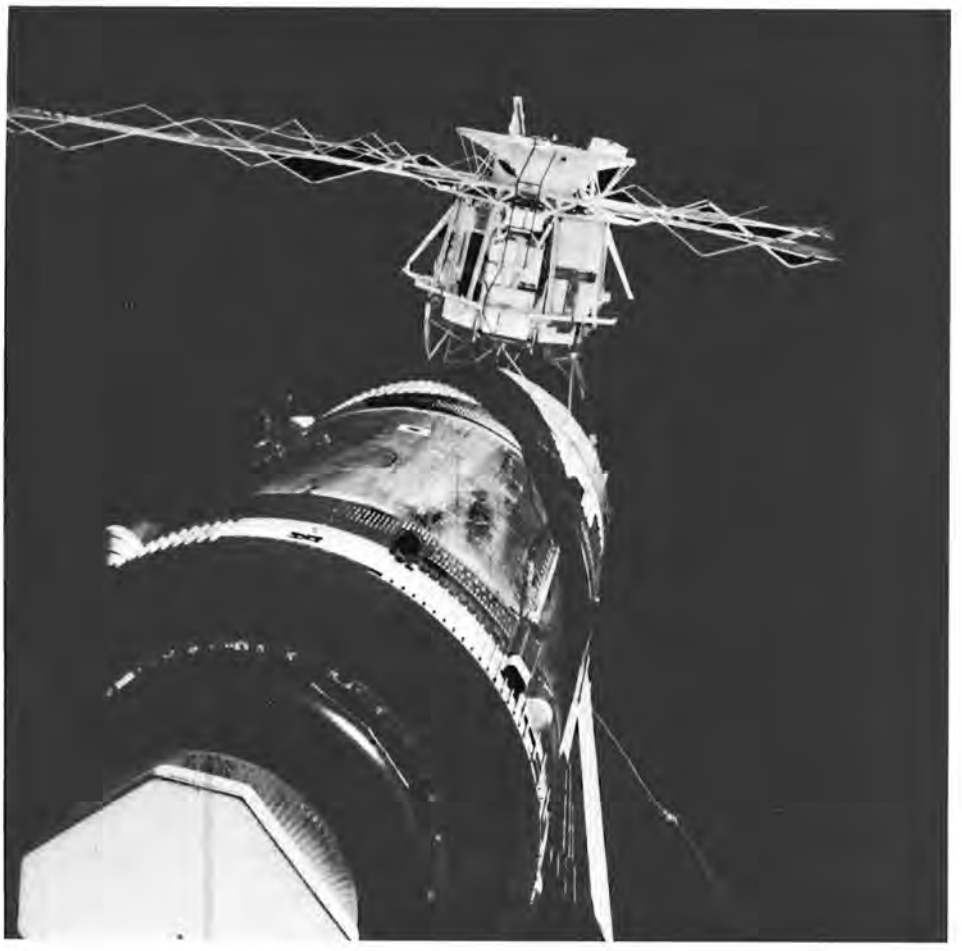
U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Skylab: Hearing on Status of Skylab Mission,* 93d Cong., 1st sess., 23 May 1973, pp. 4–17.

23–24 A design certification review was held for the revised Skylab 2 mission. The review board determined that a "Skylab parasol," with a strengthened ultraviolet resistant material, deployed through the scientific airlock would be the prime method for the deployment of a thermal shield on the Orbital Workshop. A "twin pole" thermal shield and a standup extravehicular thermal sail would be flown as backup methods. Following final assessment of mission readiness with favorable recommendations, a certification of flight worthiness for the new hardware was executed.

Letters, William C. Schneider, NASA Hq, to SL–1 and –2 Flight Readiness Review Board, "Confirmation of Flight Readiness for SL–2 Launch," 31 May 1973; William C. Schneider to Dist., "Skylab Design Certification Review of New or Changed Equipment and Procedures for Revised SL–1/SL–2 Mission," 11 June 1973.

25 At 9:00 a.m. EDT, *Skylab 2* lifted off from Pad B, Launch Complex 39 at KSC. The vehicle was manned by astronauts Charles "Pete" Conrad, Jr., Joseph P. Kerwin, and Paul J. Weitz.

Skylab 2, consisting of a modified Apollo CSM payload and a Saturn IB launch vehicle, was inserted into Earth orbit approximately 10 minutes after liftoff. The orbit achieved was 357 by 156 km and, during a six-hour period following insertion, four maneuvers placed the CSM into a 424 by 415 km orbit for



The wounded Skylab Orbital Workshop was photographed by the *Skylab 2* crew during a flyaround before docking with the Orbital Workshop on 25 May 1973. The micrometeoroid shield is missing; the solar array wings are missing or undeployed.

rendezvous with the Orbital Workshop. Normal rendezvous sequencing led to stationkeeping during the fifth revolution followed by a flyaround inspection of the damage to the OWS.

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The crew provided a verbal description of the damage in conjunction with 15 minutes of television coverage. The solar array system wing (beam) 2 was completely missing. The solar array system wing (beam) 1 was slightly deployed and was restrained by a fragment of the meteoroid shield. Large sections of the meteoroid shield were missing. Following the flyaround inspection, the CSM soft-docked with the OWS at 5:56 p.m. EDT to plan the next activities. At 6:45 p.m. EDT the CSM undocked and extravehicular activity was initiated to deploy the beam 1 solar array. The attempt failed. Frustration of the crew was compounded when eight attempts were required to achieve hard docking

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with the OWS. The hard dock was made at 11:50 p.m. EDT, terminating a *Skylab 2* first-day crew work period of 22 hours.

JSC, "Skylab Mission Report First Visit," JSC-08414, August 1973, p. 2-1; R. V. Gordon, JSC Skylab News Center, "Skylab 1/2 Quick Look Reference," 2 July 1973, p. 3.

26

The second manned day of the Skylab mission was focused on entry into the OWS and deployment of the Skylab parasol. The crew removed and inspected the docking probe and drogue. They then entered the MDA to activate the airlock module and MDA systems. The crew entered the OWS at 3:30 p.m. EDT. The atmosphere, although hot, was habitable, and the crew was able to work in the environment for 10- to 15-minute intervals. At 5:00 p.m. the crew began deployment of the parasol; the task was completed at 7:30 p.m.

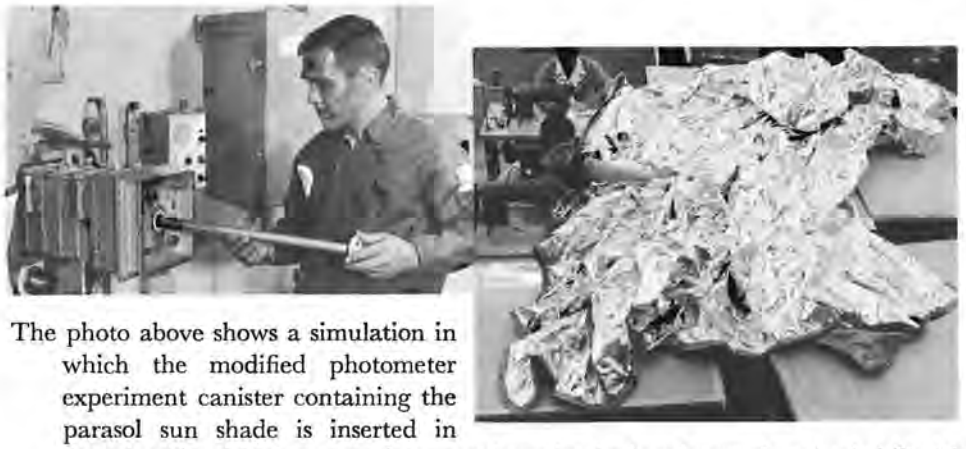
The parasol provided thermal shielding for the area of the Workshop exposed to the Sun because of the missing meteoroid shield. The parasol concept, design, development, construction, and delivery to KSC was completed in seven days by JSC. Two other thermal protection devices were also devised and delivered during this same time period. One was a sail, produced by JSC and designed to be deployed by an extravehicular crewman standing in the command module hatch while the spacecraft was being flown in close to the OWS. The other, called a twin-boom sunshade and produced by MSFC, was designed to be deployed by extravehicular crewmen from the ATM station.

The parasol provided a thermal protective device which was simple, and deployment could be accomplished from within the OWS in a shirt-sleeve environment. The system was capable of being jettisoned.

The parasol concept made use of a spare experiment T027 (ATM contamination measurement) canister which was designed to interface with the solar scientific airlock. The seal design used in the back plate of the experiment canister was incorporated into a new back plate required for the parasol. This allowed the use of deployment rods which were of the same type used for experiment deployment, and also allowed use of the experiment T027 photometer ejection rod, if jettisoning became necessary.

Major components of the parasol, other than the modified canister, were a 6.7- by 7.3-m aluminized Mylar/nylon laminate canopy that was partially opaque to solar thermal energy, a canopy mast, a mast hub with deployment springs, four telescoping deployment rods, seven extension rods, and the experiment T027 canister support tripod.

Deployment was accomplished through the solar scientific airlock by attaching the extension rods to the mast and pushing the rod assembly outward. As the mast hub was extended to 4.9 m above the opening of the airlock, the telescoping deployment rods became fully extended and locked and the tip retainers



The photo above shows a simulation in which the modified photometer experiment canister containing the parasol sun shade is inserted in the scientific airlock so that the parasol can be deployed over the crippled Skylab space station.—Martin Marietta photo. At right, Dolores Zeroles, foreground, and Ceal Webb of International Latex Corporation sew a solar shield from a nylon-base material to be used on the twin-pole shade designed at MSFC.

for the telescoping rods were released. The mast hub was then extended to 6.4 m above the outer surface of the OWS, allowing the rod tips to swing free of the solar scientific airlock opening and deploy the canopy. The parasol was then retracted to its final position a few centimeters above the OWS outer surface. During the retraction process, the long extension rods were removed, and the short extension rod was left in place. 1973 May

OWS temperatures started dropping immediately upon parasol deployment. The initial temperature drop for the outer wall exceeded 36 K (65°F) per hour. Temperatures within the OWS, though dropping at a much slower rate, were below 311 K (100°F) within a day of deployment. The inside temperature continued a steady decline until stabilization was reached somewhat below 297 K (75°F). At the end of the first visit, the temperatures increased because of the increase of daytime exposure for the orbital plane at that time of the year.

R. V. Gordon, JSC Skylab News Center, "Skylab 1/2 Quick Look Reference," 2 July 1973, p. 3; JSC, "Skylab Mission Report First Visit," JSC-08414, August 1973, pp. 2-2, 3-1, and 3-6; abstract, J. A. Kinzler, JSC, "The Skylab Parasol," ca. January 1974.

A Skylab Program Director's meeting was held to identify further actions required for the SL-2 mission and actions required for the SL-3 mission. The following agreements were reached: 27

- The parasol installed on the OWS would not be jettisoned until a replacement thermal shield was on board, if a twin-boom thermal shield had not been deployed during the SL-2 mission.
- The twin-boom sunshade and the JSC sail would be retained in the OWS at the end of the SL-2 mission.

"Minutes of Skylab Program Director's Meeting," 27 May 1973.

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Following the successful deployment of the parasol, the Skylab–2 crew began to transfer and store equipment and activate experiments. On 29 May, everything in the OWS was turned on for the first time. The crew checked out the EREP and the ATM.

On 7 June astronauts Conrad and Kerwin performed an EVA to free the undeployed OWS solar array. EVA began at 11:15 a.m. EDT. At 2:01 p.m., the strap restraining the solar wing was severed, the beam was fully deployed, and the three panels had begun to deploy. The 3-hour 25-minute EVA was completed at 2:40 p.m. By 8:55 p.m., all the solar array system solar power sections were deployed, and the OWS power crisis had abated.

At 3:22 a.m. EDT, 18 June, the crew of SL–2 broke the space flight record of 570 hours 23 minutes set by the Soviet *Soyuz 11* flight in June 1971.

During the SL–1/SL–2 mission, the following experiments were conducted:

- Medical—all medical experiments were successfully conducted with a completion range of 80 to 100 percent.
- Apollo telescope mount—82 hours of manned viewing time and 154 hours of ground commanded data gathering were accomplished.
- EREP—11 passes with a full range of instrument operation and task site assignments were completed. (Prelaunch planning called for 14 passes.)
- Corollary—56 hours of crew time were devoted to these experiments. (Prelaunch planning called for 64 hours.)

A breakdown of the actual crew time allocation for experiments as opposed to the preflight plan is shown in the following chart.

Category	Manhours Utilization, hr:min (percent of total)	
	Actual	Preflight Allocation
Medical experiments	145:13 (7.4)	157:51 (8.0)
Apollo telescope mount experiments	117:09 (6.0)	152:51 (7.7)
Earth resources experiment package	71:24 (3.6)	85:55 (4.3)
Corollary experiments	54:24 (2.8)	62:20 (3.2)
Subsystem detailed test objective	7:03 (0.4)	7:07 (0.4)
Student experiments	3:41 (0.2)	4:41 (0.2)
Operational[a]	1562:07 (79.6)	1509:39 (76.2)

[a] Includes sleeping, eating, housekeeping, etc.

TWX, G. S. Lunney, JSC, to American Embassy Science Attache, Moscow, U.S.S.R., 22 June 1973; R. V. Gordon, JSC Skylab News Center, "Skylab 1/2 Quick Look Reference," 2 July 1973; NASA Hq Post Launch Mission Operations Report No. M-960-SL-1/SL-2, 14 July 1973.

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The following editorials were typical of those evoked by the launch of *Skylab 1* with its attendant anomalies. The first editorial quoted is from the Los Angeles *Times*.

> The men of NASA at Cape Kennedy and Houston were getting ready to pass another miracle, but there had been so many—the first men on the moon followed by a succession on moon landings—that the success of the latest adventure in space was taken for granted. Even the crowd of spectators on the cape was less than a quarter of the million persons who watched the last of the Apollo moon missions Dec. 7.
>
> The launch went smoothly, as Skylab, an 85-ton vehicle perched atop a Saturn 5 rocket, ascended majestically May 14 from a roaring flame and disappeared into the heavens on its journey into orbit 270 miles above the earth. "Everything looks super-good so far," Mission Control in Houston reported, and Skylab, the largest weight ever thrust into space, began to respond to radio signals.
>
> Minutes later, the $2.6 billion project was in trouble. Two solar panels failed to deploy. The launching of three astronauts, scheduled to dock in space with Skylab the next day, had to be postponed. Skylab 2 was recycled for five days until May 20 and again for May 25, last Friday. What was needed was a simple little plan to shield the space laboratory from the sun—something like an umbrella.
>
> An umbrella. Why, of course, Jack Kinzler, a NASA technician with a reputation as a fix-it man, started thumbing through the Yellow Pages. He found what he was looking for—fishing poles that would telescope down to 18 inches. Using the poles as ribs, he and other technicians constructed an umbrella with a 24-by-28 foot expanse of coated nylon, designed so that the collapsed umbrella could be projected through an 8-by-8 inch airlock passage and deployed over the laboratory.
>
> It was packed, handy-like, in a small metal box and placed in Skylab 2 when the three astronauts were launched into space for their delayed rendezvous with Skylab 1. The astronauts poked the umbrella through the airlock in careful stages. The gadget worked. [A more sophisticated version of Kinzler's idea was produced and flown.]
>
> It wasn't much, really. Just a few fishing poles and a spread of nylon. In all, a modest little miracle, but enough. Enough to save Skylab and enough to give a lift to the spirit of all who followed the latest human drama enacted in space.

The following editorial is taken from *Test* magazine.

> IN OUR PRESENT pre-occupation with consumer products and problems, it is easy to forget the miracles of our great space projects. Skylab's failures tend to bring space and space testing back into focus.
>
> It is possible to speculate, as some authorities are doing already, that the damage done to Skylab on its way into orbit was due either to (a) the unanticipated

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effects of vibration in the Saturn rocket or (b) the under-design of the failed Skylab components or (c) a combination of both.

In any event, it would seem likely that insufficient testing was done in the effort to live within what is generally considered to be a too-tight budget. After the vast achievements of Project Apollo, one would think that the accumulated knowledge of NASA as to how to achieve the essential near 100% reliability in a space flight would have caused NASA managers to throw out enough stern warnings to Congress and to the public about underfinancing and possible failures. In a project running to two and one-half billion dollars, perhaps another $250 million (10%), for example, for more testing and redesign might have made the difference. At this writing, three highly intelligent, highly trained, highly motivated men are out there trying with all their ingenuity and that of NASA to salvage some part of this all-important basic Skylab mission. Of course, their success in this attempt is fervently prayed for by everyone.

"A Modest Little Miracle," Los Angeles *Times*, 30 May 1973; R. H. Mattingley, Editor's Page, *Test* Magazine, June 1973.

31 During a Manned Space Flight Management Council telecon, four agenda items were discussed: an early launch date for SL–3; plans for an EVA solar array system repair; deorbiting of the Skylab cluster; and lengthening the SL–2 mission.

The Council decided to go for a 27 July launch date, with the possibility of a further acceleration on a crash effort basis to 22 July if possible degradation of hardware because of unexpected thermal stresses required an earlier launch. Decisions on the other three agenda items were deferred pending further study.

"Minutes of Management Council Telecon," 31 May 1973; memorandum, Dale D. Myers, NASA Hq, to Associate Administrator through Deputy Administrator, "Launch Date for SL–3," 8 June 1973.

June

1 William C. Schneider, NASA Hq, expressed regret that certain experiments would be deleted from the Skylab Program because of loss of the micrometeoroid thermal control shield and the subsequent deployment of the parasol. Schneider also requested that Principal Investigators wishing to make changes in their experiments' protocol submit proposed changes by 5 June 1973, in order that the changes might be reviewed by the Skylab advisory group for experiments.

TWX, William C. Schneider to JSC, MSFC, Dudley Observatory, Naval Research Laboratory, Martin Marietta Corporation, Denver Div., and Westinghouse Electric Corporation, Pittsburgh, "Deletion of Change in Protocol for Certain Experiments on Skylab Missions," 1 June 1973; memorandum, William C. Schneider to Associate Administrator for Manned Space Flight, "Experiments Deleted from Skylab SL–1/SL–2 Mission—Costs, and Alternate Approaches for Operation on SL–3/SL–4 Missions," 22 June 1973.

4 Testing began on 1200 OWS flight food samples and 5 cu m of ground test analytical food samples. They would be exposed to a thermal profile simulating that on the OWS, to verify that the food safety and quality had not been com-

promised by the 17 days of high temperature to which the OWS had been subjected. 1973 June

JSC, "Skylab Program Office Weekly Activity Report," 15 June 1973.

The Skylab 3 space vehicle was moved to KSC Launch Complex 39, Pad B, on 11 June in preparation for launch. The space vehicle consisted of a Saturn IB launch vehicle—S–IB–207 first stage, S–IVB–207 second stage, and a S–IU–208 instrument unit; a CSM; and a spacecraft lunar module adapter. The SL–3 crew consisted of commander Alan L. Bean, science pilot Owen K. Garriott, and pilot Jack R. Lousma. June 11–July 28

On 6 June, the SL–3 launch date had been changed from 8 August to 27 July; the launch date was subsequently changed to 28 July to optimize the rendezvous conditions. The prelaunch checkout was accelerated accordingly.

The S–IVB stage had arrived at KSC on 26 August 1971 and was placed in storage until 28 November 1972. The CSM arrived on 1 December 1972 and was moved into the Operations and Checkout Building for systems testing. The S–IB stage arrived 30 March 1973 and was erected on Mobile Launcher 1 on 28 May. The IU arrived at KSC 9 May.

The S–IVB and IU were mated to the S–IB 29 May. On 7 June the CSM/spacecraft lunar module adapter was moved to the Vehicle Assembly Building and mated to the launch vehicle the following day. SL–3 transfer to LC–39B was completed on 11 June.

On 17 June, the mobile launcher and mobile service structure sustained several lightning strikes. The damaged parts for the CSM, mostly instrumentation, were replaced and retested or waived. The damaged ground support equipment parts were replaced and retested. The launch vehicle lightning retest revealed no related failures or effects on the launch vehicle or ground support equipment.

The flight readiness test was completed on 29 June. The final countdown began at 7:00 a.m. EDT 25 July in preparation for a 28 July launch (see 28 July entry).

KSC, "Skylab 3 Post-Launch Report," 20 August 1973, pp. 7–1, 7–2.

A review was conducted at NASA Hq to determine whether the astronaut maneuvering unit and foot controller maneuvering unit could be safely used within the confines of the OWS. It was concluded that the units could be safely operated, and approval was given for scheduling their use. Previously, a decision to operate the units had been deferred until a more thorough briefing could be provided. Concern over their use had been based on the Aerospace Safety Advisory Panel Report on Skylab. 15

Astronauts Edward G. Gibson and Russell L. Schweickart are shown in the MSFC Neutral Buoyancy Tank, above, simulating use of various cutting tools to be used by the *Skylab 2* crew in an effort to free the Workshop's solar wing. At right, the Saturn IB launch vehicle to be used for the Skylab 3 mission is shown as it was rolled out to Launch Complex 39–B on 11 June 1973.

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Memorandum for record, R. A. Aller, NASA Hq, "Deputy Administrator Briefing on Skylab Experiments M509/T020," 21 June 1973.

June

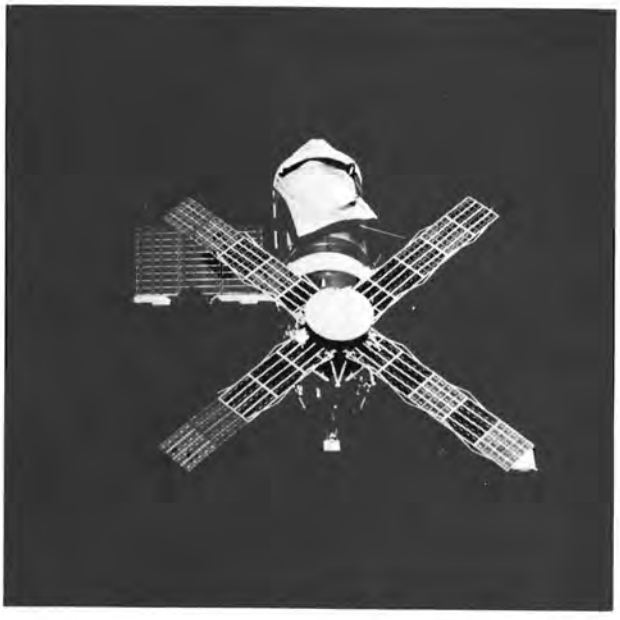
20 A recommendation to jettison the docking ring and probe assembly on SL–2 while the crew was unsuited was reaffirmed. Major considerations in arriving at the recommendations were that a suited landing was unacceptable, the additional risk of performing the operation unsuited was extremely low, and the crew had trained premission and in flight using the proposed timeline for an unsuited jettison of the docking ring and probe assembly.

Memorandum, Dale D. Myers, NASA Hq, to the Deputy Administrator, "Separation of Docking Ring and Probe Assembly," 20 June 1973.

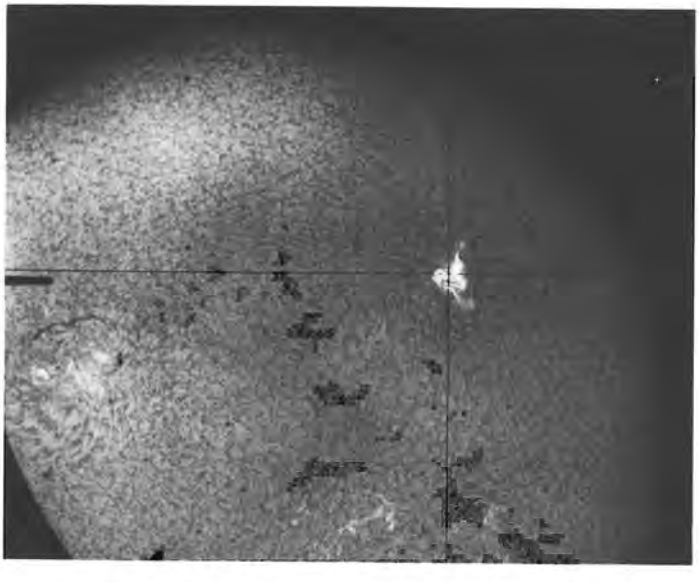
22 At 9:49 a.m. EDT, *Skylab 2* splashed down in the Pacific Ocean 9.6 km from the recovery ship, U.S.S. *Ticonderoga,* and 1320 km southwest of San Diego. At 10:28 a.m., the crew and spacecraft were aboard the *Ticonderoga.*

The objectives of the SL–1/SL–2 mission were to establish the Orbital Workshop in Earth orbit, obtain medical data on the crew for use in extending the duration of manned space flight, and perform inflight experiments. A summary

When *Skylab 2* rendezvoused with the crippled Orbital Workshop, a pressing assignment was to draw in close and assess the damage. This closeup photograph (above) shows the underside of the partially deployed solar array wing. The dangling aluminum strap, debris from the destroyed meteoroid shield, was jamming the deployment mechanism. On 7 June, astronauts Charles Conrad, Jr. (top, in background), and Joseph P. Kerwin clambered out in their space suits to try to cut away the strap and free the wing. Conrad holds the cable cutter while Kerwin holds him. After some struggle Conrad was successful; the wing fully deployed and the Workshop was operational.



The photograph above, left, shows central Florida and was taken from an altitude of 432 km by the *Skylab 2* crew on 13 June 1973. The outlines of the Green Swamp area are (1) Zenith Acres; (2) Groveland Ranch Estates; and (3) Groveland Ranch Acres. The city of Orlando is at center right. Above right is an overhead view of the Skylab space station as photographed from the *Skylab 2* CSM during its final flyaround inspection.



Above is a photo of a significant solar flare reproduced from a frame of flight film recovered from the Hydrogen Alpha telescope No. 1 and returned on *Skylab 2*. The solar flare occurred on 15 June 1973.

The *Skylab 2* mission was completed when the spacecraft was hoisted aboard the U.S.S. *Ticonderoga* 1320 km southwest of San Diego, 22 June 1973, at the conclusion of its 28-day stay in space.

assessment of the mission objectives indicated a very high degree of completion, particularly when the reduction in experiment time due to parasol deployment, solar array wing deployment, and OWS system anomalies were considered. Primary mission objectives were accomplished, and a majority of the assigned experiment-detailed objectives were completed.

The following conclusions were drawn from the SL–1/SL–2 mission:

• Resolution of the seemingly insurmountable system difficulties that occurred on the flight demonstrated the advantage of having man on board space vehicles.

• The flight demonstrated that for long-term manned and unmanned space flight, provisions needed to be made for unforeseen inflight repair and

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maintenance in the form of accessibility, handholds, tools, facilities, materials, and hardware appropriate for interior and exterior operation.

- There were no operationally significant physical or psychological health problems associated with the space vehicle environment for the 28-day visit. There were no findings that would preclude longer duration visits.
- The habitability provisions were satisfactory and contributed to the ability of the crew to work effectively for a visit of this duration. No factors were identified to preclude longer duration visits.
- Operation of the command and service module systems in a semiquiescent state was demonstrated for the 28-day period. No factors were identified which precluded operation for longer periods.
- Extensive scientific data were returned in all planned experiment disciplines.
- The methods and techniques employed in the daily flight planning provided the flexibility to react to major departures from preflight plans and constraints. This ability was an important factor in optimizing the scientific return.
- The various experiment groups were organized effectively within each discipline and functioned well as a unit. In addition, with the excellent cooperation between the various experiment groups, flight planning techniques were effective in resolving interdisciplinary conflicts and integrating the diverse experiments program.
- Long-duration flight with sophisticated multidiscipline experiments generated large amounts of data requiring ground data handling and processing capabilities.
- Overall objectives of the visit were accomplished.

Memorandum, Dale D. Myers, NASA Hq, to Administrator, "Skylab Mission SL–1/SL–2," 10 July 1973; Post-Launch SL–1/SL–2 Mission Operation Report No. M–960–73–01102, 14 July 1973; TWX, G. S. Lunney, JSC, to Science Attache, American Embassy, Moscow, 22 June 1973; JSC, *Skylab Mission Report First Visit,* JSC–08414, August 1973, pp. 14–7 and 18–1.

July

2

NASA Hq issued guidelines for the preparation of a Skylab mission evaluation report that would consist of a unified set of individual reports or sections. The report, which would be prepared by NASA Hq and the three manned spacecraft Centers, would cover such areas as summary and objective assessment, Skylab vehicle description, Orbital Workshop, command and service modules, crew equipment and activities, experiments, pilots' report, and operations.

Letter, William C. Schneider, NASA Hq, to Dist., "Guidelines for Preparation of Unified Skylab Mission Evaluation Report," 2 July 1973; JSC, "Skylab Program Office Weekly Activity Report," 13 July 1973; Skylab Program Directive No. 35, "Skylab Mission Evaluation Requirements," 22 April 1971.

3

The launch date for Skylab 3 was officially established as 28 July 1973. The launch window would open at 7:08 a.m. EDT for 10 minutes and would provide for a rendezvous in five revolutions. Recovery of SL–3 was planned for 22 September 1973.

Two members of the Skylab 3 crew, Jack R. Lousma, left, and Owen K. Garriott, center, inspect a part of the twin-pole solar sail at MSFC (above). At right, Lousma practices erecting the solar sail over a portion of the Orbital Workshop mockup in the MSFC Neutral Buoyancy Tank. Nylon netting was used for this underwater training instead of the aluminized fabric the actual sail was made of.

TWX, William C. Schneider, NASA Hq, to JSC, KSC, and MSFC, "SL–3 Launch Date," 3 July 1973; memorandum, Dale D. Myers, NASA Hq, to the Administrator, "SL–3 Launch Date," 5 July 1973.

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5 William H. Rock was appointed Acting Manager of the Apollo-Skylab Programs at KSC. He succeeded Robert C. Hock, who was named Acting Director of Executive Staff. Rock would also continue to serve in his previous position as Manager, Science and Applications Project Office.

KSC Announcement, "Mr. William H. Rock Named Acting Manager, Apollo-Skylab Programs," 5 July 1973.

12 Joint Skylab 3 flight readiness reviews and thermal shield design certification reviews were held at KSC. A comprehensive series of center reviews were completed before, and in preparation for, the flight readiness reviews.

"Minutes of the Skylab SL–3 Flight Readiness Review and the Thermal Shields Delta DCR," 12 July 1973.

13 Premature deployment of the meteoroid shield during the *Skylab 1* launch interjected additional factors in the consideration of the OWS deorbit. (Reference entry of 3 April 1973.) Because of the additional uncertainties and complications

Skylab 3 crewmen (left to right) Alan L. Bean, Owen K. Garriott, and Jack R. Lousma during egress training at MSFC before their liftoff. This operation was an alternate recovery plan in case of rough seas and the command module's floating in the upside-down position.

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deriving from these factors and the inherent crew and mission risks involved in the OWS deorbit even under expected conditions, the decision was taken to terminate all OWS deorbit efforts.

Letter, William C. Schneider, NASA Hq, to JSC and MSFC, "SWS Deorbit," 13 July 1973.

17

Testifying before a joint Congressional Committee hearing, astronaut Charles "Pete" Conrad, Jr., stated:

> . . . I like to think of it as the Pete Conrad private citizen approach—as an overall systems design, tie all of these things we talk about with different satellites into a big picture.
>
> Through something like the shuttle vehicle you maintain a space orientation that allows you to do communications, weather, Earth resources. And there are many other things I can conjecture about such as typing computers and telemetry from airplanes for air traffic control. There are all kinds of things you can get into. But I feel that these little niches we are making with the data we brought back from the Moon gave us a system that allowed us to, in a relatively inexpensive manner, fly a space station for the flight that we flew. And it will fly several more flights. And the future says that we have a tremendous capability to help mankind, if it is developed. And I feel it has to be developed in a profitable nature. And that is something this country can do under the free enterprise system. It is the payloads of the future and how they are integrated into the system that will give us all of these benefits, Earth resources, solar technology and many of the other things that are being done by the unmanned satellites. I think man is a necessary link in this system because he has to repair it, maintain it and operate it. That means not only on the ground but also in the air. I could go on forever with what I think

Alan L. Bean looks over the data acquisition camera mounted on the water tank in the upper level of the Orbital Workshop one-g trainer at JSC, while preparing for the Skylab 3 mission.

some of the systems could be. But I think we are giving enough data to the citizens of this country that they should appreciate that there is a place for using this system that we have developed that will really bring benefits to many, many people. . . .

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U.S. Congress, Senate Committee on Aeronautical and Space Sciences and House Committee on Science and Astronautics, *Testimony from Skylab Astronauts: Joint Hearing*, 93d Cong., 1st sess., 17 July 1973, p. 10.

Twice-weekly experiment planning meetings were being instituted for the 59-day Skylab 3 mission. The purpose of the meetings was to formulate a balanced set of experiment requirements for each upcoming week based on a consideration of plans for the remainder of the mission.

25

Letter, William C. Schneider, NASA Hq, to Principal Investigators, "Second Skylab Mission," 25 July 1973.

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Skylab 3 lifted off from Pad B, Launch Complex 39, KSC, at 7:10:50.5 a.m. EDT. The vehicle was manned by astronauts Alan L. Bean, Owen K. Garriott, and Jack R. Lousma.

The space vehicle, consisting of a modified Apollo command and service module payload on a Saturn IB launch vehicle, was inserted into a 231.3 by 154.7 km orbit. Rendezvous maneuvers were performed during the first five orbits as planned. During the rendezvous, the CSM reaction control system forward firing engine oxidizer valve leaked. The quad was isolated. Station-keeping with the Saturn Workshop began approximately 8 hours after liftoff, with docking being performed about 30 minutes later.

JSC, *Skylab Mission Report Second Visit,* JSC–08662, January 1974, p. 2–1.

July 28–

September 25

The Skylab 3 crewmen experienced motion sickness during the first three visit days. Consequently, the Orbital Workshop activation and experiment implementation activities were curtailed. By adjusting the crew's diet and maintaining a low workload, the crew was able to complete the adjustment to space flight in five days, after which flight activities returned to normal.

On 2 August the service module reaction control system engines were inhibited, and the isolation valves closed because of another leak. Acceptable control modes and deorbit and entry procedures were defined, consistent with the constraints imposed by the two reaction control system problems.

The first extravehicular activity was delayed until 6 August because of the crew's motion sickness. The EVA lasted almost six and one-half hours during which time the crew changed the Apollo telescope mount film, deployed the twin-pole sun shield (see 6 August entry), inspected and performed repair work on the S055 (ultraviolet spectrometer) experiment, deployed the S149 (particle collection) experiment, and installed the calibration shield from experiment S230 (magnetospheric particle composition).

A second EVA was performed on 24 August. It lasted 4 hours 30 minutes. The tasks accomplished included installation of a rate gyro package, deployment of a thermal shield material sample, retrieval and replacement of the ATM work station film, temporary stowage of the experiment S149 in the fixed airlock shroud and redeployment at the Sun end, and removal of the aperture door/ramp latch from two ATM experiments.

A third EVA was accomplished in 2 hours and 45 minutes on 22 September. Its purpose was to retrieve the expended film on the ATM solar experiments and experiments S230 and S149.

Earth resources experiment package activities included 39 passes with a total of 930 minutes of data. All experiment coverage was normal with the exception

of the loss of experiment S193 (microwave radiometer/scatterometer and altimeter) when the antenna failed to operate during data pass 29.

A series of medical experiments was accomplished which assessed the effect of a 59-day space mission on the crewmen. Included were a hematology and immunology program, a mineral balance assessment, an evaluation of the changes in hormonal and associated fluid and electrolyte parameters, the extent of bone mineral loss, the cardiovascular effects utilizing the lower body negative pressure experiment and the vector-cardiogram, and an assessment of metabolic activity.

Four astrophysics experiments were successfully performed: experiment S019 (ultraviolet stellar astronomy); experiment S063 (ultraviolet and visible Earth photography); experiment S149 (particle collection); and experiment S230 (magnetospheric particle composition). Data were obtained for studies of the habitability and crew quarters and crew activities and maintenance. In addition, several experiment M509 (astronaut maneuvering unit) sequences were performed. The chart below gives a comparison of the actual crew time devoted to experiments as opposed to that allocated in the preflight plan.

Category	Man-hours Utilization			
	Actual		Preflight Allocation[b]	
	Hr:min	Percent	Hr:min	Percent
Medical experiments	304:47	7.2	291:22	6.9
Apollo telescope mount experiments	452:56	10.7	311:01	7.3
Earth resources experiment package	223:31	5.3	165:23	3.9
Corollary experiments	231:15	5.4	153:45	3.6
Subsystem detailed test objective	7:05	0.2	3:49	0.1
Student experiments	10:49	0.3	10:06	0.2
Operational[a]	3017:04	70.9	3314:45	78.0

[a] Included sleeping, eating, housekeeping, etc.

[b] Hours adjusted to account for increased mission duration.

On 25 September, the command module was reactivated and the crew performed the final OWS closeout. Following undocking and separation, the command module entered the atmosphere and landed in the Pacific Ocean approximately 300 km southwest of San Diego. Splashdown was at 6:20 p.m. EDT. The recovery ship, U.S.S. *New Orleans*, retrieved the command module and crew 42 minutes after landing. The total flight time was 1427 hours 9 minutes 4 seconds.

R. V. Gordon, "JSC PAO Skylab Activities Summary," September 1973; JSC, *Skylab Mission Report Second Visit*, JSC-08662, January 1974, pp. 2-1, 2-2, and 15-2.

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Lewis Research Center Director Bruce T. Lundin, who served as chairman of the Skylab 1 Investigation Board, presented the findings of the board and the recommended corrective actions in congressional testimony:

"... the Board developed 14 findings, quoted directly herein as contained in our report to the Administrator of NASA.

1. The launch anomaly that occurred at approximately 63 seconds after lift-off was a failure of the meteoroid shield of the OWS.

2. The SAS–2 wing tie downs were broken by the action of the meteoroid shield at 63 seconds. Subsequent loss of the SAS–2 wing was caused by retrorocket plume impingement on the partially deployed wing at 593 seconds.

3. The failure of the S–II interstage adapter to separate in flight was probably due to damage to the ordnance separation device by falling debris from the meteoroid shield.

4. The most probable cause of the failure of the meteoroid shield was internal pressurization of its auxiliary tunnel. This internal pressurization acted to force the forward end of the tunnel and meteoroid shield away from the OWS and into the supersonic air stream. The resulting forces tore the meteoroid shield from the OWS.

5. The pressurization of the auxiliary tunnel resulted from the admission of high pressure air into the tunnel through several openings in the aft end. These openings were: (1) An imperfect fit of the tunnel with the aft fairing; (2) an open boot seal between the tunnel and the tank surface; and (3) open stringers on the aft skirt under the tunnel.

6. The venting analysis for the tunnel was predicated on a completely sealed aft end. The openings in the aft end of the tunnel thus resulted from a failure to communicate this critical design feature among aerodynamics, structural design, and manufacturing personnel.

7. Other marginal aspects of the design of the meteoroid shield which, when taken together, could also result in failure during launch are:

a. The proximity of the MS [meteoroid shield] forward reinforcing angle to the air stream.

b. The existence of gaps between the OWS and the forward ends of the MS.

c. The light spring force of the auxiliary tunnel frames.

d. The aerodynamic crushing loads on the auxiliary tunnel frames in flight.

e. The action of the torsion-bar actuated swing links applying an outward radial force to the MS.

f. The inherent longitudinal flexibility of the shield assembly.

g. The nonuniform expansion of the OWS tank when pressurized.

h. The inherent difficulty in rigging for flight and associated uncertain tension loads in the shield.

8. The failure to recognize many of these marginal design features through 6 years of analysis, design and test was due, in part, to a presumption that the meteoroid shield would be "tight to the tank" and "structurally integral with the S–IVB tank" as set forth in the design criteria.

9. Organizationally, the meteoroid shield was treated as a structural subsystem. The absence of a designated "project engineer" for the shield contributed to the lack of effective integration of the various structural, aerodynamic, aeroelastic, test, fabrication, and assembly aspects of the MS system.

10. The overall management system used for Skylab was essentially the same as that developed in the Apollo program. This system was fully operational for

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Skylab; no conflicts or inconsistencies were found in the records of the management reviews. Nonetheless, the significance of the aerodynamic loads on the MS during launch was not revealed by the extensive review process.

11. No evidence was found to indicate that the design, development, and testing of the meteoroid shield were compromised by limitations of funds or time. The quality of workmanship applied to the MS was adequate for its intended purpose.

12. Given the basic view that the meteoroid shield was to be completely in contact with and perform as structurally integral with the S-IVB tank, the testing emphasis on ordnance performance and shield deployment was appropriate.

13. Engineering and management personnel on Skylab, on the part of both contractor and Government, were available from the prior Saturn deployment and were highly experienced and adequate in number.

14. The failure to recognize these design deficiencies of the meteoroid shield, as well as to communicate within the project the critical nature of its proper venting, must therefore be attributed to an absence of sound engineering judgment and alert engineering leadership concerning this particular system over a considerable period of time.

These findings led the Board to offer the following four corrective actions, again quoted directly from our report to the Administrator.

1. If the backup OWS or a similar spacecraft is to be flown in the future, a possible course of action is to omit the meteoroid shield, suitably coat the OWS for thermal control, and accept the meteoroid protection afforded by the OWS tank walls. If, on the other hand, additional protection should be necessary, the Board is attracted to the concept of a fixed, nondeployable shield.

2. To reduce the probability of separation failures such as occurred at the S-II interstage second separation plane, linear shaped charges should be detonated simultaneously from both ends. In addition, all other similar ordnance applications should be reviewed for a similar failure mode.

3. Structural systems that have to move or deploy, or that involve other mechanisms, equipment or components for their operation should not be considered solely as a piece of structure nor be the exclusive responsibility of a structures organization.

4. Complex, multidisciplinary systems such as the meteoroid shield should have a designated project engineer who is responsible for all aspects of analysis, design, fabrication, test, and assembly."

U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Skylab—Part 2: Hearing on Report of Skylab 1 Investigation Board,* 93d Cong., 1st sess., 30 July 1973, pp. 25–26; U.S. Congress, House, Subcommittee on Manned Space Flight of the Committee on Science and Astronautics, *Skylab 1 Investigation Report: Hearing,* 93d Cong., 1st sess., 1 August 1973, pp. 29–30; memorandum, G. M. Low, NASA Hq, to Program Associate Administrators, "Skylab 1 Investigation Board Report," 19 July 1973.

30

In a letter to the White House, NASA Administrator James C. Fletcher summarized the *Skylab 2* mission:

> . . . A situation that was bleak indeed on May 14, and for several days thereafter, improved to a point well beyond our most optimistic forecasts at that time. This of course was due to a courageous crew and a dedicated team of government and industrial contractor personnel, whose dedication and ability cannot be overemphasized.

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Not only was the crew able to accomplish the great majority of the technical and scientific objectives established for this first Skylab mission, but they were able also to repair the Skylab space station and leave it in a condition which will allow the satisfactory completion of nearly all that we desired from the overall Skylab Program, with the unexpected additional accomplishments of demonstrating the ability to respond to adversity and demonstrating the flexibility provided by the use of man and his faculties in a hostile environment. . . .

Letter, James C. Fletcher to the President, 30 July 1973.

August

1 *Skylab 2* postflight medical debriefings indicated the desirability of minimizing crew exposure to recovery ship motions for both crew reconditioning and post-recovery medical evaluations. In order to provide the *Skylab 3* crew with this minimum exposure, mission duration was extended to 59 days. This allowed for a splashdown closer than 550 km of San Diego, and a crew stay time aboard the recovery ship of only 17 hours.

Letter, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "SL–3 Mission Duration," 1 August 1973.

2 During weekly medical briefings scheduled to begin on Thursday, 23 August, JSC would provide the Skylab Program Director with an in-depth review on all medical experiments and a consolidated systems-type clinical summary on crew health status. Where possible, a projection of anticipated crew performance would also be presented.

Letter, Kenneth S. Kleinknecht, JSC, to Skylab Program Director, "Medical Review of SL–3 Results," 2 August 1973; TWX, William C. Schneider, NASA Hq, to JSC Manager, Skylab Program, "Medical Status," 26 July 1973.

6 During EVA by crew members of *Skylab 3*, a twin-boom sunshade, developed by MSFC, was deployed over the parasol of the OWS. A redesigned and refined thermal parasol had been launched with *Skylab 3*. However, its use would have required jettisoning the parasol deployed by crew members of *Skylab 2*, with the possibility of creating the same thermal problems that existed on the OWS prior to the parasol deployment. Following erection of the twin-pole sunshade, the cabin temperature stayed at a comfortable 293–297 K (67.7°F–74.9°F).

JSC, *Skylab Mission Report Second Visit*, JSC–08662, January 1974, pp. 3–1 and 10–37.

6 Anomalies that had occurred during micrometeoroid shield testing were summarized:

A series of deployment tests were conducted on the micrometeoroid shield during the course of two years prior to launch. Only one component actually failed during this testing. This failure was the rupture of an ordnance expandable tube which did not affect its intended function of breaking the tension strap, but did allow contaminants in the form of explosive residue to be released. Redesign was accomplished and no further problems were encountered.

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Other anomalies that occurred which precluded the tests from being successful were misalignment of deployment latches and failure of latches to engage. All deployment tests were successful from the standpoint of deploying the micrometeoroid shield to a position which would have been acceptable for orbital operations.

A second micrometeoroid shield component failure occurred during ultimate pressure testing of the dynamic test article. Three of twenty-four hinges that connect the micrometeoroid shield to the straps which run under the main tunnel yielded. The straps were subsequently redesigned to provide greater strength and no further problems were encountered.

The decision to utilize solar panels instead of fuel cells or some form of generator was not made because of economical reasons. Fuel cells had originally been considered; however, due to extension of the mission to 240 days total, and the continued increase in power requirements, the fuel cell concept became inadequate. The solar panels were developed to satisfy the extended mission and high power requirements.

Memorandum, W. K. Simmons, Jr., MSFC, to G. C. Hunt, MSFC, "Skylab Micrometeoroid Shield Inquiry," 6 August 1973.

7–15

A meeting was held at MSFC to define a viewing program for the comet Kohoutek during the SL–4 mission. Representatives from NASA Hq, MSFC, GSFC, and JSC attended. Results of a feasibility study for viewing the comet were presented to the NASA Administrator on 15 August. It was agreed that observations of Kohoutek would be made at appropriate times during the SL–4 mission.

JSC, "Skylab Program Office Weekly Activity Reports," 10 August and 23 August 1973; TWX, William C. Schneider, NASA Hq, to MSFC, JSC, and KSC, "SL–4 Mission Schedule," 16 August 1973.

13

NASA decided to delete the Skylab backup Saturn V Orbital Workshop launch capability effective 15 August. All work associated with the completion, checkout, and support of Skylab backup hardware, experiments, software, facilities, and ground support equipment would be canceled immediately, except for the work that would directly support SL–3, SL–4, and rescue missions.

Memoranda, Dale D. Myers, NASA Hq, to James C. Fletcher, NASA Hq, "Cancellation of Skylab Back-up Saturn V Workshop Launch Capability," 8 August 1973; James C. Fletcher to Dale D. Myers, same subject, 13 August 1973; TWX, William C. Schneider, NASA Hq, to JSC, MSFC, KSC, LaRC, and ARC, same subject, 15 August 1973.

August 14–

November 16

The Skylab 4 space vehicle was moved from the KSC Vehicle Assembly Building to Launch Complex 39, Pad B, on 14 August. The space vehicle consisted of a Saturn IB launch vehicle—S–IB–208 first stage, S–IVB–208 second stage, and S–IU–207 instrument unit; a CSM–118; and a spacecraft lunar module adapter. The SL–4 crew was made up of commander Gerald P. Carr, science pilot Edward G. Gibson, and pilot William R. Pogue.

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The S–IVB stage had arrived at KSC on 4 November 1971 and had been placed in storage until 15 December 1972. The CSM arrived on 10 February 1973 and was moved into the Operations and Checkout Building for systems testing. The S–IB stage arrived on 20 June 1973 and was erected on Mobile Launcher 1 on 31 July 1973. The IU arrived at KSC on 12 June 1973. The S–IVB and IU were mated to the S–IB on 1 August 1973.

The processing schedule was accelerated on 3 August to a seven-day, 24-hours-per-day workweek to make SL–4 ready for a possible early flight to rescue the orbiting SL–3 crew, which was having serious leakage problems in their service module reaction control system. This accelerated schedule would support a launch on 9 September. As a better understanding of the SL–3 problem was obtained, the SL–4 checkout flow was adjusted on 13 August to support an earliest launch date of 25 September, which allowed a complete spacecraft integrated systems test to be conducted. With this schedule, hypergolic loading, anticipated for 9 September, would be a decision point for a rescue need with earliest launch readiness of a rescue mission nine days from commitment to hypergolic load. Upon completion of the hypergolic loading preparations on 10 September, the space vehicle remained on a launch minus nine days status until the splashdown of SL–3 on 25 September, when the schedule was readjusted for a 10 November launch.

On 15 August, the mobile launcher sustained several lightning strikes. Damaged components of the CSM, mostly guidance system units, were replaced and retested. The launch vehicle lightning retest revealed no related failures or effects on the launch vehicle or ground support equipment.

Cracks in an S–IB upper "E" beam forging were found on 27 August; repairs were completed on 3 September.

The flight readiness test was completed on 5 September. Processing of the space vehicle continued until 9 September, at which point it was ready for start of hypergolic loading. The space vehicle remained in this mode until 25 September, when the SL–3 astronauts splashed down successfully. Scheduled processing began immediately for a standard mission November launch.

A rerun of the flight readiness test was completed on 11 October. Space vehicle hypergolic loading was completed on 19 October. On 23 October, two S–IB fuel tank domes were inverted due to a partial vacuum pulled on the tanks; two days later a tank pressurization returned the tanks to their original configuration.

As on SL–3, the countdown demonstration test was combined with the countdown into one function, with a launch countdown–wet (LCD-wet) followed by securing and 42½ hours of final countdown tasks. The LCD-wet began at 10:00 p.m. EST on 28 October and finished at 11:40 a.m. EST on 2 November.

Discovery and repair of cracks in the S–IB fins caused a five-day postponement of the launch date, and one additional day was needed to inspect the S–IVB

structure. These delays moved the scheduled launch date to 16 November. The final countdown began at 2:30 a.m. EST on 14 November with launch at 9:01 a.m. EST, 16 November (see 16 November entry).

KSC, "Skylab 4 Post-Launch Report," 10 December 1973, pp. 7–1, 7–2; *Astronautics and Aeronautics, 1973* (NASA SP–4018), Washington, D.C., 1975, p. 244.

16

A telecon was held to discuss the guidelines to be used for SL–4 planning. The key points resulting from this discussion were:

(1) The normal mission launch would be scheduled to allow the first fifth-orbit rendezvous opportunity occurring on or after 9 November 1973. Current estimates indicated an 11 November launch.

(2) The mission would be planned for a nominal 56- to 59-day duration. Splashdown date would be adjusted so that a return to port would be accomplished within 24 hours after recovery.

(3) There would be no primary recovery ship utilization planned for other than a normal end-of-mission recovery.

(4) KSC would continue the present rescue vehicle flow through 9 September 1973 (readiness for hypergolic loading), at which time a hold mode with a nine-day launch capability would be maintained. The decision to load hypergolics would be made by the Program Director.

(5) A review to examine the Workshop systems fully would be held on 17 September 1973, at which time the capability of the Workshop to perform the normal scheduled mission on the scheduled date would be established. For planning purposes, a minimum of 21 days' preparation would be allowed for an orderly launch acceleration if the review showed such a necessity.

(6) At SL–3 splashdown, the SL–4 KSC flow would revert to the normal mode. Retesting and additional tests would be performed as necessary.

(7) The SL–4 mission was not to be predicated on the availability of the S201 far ultraviolet camera. However, attempts would be made to accomplish its development.

(8) Onboard consumables would be reserved for comet observations. Film was to be budgeted to ensure that an ample quantity was available for the comet viewing period. Mission planning would assume no additional film or tapes beyond those currently baselined.

(9) Three EVAs would be baselined for conduct of scientific experiments. However, expendables to enable one unscheduled EVA for system contingencies would be provisioned. Mission planning would reserve those expendables.

(10) Comet observation would be given the highest priority over other experiment activities during the period from 16 December 1973 to the end of the mission.

(11) One maneuver per day would be baselined for comet observation, with a goal to conduct an added maneuver to meet established experiment objectives. Maneuvers would be constrained as outlined in the systems management criteria document.

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(12) Funding for the experiment modifications would be the responsibility of the development center after 16 August 1973.

TWX, William C. Schneider, NASA Hq, to JSC, KSC, and MSFC, "SL–4 Planning," 17 August 1973.

30

Guidelines were issued by NASA Hq for release, disposition, and storage of all unneeded Skylab Program equipment. Two Saturn Vs, two Saturn IBs, three command and service modules, the backup Skylab cluster, and appropriate spares would be placed in minimum cost storage as soon as program requirements permitted.

Letter, William C. Schneider, NASA Hq, to MSFC, JSC, and KSC, "Storage and Disposition of Skylab Hardware and Associated GSE," 30 August 1973; TWX, William C. Schneider to KSC, MSFC, and JSC, "Teleconference on Storage and Disposition of Excess Skylab Hardware and Associated GSE," 26 September 1973.

31

The results of solar radiation tests on the Skylab parasol material was released by LaRC. The accelerated testing indicated more severe degradation than would be experienced had the tests been conducted in real-time conditions. However, even with the severe degradation rate, the samples retained over 50 percent of their original tensile strength and elongation and showed no signs of delamination after the equivalent of 3316 solar hours of exposure.

Letter, Wayne S. Slemp, LaRC, to S. Jacobs, JSC, "Results of Tests on Skylab Parasol Material," 31 August 1973.

September

6

At the request of the Space Shuttle Program Manager, equipment had been carried aboard a Navy salvage vessel (a part of the launch abort contingency task force) for the purpose of monitoring the sonic booms created by *Skylab 1* and *2* launch vehicles. However, the necessary data were not obtained from the SL–2 launch because the ray pattern was distorted away from the salvage ship by a high-altitude inversion layer. Therefore, it would be necessary to obtain sonic boom data from the SL–4 mission. Action was being initiated to accomplish this.

Memorandum, M. S. Malkin, NASA Hq, to Director, Skylab Program, "Obtaining Sonic Boom Data During Skylab Launch," 6 September 1973; TWX, William C. Schneider, NASA Hq, to Kenneth S. Kleinknecht, JSC, "Langley Research Center Sonic Boom Tests for Skylab 1/2," 7 May 1973.

6

At a Kohoutek status meeting, JSC was requested to determine if additional ultraviolet eye protection would be required by the Skylab 4 astronaut while performing Kohoutek operations. A study indicated that no additional eye protective devices would be required for either intra- or extravehicular viewing of the comet. The use of the existing space suit sun visors would be required during extravehicular viewing.

JSC, "Skylab Program Office Weekly Activity Report," 21 September 1973.

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September
13

Discussions confirmed that there was reasonable assurance that an Apollo-Soyuz Test Project (ASTP) revisit to Skylab in mid-1975 was feasible. However, such a dual mission would create a significant planning problem for the operations team and would introduce many new considerations to the inflight planning and execution because of uncertainties in the orbital mechanics.

Memorandum, William C. Schneider, NASA Hq, to the Program Director ASTP, "ASTP-Skylab Revisit," 13 September 1973; letter, G. S. Lunney, JSC, to Program Director, ASTP, "Skylab Revisit," 26 November 1973.

15

The Director of the Skylab Program, in offering his counterpart in the ASTP some advice in establishing an ASTP television program, stated: " . . . I ascribe at least two of my many ulcers to television. It's an emotional subject because everyone is an expert on requirements. If you can get:

a. The groundrules stated,
b. The requirements from the senior man who feels responsible,
c. Then treat it like any other requirement,
d. Put a discipline in the system more rigorous than I did,
e. Take the requirements people out of the day-to-day implementation, you may only get only one TV ulcer."

Memorandum, William C. Schneider, NASA Hq, to Director, Apollo-Soyuz Test Project, "Skylab Television Experience," 15 September 1973.

18

Fish and embryo that were part of a Skylab science demonstration would be returned to JSC by *Skylab 3*, provided that one or more of the fish were still alive at the time of deactivation. Upon return to the recovery ship, the fish would be photographed and observed to determine any reaction to the one-g environment. They would then be returned to JSC for comparison with the backup fish and embryo which were being held in the JSC laboratory. Later histological observations and examinations of their vestibular apparatus would be performed to determine any changes between the two groups.

Memorandum, William C. Schneider, NASA Hq, to Associate Administrator for Manned Space Flight, "Return of Fish and/or Embryo and SL-3," 21 September 1973.

18

More high-quality solar data were recorded by the SL-1/2 mission than all previous solar research efforts combined. This was achieved with the ATM—a configuration of high-resolution instruments on a single platform with a wide range of spectral coverage pointed simultaneously at specific targets. In addition, man was integrated as a scientific observer, operator, and repairman to ensure maximum return of data.

Letter, R. Ise, MSFC to Dist., "ATM Results," 18 September 1973.

A *Skylab 3* onboard photo shows astronaut Jack R. Lousma as he flew the astronaut maneuvering unit in the forward dome of the space station while in Earth orbit.

1973

September

21

The final Earth resources experiment package pass for *Skylab 3* ended. In all, 39 Earth-oriented passes, six solar inertial passes, two Earth-limb surveys, and two lunar calibration sequences were completed.

The 15 hours of data acquisition was about 40-percent higher than the premission flight plan and included 15 780 photographs and 28 000 m of magnetic tape. Data were acquired over the United States, Central and South America, Europe, Africa, Japan, and Southeast Asia. Special observations were made of tropical storm Christine, the Sargasso Sea, the African drought area, and the Pakistan flood area. Oblique and nadir photography was obtained for most of Paraguay as part of a joint U.S./IAGS (Inter-American Geodetic Survey) Paraguay mapping experiment.

Memorandum, T. L. Fischetti, NASA Hq, to Dist., "SL–3 Summary and EREP Program Status," 26 September 1973.

25

All primary mission objectives for *Skylab 3* were accomplished with the safe recovery of the crew and vehicle. These objectives were to

(1) Perform unmanned Saturn Workshop operations by obtaining data for evaluating the performance of the unmanned Saturn Workshop and obtaining solar astronomy data through unmanned ATM observations.

The photo at the left shows a most welcome sight to all returning astronauts from Skylab missions—parachutes. Here the *Skylab 3* parachutes unfurled before opening at 10 000 m. Right, the *Skylab 3* crew (left to right), Jack Lousma, Owen Garriott, and Alan Bean, are pictured after their recovery by the U.S.S. *New Orleans* about 300 km southwest of San Diego.

(2) Reactivate the orbital assembly in Earth orbit by operating the orbital assembly (Orbital Workshop plus command and service module) as a habitable space structure for up to 59 days after the launch of the second-visit spacecraft and obtaining data for evaluating crew mobility and work capability during both intravehicular and extravehicular activities.

(3) Obtain medical data on the crew for use in extended duration manned space flights by obtaining medical data for determining the effects on the crew of a space flight of up to 59 days' duration and obtaining medical data for determining if a subsequent Skylab mission of greater than 59 days' duration is feasible and advisable.

(4) Perform inflight experiments by obtaining ATM solar astronomy data for continuing and extending solar studies beyond the limits of Earth-based observations; obtaining Earth-resources data for continuing and extending multisensor observation of the Earth from low-Earth orbit; and performing the assigned scientific, engineering, technology, and Department of Defense experiments.

A summary of the objectives accomplished showed a very high degree of completion, especially considering the reduction of experiment time early in the mission caused by the motion-sickness problems. After the first few days, the crew quickly caught up and, during the remainder of the mission, exceeded the preplanned workload. For many experiments, the baseline requirements were exceeded, and a number of experiments planned for the third visit were accomplished. (See chart in entry for 28 July–25 September 1974.)

From the successful completion of the *Skylab 3* mission, the following conclusions

1973 were reached:

September

(1) The ability of the crew to correct systems difficulties by actions such as deployment of the twin-pole sunshield, replacement of the rate gyro package, repair of the teleprinter, and repair of the ATM experiment door enabled the second visit to proceed as planned and again demonstrated the advantage of having man on board the vehicle.

(2) Revisits provided the opportunity to correct hardware problems, restructure objectives, and revise replaceable commodities based on actual experience.

(3) Psychological and physical conditions resulting from the 59-day mission indicated no constraints for longer duration flights.

(4) Ordinary hand tools could have been used effectively in place of special tools in the zero-g environment when making repairs and adjustments.

(5) The limitations of noncontinuous ground station coverage imposed restrictions on data return, systems management, and uplink information.

(6) The skills learned in underwater training were almost identical to the skills used in actual performance of tasks during EVA and, if instructions were adequate, a crewman could perform extravehicular tasks for which he had not specifically trained. Tasks were somewhat easier to perform in zero-g than in underwater training.

JSC, *Skylab Mission Report Second Visit,* JSC–08662, January 1972, pp. 14–1, 14–2, and 18–1; memorandum, William C. Schneider, NASA Hq, to the Administrator, 15 October 1973.

October

4 An ad hoc committee was established to analyze the vestibular problems which occurred in previous manned space flights and to make recommendations concerning prevention and control on future flights. Particular emphasis was placed on the experiences of the *Skylab 3* crew. As a result of the committee meeting, it was recommended that the crewmen of SL–4 take anti-motion-sickness medication immediately upon orbital insertion and follow this with periodic doses for the first three days of flight.

Memoranda, S. B. Vinograd, NASA Hq, to the JSC Director of Life Sciences, "Ad Hoc Committee on Skylab Vestibular Effects," 4 October 1973; C. A. Berry, NASA Hq, to Director, Skylab Program, "Use of Anti-Motion-Sickness Medication for SL–4 Launch," 5 November 1973; Kenneth S. Kleinknecht, JSC, to Skylab Program Director, "Medical Action Items," 6 November 1973; William C. Schneider, NASA Hq, to JSC Skylab Program Director, "Skylab Action Items," 9 November 1973.

5 All elements of the Skylab organization (NASA Hq, JSC, MSFC, and KSC) would prepare documentation of significant Skylab experiences. Preliminary drafts of these "Lessons Learned" would be circulated to other Centers and Headquarters for review and comment prior to final publication. It was anticipated that the reports would be ready for final publication about the time of the SL–4 splashdown.

Letters, William C. Schneider, NASA Hq, to MSFC, JSC, and KSC, "Documentation of Significant Skylab Experiences," 5 October 1973; William C. Schneider to Ames Research Center, same subject, 6 December 1973; JSC, "Skylab Program Office Weekly Activity Report," 7 December 1973.

1973

October

20 The crew of Skylab 4 began a 21-day prelaunch isolation period. Established prelaunch procedures required each Skylab flight crew to begin a health stabilization program 21 days before liftoff.

JSC News Release 73–138, "Astronauts to Begin Isolation Period," 23 October 1973.

24 A review of *Skylab 3* medical data and SL–4 mission planning was conducted by the NASA Administrator. Among the items covered were a plan for measuring both the pre- and postflight cardiac outputs of the SL–4 crew; elimination of all activities in the deactivation sequence not absolutely required; and a plan for accommodation of the circadian shift necessary for missions of various durations.

TWX, William C. Schneider, NASA Hq, to JSC, MSFC, and KSC, "Skylab Mission and Medical Review," 25 October 1973.

30 Because of an extension in mission duration and changes in mission requirements, publication deadlines would not be met for a final flight plan for Skylab 4. Therefore, summaries were in preparation that would incorporate all known changes in mission requirements. These would be available for limited distribution prior to liftoff.

Memorandum, J. W. Bilodeau, JSC, to Dist., "SL–4 Flight Plan," 30 October 1973.

October 30–November 6 Two vials, each containing 500 gypsy moth eggs, were hand carried to JSC from the Department of Agriculture. After being loaded in flight containers, they were hand carried to KSC. The eggs would be launched on Skylab 4 and then transferred to the OWS sleep compartment area where they would be monitored during the course of the SL–4 mission. The eggs were being carried at the request of the Secretary of Agriculture.

JSC, "Skylab Program Office Weekly Activity Reports," 3 and 9 November 1973.

November 6 A shift in the Skylab 4 launch schedule was required in order to replace eight cracked fins on the S–IB. The hairline cracks were discovered during a post-countdown demonstration test inspection. Initial indications were that the 14 cracks were caused by load stress or salt air, or possibly a combination of both.

"Minutes of Manned Space Flight Management Council Meeting," 7 November 1973.

6 A high-energy food bar was added to the menu of the Skylab 4 astronauts. The 72 kg of additional food placed aboard the SL–4 command module included 39 kg of high-energy food bars and would supply sufficient food for an extension

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November

of the mission to 85 days, plus an additional 10 days' supply for a rescue capability. The food bars, which contained 300 calories each, would be used by the crewmen every third day of the mission in combination with the normal Skylab food. There were three kinds of energy bars—chocolate chip, crispy, and flake. Each was coated with one of three flavors—vanilla, chocolate, or strawberry—making nine different varieties. The bar, a modification of a commercially available Pillsbury food stick, was an offspring of a bar developed jointly by NASA, the U.S. Air Force, and the Pillsbury Company.

JSC News Release 73-143, "New Food for Third Skylab Mission," 6 November 1973.

14

A launch readiness review was held at KSC. From the review and closeout of action items, the Skylab 4 vehicle was determined to be ready for launch on 16 November 1973. Other reviews included the KSC flight readiness review, 18 October; the JSC Director's flight readiness review and the JSC command and service module flight readiness review, 11 October; the MSFC review of the Skylab Workshop systems capabilities, 17 September; and the KSC SL-4 launch readiness review, 15 October 1973.

Letters, W. C. Schneider, NASA Hq, to Skylab 4 Flight Readiness Review Record, "Confirmation of Flight Readiness for Skylab 4," 14 November 1973; W. H. Rock, KSC, to JSC Skylab Program Manager, "SL-4 Launch Readiness Review," 4 October 1973; memoranda, W. C. Schneider to Dist., "Skylab L-2 Day Readiness Review for SL-4," 17 October 1973; W. C. Schneider to JSC, MSFC, and KSC, "SL-4 Planning," 4 October 1973; W. C. Schneider to MSFC and JSC, "Mission Planning for SL-4," 26 September 1973; W. C. Schneider to Dist., "Skylab Systems Status Review for SL-4 Launch Planning," 19 September 1973; TWXs, W. C. Schneider to JSC, MSFC, KSC, and GSFC, "SL-4 FRR and DCR Schedule," 7 September 1973; L. F. Belew, MSFC, to NASA Hq, KSC, and JSC, "SL-4 Pre-Mission Planning and SWS Systems Status Review," 7 September 1973; "Minutes of JSC Flight Readiness Review for Skylab 4," 16 October 1973; "Minutes of JSC Flight Readiness Review Board CSM 118/SLA 24," 11 October 1973.

16

Skylab 4 was launched at 10:01:23 a.m. EDT from Pad B, LC-39, at KSC. Planned duration of the mission was 56 days, with the option of extending it to a maximum of 84 days. The crewmen were Gerald P. Carr, Edward G. Gibson, and William R. Pogue.

The space vehicle consisted of a modified Apollo CSM and a Saturn IB launch vehicle. All launch phase events were normal, and the CSM was inserted into a 150.1- by 227.08-km orbit. The rendezvous sequence was performed according to the anticipated timeline. Stationkeeping was initiated about seven and one-half hours after liftoff, and hard docking was achieved about 30 minutes later following two unsuccessful docking attempts.

JSC, *Skylab Mission Report Third Visit*, JSC-08963, July 1974, p. 2-1.

November 17–
February 7

During 17 and 18 November, Orbital Workshop activation was accomplished by the crew of *Skylab 4*. The reactivation included the reservicing of the airlock module primary coolant loop.

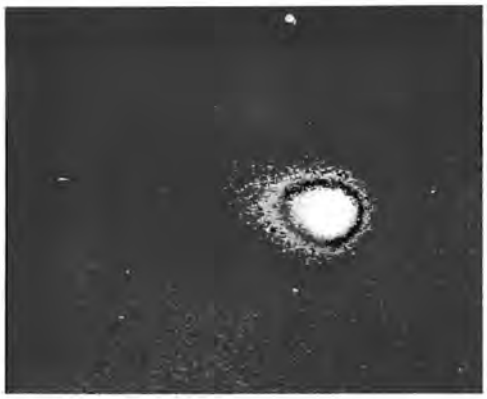
Skylab 4 was launched from KSC at 10:01 a.m. EDT, 16 November 1973, the final launch of the Skylab program.

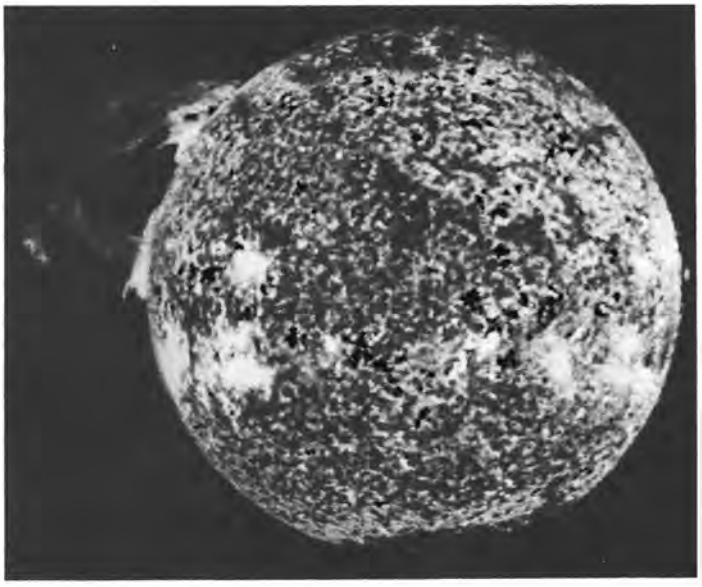
The commander and pilot experienced symptoms resembling motion sickness during the initial three days of the visit, and flight plan activities were adjusted accordingly. Crew health was good thereafter. The medical experiments conducted during the first and second visits were continued during the third visit to assess the effects of the space visit on the crewmen. Some changes were made, and many new medical detailed test objectives were added.

EREP observations were conducted throughout the visit. Thirty-nine data passes were performed with the full complement of instruments operating, and several additional data passes were made for special purposes such as instrument calibration. Although the data acquisition sites were mostly concentrated in the United States, Mexico, and South America, data were also obtained while over Europe, Africa, Asia, and Australia. In addition to the EREP observations, about 850 visual observations were made, and more than 2000 photographs were taken by the crew using hand-held cameras to document specific areas of interest on Earth.

The Apollo telescope mount was operated by the crew for a total time of approximately 519 hours, with over 337 hours of solar, stellar, and Comet Kohoutek data being obtained. Some of the significant accomplishments were obtaining coverage of the Comet Kohoutek, a solar eclipse, the brightest coronal transient observed during the Skylab Program, and two solar flares which included flare rise.

Twenty-eight experiments in the fields of astrophysics, engineering, and technology were included in the third visit, and 235 crew man-hours were devoted to their





Top, left, is a view of the Comet Kohoutek from *Skylab 4* on 25 December 1974, when its halo was about 2.6 million km in diameter. At top right, on the same day Kohoutek's tail was approximately 4.8 million km long. Above right, is a 19 December 1973 photo of the most spectacular solar flare yet recorded (upper left), spanning more than 588 000 km across the solar surface. The darkened areas at top and bottom are polar areas. At right is a near-vertical Earth view, showing about 30 percent of Wyoming and small portions of Montana and Idaho; the dark area at left is Yellowstone National Park. Above is a view of the ice-filled mouth of the St. Lawrence River in Canada; Anticosti Island is in the center.

performance. More than 200 man-hours were devoted to Comet Kohoutek observations, with six special experiments plus the ATM instruments.

Orbital activities included four periods of EVA totaling approximately 22¼ hours. The first EVA was accomplished 22 November and lasted 6 hours 34 minutes. The primary purpose of the activity—installation of film magazines in the ATM cameras—was accomplished satisfactorily. Other tasks accomplished included performing corrective maintenance on the experiment S193 (microwave radiometer/scatterometer and altimeter) antenna, deploying panels of experiment D024 (thermal control coatings), deploying impact detectors of experiment S149 (particle collection), deploying detector modules of experiment S228 (trans-uranic cosmic rays), and deploying collector assemblies of experiment S230 (magnetospheric particle composition).

The second and third EVAs were conducted on Christmas day and 29 December to take photographs of the Comet Kohoutek prior to and after perihelion. The instruments for experiments S201 (extreme ultraviolet camera) and T025 (coronagraph contamination experiment) were used for this purpose. Experiment S020 (X-ray/ultraviolet solar photography) was also conducted on the second and third EVAs. Other tasks performed during the extravehicular activity consisted of replacing film magazines in the ATM cameras, pinning open the door of experiment S082A (extreme ultraviolet spectroheliograph), manually repositioning the filter wheel on experiment S054 (X-ray spectrographic telescope), and retrieving experiment S149 (particle collection) impact detectors. The duration of the second EVA was 6 hours 54 minutes; the third 3 hours 29 minutes.

The fourth and final EVA was performed on 3 February 1974. The major tasks accomplished consisted of retrieval of the ATM film, an additional performance of experiment S020, and performance of experiment T025. Other tasks consisted of retrieval of modules, panels, assemblies, and samples that were to be returned to the ground for analysis, and deployment of cassettes and panels for potential retrieval in the future. The duration of the fourth EVA was 5 hours 19 minutes.

The actual allocation of crew time to experiments, as opposed to the preflight plan, is shown in the following chart:

Category	Allocation, Man-hours		
	Previsit	Adjusted as of Visit Day 28	Actual
Medical experiments	476	422	397
Apollo telescope mount experiments (solar)	509	417	466
Earth resources experiment package	295	242	275
Corollary experiments	297	245	235
Comet Kohoutek	282	231	204
Miscellaneous	110	58	96
Total	1969	1615	1673

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R. V. Gordon, JSC PAO, "Skylab 4 Events," February 1974; JSC, *Skylab Mission Report Third Visit,* JSC-08963, July 1974, pp. 2-1, 2-2, and 14-2.

November

26

The Skylab rescue mission hardware was on schedule, and vehicle rollout to the launch complex was scheduled for 5 December. Integrated testing and the flight readiness test would be completed about 13 December. Flight readiness review dates would only be established if a rescue launch was required.

JSC, "Skylab Program Office Weekly Activity Report," 26 November 1973.

December

10

The Skylab Program organization at NASA Hq would be disestablished in March 1974. A small group headed by T. E. Hanes would be retained to manage the Skylab closeout. In addition to administering the equipment disposition and contract closeout activities, the group would lead and coordinate activities related to exploitation of the Skylab experience and scientific data. Arnold D. Aldrich was named Skylab Program Manager, and W. D. Wolhart would handle these special activities on a full-time basis at JSC. By mid-February, MSFC would also name an individual for the Skylab follow-on activities. In the meantime, Leland F. Belew would be the Center contact.

Letters, Dale D. Myers, NASA Hq, to Center Directors of JSC, KSC, and MSFC, "Close Out of the Skylab Program," 10 December 1973; Rocco A. Petrone, MSFC, to Dale D. Myers, same subject, 21 December 1973; memorandum, G. S. Lunney, JSC, to JSC Director, same subject, 2 January 1974.

10

A message of congratulation was read to the *Skylab 4* crewmen for the tremendous contribution they were making toward procuring medical data which would provide the base for future manned space flight efforts. The message was from the Soviet delegation of the joint working group in space biology and medicine.

Letter, John H. Disher, NASA Hq, to JSC Skylab Program Manager, "Message to SL-4 Crew," 10 December 1973.

26

The AP's top 1973 news stories in order of balloting were Watergate, Spiro T. Agnew, end of war in Vietnam and the release of prisoners, the economy, war in the Middle East, the energy crisis, the slaying of 27 boys in Texas, the death of Lyndon B. Johnson, Skylab space missions, the revolution in Chile.

Memorandum, W. W. Pomeroy, NASA Hq, to Associate Administrator for Manned Space Flight, "Editors Rank Skylab in Top 10 News Stories," 26 December 1973.

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3

Flexibility to conduct a second Skylab mission would be retained until such time as NASA planning for the FY 1976 budget was complete. To accomplish this, NASA issued the following guidelines.

- Launch umbilical tower 2 would be retained in its present status for possible Skylab usage until a decision was made to prepare for a Skylab launch or to begin modifications for the Shuttle Program.

1974
January

• Action would be continued to place in storage existing hardware (including appropriate backups and spares) required for conduct of a Skylab mission.

• The Skylab Program would fund the activities required to place the hardware in minimum cost storage and the storage costs through June 1974.

Letter, Dale D. Myers, NASA Hq, to the Directors, MSFC, JSC, and KSC, "Retention of Skylab II Capability," 3 January 1974.

10

Studies had been conducted to determine an end-of-mission configuration for the Orbital Workshop and for maintaining the option of an OWS revisit at some future date. MSFC assessed the special deactivation requirements for the AM, MDA, and the Workshop required to establish a satisfactory, economical configuration. JSC made an evaluation of ground support monitoring and control options. The OWS would be left in a configuration that would permit a revisit at some future date without reactivation.

"10 January 1974 Manned Space Flight Management Council Summary of Agreements and Action Items," 4 February 1974.

15

A series of engineering tests on the Orbital Workshop was authorized following completion of the *Skylab 4* mission provided that only tests which would result in significant engineering knowledge would be performed; no compromise would be made to the desired end of mission configuration by conducting the test (10 January 1974 entry); the vehicle would be left in the final configuration no later than 15 February 1974; and only a minimum of overtime and shift operation would be expended to obtain the data.

Memorandum, Dale D. Myers, NASA Hq, to the Skylab Program Director, "End of Mission Configuration of Skylab," 15 January 1974.

24

Significant repair and maintenance accomplishments of the three manned Skylab missions were reported:

• For the first 11 days, ground operations control kept the Skylab alive and allowed time for planning and hardware manufacturing necessary to salvage the mission.

• The first manned crew deployed the parasol which brought the OWS internal temperatures down.

• On the 13th mission day, beam 1 and its solar array were deployed to provide adequate power for normal mission.

• The crew succeeded in reactivating a malfunctioning battery, providing additional power. (This was accomplished by whacking it with a hammer during EVA.)

• The first crew performed a variety of repairs and fixes on experiments, such as disassembly and repair of the S019 (UV stellar astronomy) mirror gear drive mechanism; replacing M074 (specimen mass measurement) electronics package; clearing jammed film plate on S183 (ultraviolet panorama); manual opening of

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stuck S054 (X-ray spectographic telescope) door; camera/magazine changeout for S082 (extreme ultraviolet spectograph/spectroheliograph); clearing particle contamination from S052 (white light coronograph) occulting disc.

• The second manned crew installed a larger thermal canopy over the parasol which provided long-duration thermal protection.

• A complex package of six anciliary rate gyros was installed and provided the needed control and backup control for pointing the Skylab.

• The second crew pressurized and flushed the condensate lines and replaced the discharge assembly, thus allowing normal use of the waste water management system.

• Detailed inspection and checkout of the primary and secondary airlock module coolant loops to determine internal and external leakage were performed, and the information relayed to ground for analysis.

• The second crew also corrected significant experiment and support system problems, such as jettisoning T027 (Apollo telescope mount contamination measurement) to clear scientific airlock; replacing video tape recorder and teleprinter head; removing ATM door ramps to improve door closing and opening operations; repairing Mark I exerciser; correcting S019 (ultraviolet stellar astronomy) articulating mirror malfunction; checking out and restoring lighting control; replacing defective TV monitor and TV power cable; replacing and analyzing causes for malfunctioning tape recorders; correcting seal problem on M092 (inflight lower body negative pressure); hooking up the sensor down-link data cable assembly of the Earth resources experiment package for ground data diagnosis.

• The third manned crew successfully replaced the malfunctioning ATM TV monitor in the control and display panel; this restored the display redundancy critical for effective ATM solar pointing.

• The depleted primary AM coolant loop was reserviced using the coolanol servicing kit resupplied on SL–4, thus ensuring continued thermal control of a critical internal Skylab system.

• An automatic timer and cable was launched on SL–4 and installed by the crew on the ATM control and display console to correct erratic exposure operation resulting in loss of S082 experiment data.

• During SL–4 EVA 1, the crew performed troubleshooting and inspection of the inoperative S193 (microwave radiometer/scatterometer radar and altimeter) antenna and then locked the antenna in a position to permit continued operation of the experiment.

• The crew installed replacement units and provided an operational TV system to replace the system which failed on SL–3.

• The "noisy" multispectral scanner hardware was corrected by replacing a modified attenuator and the sensitivity of the unit was improved by installing a modified detector/coder/dewar assembly.

• Successful crew investigation and rerouting of dumpline into the waste tank eliminated venting disturbances.

• Other experiment and support system repairs performed by the third crew included installation of liquid crystal thermometers for rate gyro 6-pack assem-

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bly; replacement of S009 (nuclear emulsion) drive assembly; pinning of H-alpha door; S019 (ultraviolet stellar astronomy) mirror replacement; S190B (Earth terrain camera) clock replacement.

Attachment to letter, William C. Schneider, NASA Hq, to Leland F. Belew, MSFC, Kenneth S. Kleinknecht and P. J. Weitz, JSC, "AIAA Skylab Session," 21 January 1974.

25

Although the probability was remote that the Apollo-Soyuz Test Project mission would not be flown, it was necessary that an alternate mission plan be considered. Minimum effort and funds would be expended in the planning and preparation of an alternate mission.

Letter, C. M. Lee, NASA Hq, to JSC and MSFC, "ASTP Alternate Mission Revisit to Skylab," 25 January 1974.

February

8

Skylab 4 was undocked from the OWS at 6:28 a.m. EDT. A flyaround inspection of the OWS was made following undocking. Because of a suspected propellant leak on command module reaction control system 2, reentry was made using only system 1. The command module landed in the Pacific Ocean 289 km southwest of San Diego at 11:16:54 a.m. EDT, for a flight duration of 84 days 1 hour 15 minutes 31 seconds. The crew and the command module were taken aboard the recovery ship U.S.S. *New Orleans* approximately 40 minutes after landing.

With the third-visit landing, the Skylab mission was concluded. The total flight time for the three visits was 4117 hours 14 minutes 24 seconds, during which the nine crewmen accrued a total of 12 351 hours 43 minutes 12 seconds of flight time.

JSC, *Skylab Mission Report Third Visit*, JSC–08963, July 1974, p. 2–3; R. V. Gordon, JSC PAO, "Skylab 4 Events," February 1974.

8

KSC was directed to discontinue plans for the Skylab rescue capability and to move the rescue vehicle (SA–209 and CSM–119) back to the Vehicle Assembly Building. Upon completion of this action, Headquarters responsibility for the SA–209 and CSM–119 would be transferred to the Program Director of the Apollo-Soyuz Test Program.

TWX, Director, Skylab Program to KSC, MSFC, and JSC, "Skylab Rescue Vehicle," 8 February 1974.

8–22

Following the successful completion of the Skylab Program, a series of news conferences was conducted at the Skylab News Center, JSC.

Skylab 4 Post-Recovery Briefing, 8 February 1974; Skylab Review, 21 February 1974; Skylab 4 Post-Flight Crew Conference, 22 February 1974.

At left the *Skylab 4* crew performs housekeeping duties. Astronaut William R. Pogue holds onto the crew quarters roof and prepares to jump onto the airlock hatch cover to force a trash bag farther down into the airlock that leads to the Orbital Workshop waste disposal tank. Astronaut Gerald P. Carr assists by holding two more trash bags as a third bag floats past. Top right is a closeup view of the Orbital Workshop from the command and service module as the crew made its final flyaround maneuver. The image of the space station contrasts sharply with the darkness of space. Above right is a final view of the space station as *Skylab 4* pulls away, heading for its landing in the Pacific Ocean on 12 February 1974 and ending the successful Skylab program. This photo shows the twin-pole solar shield erected by the *Skylab 3* crew.

1974

February

9

All primary mission objectives of *Skylab 4* were reported accomplished. The specific mission objectives were to

(1) Perform unmanned Orbital Workshop operations.

- Obtain data for evaluating the performance of the unmanned OWS.
- Obtain solar astronomy data by unmanned Apollo telescope mount observations.

(2) Reactivate the OWS in Earth orbit.

- Operate the orbital assembly (OWS plus command and service module) as a habitable space structure for a period of 56 days, with the option of extending to 84 days after the third-visit launch.
- Obtain data for evaluating the performance of the orbital assembly.
- Obtain data for evaluating crew mobility and work capability in both intravehicular and extravehicular activity.

(3) Obtain medical data on the crew for use in extending the duration of manned space flights.

- Obtain medical data for determining the effects on the crew which result from a nominal space flight duration of 56 days, with the option of extending to 84 days.
- Obtain medical data for determining if a subsequent manned space flight mission of greater duration than the duration of the Skylab third manned visit is feasible and advisable.

(4) Perform inflight experiments.

- Obtain Apollo telescope mount solar astronomy data for continuing and extending solar studies beyond the limits of Earth-based observations.
- Obtain Earth resources data for continuing and extending multisensor observation of the Earth from the low-Earth orbit.
- Perform the assigned scientific, engineering, technology, and Department of Defense experiments.
- Obtain Comet Kohoutek data for continuing and extending studies of comets beyond the limits of Earth-based observations.

Although not a primary mission objective, a requirement to obtain documentary motion picture photography of scenes to present the human story of Skylab was considered to be of paramount importance. Approximately 95 percent of the desired crew activity scenes were filmed.

The planned requirements were not only met, but were exceeded for almost all experiments. Also noteworthy were the large number of candidate experiments that were performed.

There were 70 telecasts during the third visit. Premission planning for this visit made provisions for the development of telecast requirements which would be timely and would not be a repeat of subjects covered during the earlier two visits. This planning included three flight-data-file "TV Numbers" which were for television on a variety of subjects. These numbers were TV–77, general purpose intravehicular activity telecast; TV–78, Earth surface features; and TV–81 optional crew day-off activities.

The following conclusions were based on *Skylab 4* activities.

(1) Crew refresher exercises in spacecraft operational modes and procedures were needed during long missions.

(2) Free and open discussions between the crew and the ground were necessary for the expeditious resolution of sensitive issues. When one party felt that the other was at fault, the existence of a routine private communications loop, less restricted use of existing capabilities for special private conferences, or less reluctance on the part of the crew and the ground to use the open communications loop to critically discuss sensitive subjects would expedite the solution of problems.

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JSC, *Skylab Mission Report Third Visit,* JSC–08963, July 1974, pp. 13–1, 13–2, and 17–1.

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MSFC published a summary of Skylab operations:

> The Skylab space station was launched May 14, 1973, from the NASA Kennedy Space Center by a huge Saturn V launch vehicle, the Moon rocket of the Apollo Space Program. Sixty-three seconds after lift-off the meteoroid shield—designed also to shade Skylab's workshop—deployed inadvertently. It was torn from the space station by atmospheric drag. This event and its effects started a ten-day period in which Skylab was beset with problems that had to be conquered before the space station would be safe and habitable for the three manned periods of its planned eight-month mission.
>
> When the meteoroid shield ripped loose it disturbed the mounting of workshop solar array "wing" two and caused it to partially deploy. The exhaust plume of the second stage retro-rockets impacted the partially deployed solar array and literally blew it into space. Also, a strap of debris from the meteoroid shield overlapped solar array "wing" number one such that when the programmed deployment signal occurred, wing number one was held in a slightly opened position where it was able to generate virtually no power.
>
> In the meantime, the space station had achieved a near-circular orbit at the desired altitude of 435 kilometers. . . . All other major functions including payload shroud jettison, deployment of the Apollo Telescope Mount (Skylab's solar observatory) and its solar arrays, and pressurization of the space station occurred as planned.
>
> Scientists, engineers, astronauts and management personnel at the NASA Marshall Space Flight Center and elsewhere worked throughout the first ten-day period of Skylab's flight to devise the means for its rescue. Simultaneously, Skylab—seriously overheating—was maneuvered through varying nose-up attitudes that would best maintain an acceptable 'holding' condition. During that ten-day period and for some time thereafter, the space station operated on less than half of its designed electrical system which, in the partially nose-up attitudes, was generating power at reduced efficiency. The optimum condition that maintained the most favorable balance between Skylab temperatures and its power generation capability occurred at approximately 50 degrees nose-up.
>
> Skylab's achievements are a summary of the accomplishments of many ground-based persons as well as its three separate crews who were launched in Apollo-type command modules by Saturn IB vehicles on May 25, July 28 and November 16, 1973. In Skylab, both the man-hours in space and the man-hours spent in performance of extravehicular activities (EVA) under zero-gravity conditions exceeded the combined totals of all the world's previous space flights.
>
> By deploying the parasol-type sun shield through Skylab's solar scientific airlock and later releasing workshop solar array wing number one during EVA, the first crew made the remainder of the mission possible. The second crew, also during EVA, erected another sun shield, a twin-pole device.
>
> The effectiveness of Skylab crews exceeded expectations, especially in their ability to perform complex repair tasks. They demonstrated excellent mobility, both in-

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ternal and external to the space station, showing man to be a positive asset in conducting research from space. By selecting and photographing targets of opportunity on the Sun, and by evaluating weather conditions on Earth and recommending Earth Resources opportunities, crewmen were instrumental in attaining extremely high quality solar and Earth oriented data.

All three crews demonstrated their technical skills for scientific, operational and maintenance functions. Their manual control of the space station, their fine pointing of experiments and their reasoning and judgments throughout the manned periods were highly effective.

The capability to conduct longer manned missions was conclusively demonstrated in Skylab, first by the crew returning from the 28 day mission and, more forcefully, by the good health and physical condition of the second and third Skylab crews, who stayed in weightless space for 59 and 84 days respectively. Also, resupply of space vehicles was attempted for the first time in Skylab and was proven to be effective.

During their time in space all three crews exceeded the operational and experimental requirements placed upon them by the pre-mission flight plan and schedule. In addition, the third crew performed a number of sightings of Comet Kohoutek which were not initially scheduled.

Prior to departure, the third crew gathered samples of hardware, food and other general items which they placed in a bag and left in the Multiple Docking Adapter. In the event of a Skylab revisit, the bag will be retrieved to determine the effects on the samples of long term storage in the space environment.

Following the final manned phase of the Skylab mission, ground controllers performed some engineering tests of certain Skylab systems—tests that ground personnel were reluctant to do while men were aboard. Results from these tests will help to determine causes of failures during the mission and to obtain data on long term degradation of space systems.

Upon completion of the engineering tests, Skylab was positioned into a stable attitude and systems were shut down.

It is expected that Skylab will remain in orbit about eight years before entering the atmosphere and burning up.

MSFC PAO, "Skylab Operations Summary," 21 February 1974.

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A group of five documents was prepared by NASA Hq, JSC, KSC, and MSFC. These "lessons learned" documents reflected the experience gained in the Skylab Program. They were intended for use by personnel in other programs who were familiar with the disciplines covered. The "lessons learned" documents are subjective and represent individual opinions; therefore, they should not be considered as official NASA policies or statements of NASA positions.

Letter, William C. Schneider, NASA Hq, to MSFC, JSC, and KSC, "Foreword for Lessons Learned Documents," 25 February 1974.

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March

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Following completion of the Skylab Program, NASA Hq was reorganized. The primary objectives of the reorganization were to consolidate under one senior line official—the Associate Administrator—the planning and direction of the Agency's research and development plans; and to consolidate under one senior line official—the Associate Administrator for Center Operations—the overall planning and direction of Center operations.

NASA Hq Special Announcement, "NASA Reorganization and Key Personnel Appointments," 5 March 1974.

July

During the Month

A JSC report summarized Comet Kohoutek's relationship to Skylab operations:

Comet Kohoutek was discovered on 7 March 1973, three months before the launch of Skylab. Preliminary feasibility studies indicated that there was insufficient time to send a suitably instrumented spacecraft to observe and study the comet at close range. However, other manned and unmanned observations were planned, with the most significant to occur during the third visit to the orbiting Skylab. Unique scientific data were obtained by the third-visit crew, helping to make Kohoutek the most comprehensively studied comet in history.

Because of the flexibility and adaptability of the manned program, changes were made in the plans for the third visit to Skylab to take additional equipment and film for ultraviolet and visible light photography. Imagery data were obtained with the extreme ultraviolet electronographic camera experiment (S201K) using special film, and a synoptic history of the comet was made with a series of visible light photographs in the Kohoutek photometric photography experiment (S233K). Existing Apollo telescope mount experiments such as white light coronagraph (S052), X-ray spectographic telescope (S054), and extreme ultraviolet and X-ray telescopes (S056) were used to obtain white light photographs and data in the ultraviolet and X-ray spectra.

Man was not only an invaluable scientific observer studying a comet for the first time from outside the Earth's atmosphere, he was required as a necessary link in the chain of experiment operations. The Skylab crew sketched the form of the comet and described various colorations, characteristics, and light intensities. Some of the preliminary findings were

- A sunward spike was discovered that was formed of relatively heavy particles released earlier from the comet.
- The tail was observed to be extremely long as the comet passed around the Sun, and water vapor within the tail was identified. An increase in the intensity of violet color in the tail was described as the comet went away from the Sun.

As data from the third-visit crew's unique observations and measurements were analyzed and correlated with data from unmanned probes and ground observatories, scientific knowledge of the composition and behavior of comets would be increased substantially.

Vice President Gerald R. Ford presented the Collier Trophy Award for 1973 to Skylab Program Director William C. Schneider on 4 June 1974 in Washington.

JSC, Skylab Mission Report Supplement 3, JSC–08963, "Flight Crew Contributions to the Skylab Mission," July 1974.

JSC reported the Skylab program had fulfilled all program objectives. The performance of the crews and their ability to correct system problems permitted the program to continue, allowed the extended period third visit, and resulted in a bonus of information returned. The following conclusions were either related to the Skylab program objectives or had a general application.

Advancement of the Sciences

Objective: To increase knowledge of medicine, astronomy, Earth meteorology, physics, and other fields, including the effects of space and solar-system phenomena on the Earth environment.

(1) The methods and techniques employed in the daily flight planning provided the flexibility to react to major departures from preflight plans and constraints. This ability was an important factor in optimizing the scientific return.

(2) There were no operationally significant physical or psychological health problems associated with the space vehicle environment for the 84-day visit.

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Findings showed that longer duration visits would be unconstrained. However, longer missions would require periodic medical monitoring.

(3) The food and sleep requirements on a long-duration mission were essentially the same as they were on Earth. However, the maintenance of an established level of physical conditioning required more programmed exercise.

(4) Long-duration flight with sophisticated multidiscipline experiments generated large amounts of data which required ground data handling and processing capabilities.

(5) The Skylab Program demonstrated the advantage of scientist astronauts in providing effective data discrimination and optimization.

(6) Complex scientific experiments should be designed for automatic sequencing to allow a more effective utilization of the scientist astronaut's time for making additional data observations, performing analyses, and applying scientific evaluation.

Practical Applications

Objective: To perfect sensing and data systems for use in agriculture, forestry, oceanography, geography, geology, water and land management, communications, ecology and pollution-control applications, and to develop zero-g manufacturing techniques.

(1) The practical application aspects of the Skylab program would require many months of data evaluation. There were no immediate results which would support the accomplishment for this objective. However, the data were of good quality, and preliminary evaluations indicated that practical applications would be possible in a number of the objective areas. One set of examples suggests that a mineral deposit has been identified near Ely, Nevada—that existing data can be used for an inventory of vegetation patterns; that the Puerto Rican trench depression is about 20 m below the mean sea level; and that pollution has been identified off the coast of Puerto Rico. Another pair of examples from the visual observations experiment indicated that new data on red plankton bloom occurrence might be of aid to biologists and that repetitive observations and photographs of snow accumulation and melting phenomenon would be useful in the study of snow as a water resource.

(2) The success of the visual observations experiment indicated the usefulness of a well-designed visual observations facility.

Durability of Man and Systems in Space

Objective: To determine the ability of man, materials, and systems to maintain their qualities and capabilities during a long period of weightlessness.

(1) The Skylab Program demonstrated that man could perform major assembly and repair tasks in the zero-g environment. Extravehicular crewmen could perform any task that could be accomplished in a one-g suited environment, provided that he was furnished with adequate tools, restraints, and training. The

design of spacecraft could take full advantage of man's capability to modify and repair. The ability of the crew to correct systems difficulties by actions such as deployment of the Workshop solar array, deployment of the parasol and sunshield, replacement of the rate gyro package, reservicing the coolanol loop, and repairing the teleprinter allowed the Skylab Program to exceed the original expectations.

(2) The Skylab Program reconfirmed that the timeline should indicate a relaxed activity at the beginning of the mission to allow the crew to become acclimated to the zero-g environment.

Spaceflight Effectiveness and Economy

Objective: To improve spaceflight technology in order to develop long-duration mission capability for future programs.

(1) The habitability provisions were satisfactory and contributed to the ability of the crew to work effectively for visits of these durations, and no factors were identified to preclude longer duration missions.

(2) The skills learned in underwater training were almost identical to the skills used in actual performance of tasks during an EVA, and, if instructions were adequate, a crewman would be able to perform extravehicular tasks for which he had not specifically trained. Tasks were somewhat easier to perform in zero-g than in underwater training.

(3) Ordinary handtools could be used effectively in place of special tools in the zero-g environment when making repairs and adjustments.

(4) Skylab revisits provided the opportunity to correct hardware problems, restructure objectives, and revise replaceable commodities based on actual experience from the first two mannings.

(5) Regularly scheduled meetings of individuals involved in experiments planning who were managed by the program scientists were effective in optimizing science data return. Additionally, the Skylab flight planning system allowed day-by-day planning with the flexibility to make adjustments to take advantage of special opportunities noted by the crew and ground personnel.

(6) Direct communication during the visits between the crew and some of the experimenters proved to be a useful capability. However, the limited air-to-ground coverage and the need to devote most of this time to operational subjects left little time for scientific discussions.

General

A number of noteworthy program conclusions that were not directly applicable to program objectives were

(1) Extensive training is required for a productive visual observations program. The crew must be trained, premission, to recognize selected areas on the ground and to discriminate important features within the areas. This requires that adequate maps and charts be provided for orientation in flight. In addition, several passes over a selected site are required for the attainment of complete data.

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(2) All work areas within a spacecraft should be provided with a suitably designed work station, with minimal considerations being adequate restraint (triangular grid floor or otherwise), workbench (where required), stowage provisions, writing provisions, and an orientation scheme that is indigenous to the local work area.

(3) Relocatable handholds should be provided to allow the crew to tailor work and maneuvering areas in order to optimize inflight activities.

(4) To optimize time utilization, data station design required automatic recording of a number of parameters which had been reported by crews in previous programs. Examples were pointing position of experiment hardware, frame count of recording instruments, f-stop position, shutter speed, magazine or cassette being used, lens identification, and filter identification.

(5) Planning should allow for crew judgment in order to obtain data over Earth sites that may be obscured by cloud cover.

(6) A shopping list would provide crews with a selection of activities to utilize when not constrained by the timeline.

(7) The existence of a dedicated communications loop for the program scientist would have been a significant asset.

(8) Underwater simulations and training were not required for intravehicular tasks unless a crewman was to be operating in a pressure suit.

JSC, *Skylab Mission Report Third Visit,* JSC–08963, July 1974, pp. 17–1 through 17–5.

NASA Administrator James C. Fletcher, left, explains the formation of the indium-antimonide crystal manufactured in space in Skylab's multipurpose furnace to President Gerald R. Ford at the White House on 4 November 1974. At the President's left is Howard W. Johnson, Chairman of the Massachusetts Institute of Technology.

August

20–22

The American Astronautical Society and the University of Southern California's Institute of Safety and System Management hosted a symposium on the definitive results of the entire Skylab Program. Among the subjects covered were the program's evolution, accomplishments, and application to future NASA programs; design and test philosophy; payload integration; living and working in space; Skylab management; crew views of Skylab; flight operations; Skylab to Shuttle (lessons learned); student science program; launch operations and Skylab technology; and science demonstrations.

Brochure from the American Astronautical Society on the Skylab Results, undated; papers on the subject matter listed above.

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October 30–November 1

A conference was held by the American Institute of Astronautics and Aeronautics and the American Geophysical Union at MSFC. A series of papers on Skylab scientific experiments was presented.

Letter, Marion I. Kent, MSFC, to Ivan Ertel, Historical Services and Consultants Co., 4 November 1974.

APPENDIXES

APPENDIX 1—GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AAP	Apollo Applications Program
AAPO	Apollo Applications Program Office
AES	Apollo Extension System
ALEM	Apollo Lunar Exploration Mission
AM	airlock module
ATM	Apollo telescope mount
BeV	Billion electron volts
BTU	British thermal unit
°C	degrees Celcius (centigrade)
cc	cubic centimeter(s)
CM	command module
cm	centimeter
CSM	command and service modules
cu m	cubic meter(s)
DOD	Department of Defense
EREP	Earth resources experiments package
ERTS	Earth Resources Technology Satellite
EVA	extravehicular activity
°F	degrees Fahrenheit
fps	foot (feet) per second
g	gram; gravity
gal	gallon
GSFC	Goddard Space Flight Center
HF	high frequency
hr, hrs	hour, hours
HSCC	Historical Services and Consultants Company
in	inch(es)
IU	instrument unit
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
kg	kilogram(s)
km	kilometer(s)
KSC	Kennedy Space Center
LaRC	Langley Research Center
LC	Launch Complex
LEM	lunar excursion module
LM	lunar module
m	meter(s)
Mc	megacycles
MDA	multiple docking adapter
MeV	million electron volts
MHz	megahertz (million cycles per second)

mi	mile(s)
min	minute(s)
mm	millimeter(s)
mo, mos	month, months
MOL	Manned Orbiting Laboratory
MORL	Manned Orbital Research Laboratory
mph	miles per hour
MSC	Manned Spacecraft Center (later JSC, Johnson Space Center)
MSFC	Marshall Space Flight Center
MW	megawatt(s)
NASA	National Aeronautics and Space Administration
nm	nautical mile(s)
OMSF	Office of Manned Space Flight
OSSA	Office of Space Sciences and Applications
OWS	Orbital Workshop
psf	pounds per square foot
psi	pounds per square inch
psia	pounds per square inch absolute
RF	radio frequency
sec	second(s)
SEB	Source Evaluation Board
SL	Skylab
SLA	spacecraft lunar module adapter
SM	service module
SSESM	spent-stage experimental support module
V	volt(s)
VHF	very high frequency
W	watt(s)
wk	week
yd	yard
yr	year

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cc	cubic centimeter(s)
CM	command module
cm	centimeter
CSM	command and service modules
cu m	cubic meter(s)
DOD	Department of Defense
EREP	Earth resources experiments package
ERTS	Earth Resources Technology Satellite
EVA	extravehicular activity
°F	degrees Fahrenheit
fps	foot (feet) per second
g	gram; gravity
gal	gallon
GSFC	Goddard Space Flight Center
HF	high frequency
hr, hrs	hour, hours
HSCC	Historical Services and Consultants Company
in	inch(es)
IU	instrument unit
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
kg	kilogram(s)
km	kilometer(s)
KSC	Kennedy Space Center
LaRC	Langley Research Center
LC	Launch Complex
LEM	lunar excursion module
LM	lunar module
m	meter(s)
Mc	megacycles
MDA	multiple docking adapter
MeV	million electron volts
MHz	megahertz (million cycles per second)

mi	mile(s)
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mo, mos	month, months
MOL	Manned Orbiting Laboratory
MORL	Manned Orbital Research Laboratory
mph	miles per hour
MSC	Manned Spacecraft Center (later JSC, Johnson Space Center)
MSFC	Marshall Space Flight Center
MW	megawatt(s)
NASA	National Aeronautics and Space Administration
nm	nautical mile(s)
OMSF	Office of Manned Space Flight
OSSA	Office of Space Sciences and Applications
OWS	Orbital Workshop
psf	pounds per square foot
psi	pounds per square inch
psia	pounds per square inch absolute
RF	radio frequency
sec	second(s)
SEB	Source Evaluation Board
SL	Skylab
SLA	spacecraft lunar module adapter
SM	service module
SSESM	spent-stage experimental support module
V	volt(s)
VHF	very high frequency
W	watt(s)
wk	week
yd	yard
yr	year

APPENDIX 2

SKYLAB SUMMARY

Skylab Summary

[Prepared by Marshall Space Flight Center]

	SL–1	SL–2	SL–3	SL–4	Totals
Launch	14 May 1973 1:30 p.m. EDT	25 May 1973 9:00 a.m. EDT	28 July 1973 7:11 a.m. EDT	16 November 1973 9:01 a.m. EST	
Recovery	.....	22 June 1973 9:49 a.m. EDT	25 Sept. 1973 6:19 p.m. EDT	8 February 1974 11:17 a.m. EDT	
Launch vehicle	Saturn V	Saturn IB	Saturn IB	Saturn IB	
Orbital parameters	431.5 × 433.7 km (268.1 × 269.5 mi)	.....	.....	.....	
Orbital inclination	50°	.....	.....	.....	
Orbital period	approx. 93 minutes	.....	.....	.....	
Distance/orbit	42 768 km (26 575 mi)	.....	.....	.....	
Distance traveled (manned)		18.5 million km (11.5 million mi)	39.4 million km (24.5 million mi)	55.5 million km (34.5 million mi)	113.5 million km (70.5 million mi)
Mission duration		28 days 49 minutes	59 days 11 hours 9 minutes	84 days 1 hour 16 minutes	171 days 13 hours 14 minutes
Number of revolutions (manned)		404	858	1214	2476
Crew					
Commander		Charles Conrad	Alan L. Bean	Gerald P. Carr	
Pilot		Paul J. Weitz	Jack R. Lousma	William R. Pogue	
Scientist pilot		Joseph Kerwin	Owen Garriott	Edward Gibson	
Man-hour utilization		Hours Percent	Hours Percent	Hours Percent	Hours Percent
Medical activities		145.3 7.5	312.5 8.0	366.7 6.1	824.5 6.9
Solar observations		117.2 6.0	305.1 7.8	519.0 8.5	941.3 7.9
Earth resources		71.4 3.7	223.5 5.7	274.5 4.5	569.4 4.8
Other experiments		65.4 3.4	243.6 6.2	403.0 6.7	712.0 6.0

Sleep, rest and off duty	675.6	34.7	1224.5	31.2	1846.5	30.5	3 746.6	31.5
Pre- and post-sleep and eating	477.1	24.5	975.7	24.8	1384.0	23.0	2 836.8	23.8
Housekeeping	103.6	5.3	158.4	4.0	298.9	4.9	560.9	4.7
Physical training and personal hygiene	56.2	2.9	202.2	5.2	384.5	6.4	642.9	5.4
Other (EVA) etc.	232.5	12.0	279.7	7.1	571.4	9.4	1 083.6	9.0
Total	1944.3	100	3925.2	100	6048.5	100	11 918.0	100
Experiment performance	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
Solar astronomy	117.2	29.9	305.1	28.2	519.0	33.2	941.3	31.0
Earth observations	71.4	18.2	223.5	20.6	274.5	17.6	569.4	18.8
Student	3.7	0.9	10.8	1.0	14.8	0.9	29.3	0.9
Astrophysics	36.6	9.4	103.8	9.6	133.8	8.5	274.2	9.0
Man/systems	12.1	3.1	117.4	10.8	83.0	5.3	212.5	7.0
Material science	5.9	1.5	8.4	0.8	15.4	1.0	29.7	1.0
Life science	145.3	37.0	312.5	29.0	366.7	23.5	824.5	27.2
Kohoutek					156.0	10.0	156.0	5.1
Totals	392.2	100	1081.2	100	1563.2	100	3036.9	100

Extravehicular activities				
Standup EVA	25 May 1973 37 minutes			
EVA 1	7 June 1973 3 hours 30 minutes	6 August 1973 6 hours 29 minutes	22 November 1973 6 hours 33 minutes	
EVA 2	19 June 1973 1 hour 44 minutes	24 August 1973 4 hours 30 minutes	25 December 1973 7 hours 1 minute	
EVA 3		22 September 1973 2 hours 45 minutes	29 December 1973 3 hours 28 minutes	
EVA 4			8 February 1974 5 hours 19 minutes	
Totals	5 hours 41 minutes	13 hours 44 minutes	22 hours 21 minutes	41 hours 46 minutes

Skylab Summary—Concluded

	SL–1	SL–2	SL–3	SL–4	Totals
Data returned					
Solar observations		28 739 frames	24 942 frames	73 366 frames	175 047 frames
Earth observations					
Film		9 846 frames	16 800 frames	19 400 frames	46 146 frames
Magnetic tape		13 716 m (45 000 ft)	28 529 m (93 600 ft)	30 480 m (100 000 ft)	72 725 m (238 600 ft)

Experiment summary	Planned	Actual	Percent Deviation	
Earth observation passes	62	99	+ 60	
Solar viewing time (above 400 km)	565 hours	724.7 hours	+ 27.5	
Manned solar viewing time	879.5 hours	941.3 hours	+ 7.1	
Biomedical investigations	701	922	+ 32	
Engineering/technology investigations	264	245	− 3.4	
Material/space manufacturing investigations	10	32	+220	
Astrophysics investigations	168	345	+105	
Student experiment investigations	44	52	+ 18	
Science demonstrations	26	11	− 42	optional SL–4 only

Consumable utilization

	Launch	End of Manned Mission	Consumables Used
Water	2 722 kg (6000 lb)	776 kg (1 710 lb)	1 946 kg (4290 lb)
Oxygen	2 767 kg (6100 lb)	1254 kg (2 764 lb)	1 513 kg (3336 lb)
Nitrogen	699 kg (1540 lb)	275 kg (607 lb)	423 kg (933 lb)
TACS	36 287 kg–sec (80 000 lb–sec)	5664 kg (12 488 lb)	*30 623 kg–sec (67 512 lb–sec)

*Over 32 percent of the TACS was used during the first 10 days of the mission.

Mission Achievements

SL–2	First Mission
	Installed solar shield "parasol" from scientific airlock
	Released solar array wing on EVA
	Doubled previous length of time in space
SL–3	Second Mission
	Installed twin-pole solar shield on EVA
	Performed major inflight maintenance
	Doubled previous length of time in space
SL–4	Third Mission
	Observed and photographed Comet Kohoutek
	Increased previous length of time in space by about 50%

APPENDIX 3—SKYLAB EXPERIMENTS

The Skylab Program, as the name implies, was designed to conduct experiments from a laboratory in space. The experiments were categorized as solar physics, Earth resources, life sciences, material science, the Skylab student project, and other experiments. While final data analysis on some of the experiments will require a number of years to accomplish, the preliminary results indicate that the Skylab Program has been man's most successful adventure in space to date. Some of the specific results obtained for each of the groups listed above follow.

In the area of solar physics, it was discovered that Sun flares occurred more often than expected and that the mechanisms at work in the different flares could vary significantly in nature. Mysterious bright spots were discovered; as many as 1500 emerged on the Sun each day with an average lifetime of eight hours. Recently discovered coronal holes were found to be persistent for several solar rotations and were a major source of solar wind. Solar observation will enhance future weather forecasting. The amount and quality of the Apollo telescope mount coronal data exceeded the total corona observations since the beginning of civilization and indicated that the notion of homogenous corona is a fiction.

In the Earth resources experiments, an important mineral deposit in Nevada, geothermal sites in the southwestern United States, and a previously unknown river in South America were identified. Several areas of citrus fruit fly infestation on the Mexican side of the Rio Grande were also identified. The use of Earth resources program imagery for inventory of vegetation patterns, regional planning and land use in urbanized areas, and city census updating was demonstrated. Also demonstrated was the use of remote sensing for snow mapping, sea state determination, and ocean current charting. In addition, the Earth resources experiments examined the growth and termination of hurricanes using information gathered for Ava, Christine, and Delia.

For the experiments conducted in the category of life sciences, based on preliminary analyses of data, findings indicated that man has demonstrated his ability to adjust to space environment and to perform useful and valuable work in space. There was evidence that space affected some physiological processes, particularly the cardiovascular system. To counteract this, space crews were advised to maintain adequate physiological reserve by ensuring that they performed adequate amounts of exercise, obtained sufficient sleep, and maintained a regular schedule of eating. While individuals varied, there seemed to be a general physiological, including cardiovascular system, adaptation to space over a period of time. Apparently during the first few days in space, the crewmen became extremely resistant to the effects of motion and maintained this state as long as they remained in space. There was also evidence that fluid and plasma volume changes leveled off in time and during recovery after the flights.

In the field of material science, 54 experiment cartridges comprising 18 experiment sets were processed in the multipurpose electric furnace. These sets are in the process of being analyzed. Three specimen discs in the metals-melting experiment and four brazed-tube specimens in the exothermic heating experiment were successfully processed in space. They, too, are being analyzed. Preliminary findings showed a higher quality and uniformity in the metal specimens which were melted by the electron beam gun. In general, the crystals grown were higher in quality, and in some cases unique crystal growth phenomena occurred. Welding in space of aluminum alloy, stainless steel, and pure tantalum presented no problems. The ability to braze tubes and sleeve joints whose gaps exceeded those required on Earth for a good braze

band was successfully demonstrated. Large, perfect, single crystals of indium-antimonide were grown to a perfection not attainable on Earth. The production technology acquired from this experiment may now be applied to other semiconductors. Larger, more perfect crystals should drastically widen the use of the semiconductor in many applications. One large, single crystal of germanium selenide was grown, which was more than a one order of magnitude increase in size over Earth-grown crystals.

Data were obtained for all of the 19 Skylab student project experiments that were selected for flight. The data were poor or marginal in three cases; however, it is expected that several of the experiments will have significant scientific value.

Among the findings obtained from the category designated "other experiments" were the following. The crew activity/maintenance study showed that the full range of human dexterity can be taken advantage of in designing hardware and tasks for future space programs. Crew comments on the habitability/crew quarters experiment indicated that the Orbital Workshop design was satisfactory. No significant contamination was found on the sample array exposed from the antisolar airlock for 46 hours. However, significant contamination was found on the thermal control samples that were continuously exposed during the first mission. Ultraviolet stellar astronomy experiments obtained scientific data on hot stars in two-thirds of the Milky Way region. Scientific observations were made of Comet Kohoutek with 11 different sensors or telescopes, covering spectral ranges down to the X-ray region. Color pictures of significant scientific value of the aurora and airglow were obtained by ultraviolet airglow horizon photography. Astronauts were able to observe and photograph barium clouds released by rocket launchings.

In the remaining pages of this appendix the individual experiments; their purpose; the Principal Investigators; and, where known, the results of the experiments are shown.

Geographic separation of major MSFC Skylab contractors demanded accurately documented interface definitions.

Coordinating the diverse Skylab Principal Investigators' experiment requirements was a major integration challenge.

MEDICAL EXPERIMENTS

M 071 Mineral Balance

Objective: Define and quantitatively assess body gains and losses of biochemical constituents, particularly water, calcium, and nitrogen.

Principal Investigator—G. D. Whedon, National Institutes of Health, Bethesda, Maryland

Coinvestigator—L. Lutwak, Veterans Administration Hospital, Sepulveda, California

Flight Assignment—SL-1/2, SL–3, SL–4

Results: Significant losses of nitrogen and phosphorus occurred, associated with observed reduction in muscle tissue. Both mineral and muscle losses occurred despite vigorous exercise regimes in flight. Conclusion was that, unless protective measures can be developed, capable musculoskeletal function is likely to be impaired in space flights of one and one-half to three years duration, for example, to Mars.

M 073 Bio-Assay of Body Fluids

Objective: Assess the effect of space flight on endocrine-metabolic functions including fluid and electrolyte control mechanisms.

Principal Investigator—C. S. Leach, NASA–JSC

Principal Coordinating Scientist—P. C. Rambaut, NASA–JSC

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Significant biochemical changes were observed which varied in magnitude and direction but which disappeared shortly after return to Earth. In areas concerned with the metabolism of bone mineral, protein, and carbohydrates unstable states appeared to persist, and it was unclear in which form the ultimate sequelae of these changes would manifest themselves after flights of much longer duration.

M 074 Specimen Mass Measurement

Objective: Demonstrate the feasibility of mass measurement without gravity.

Principal Investigator—W. E. Thornton, NASA-JSC

Coinvestigator—J. W. Ord, USAF Medical Corps, Clark AFB, Philippine Islands

Hardware Contractor—Southwest Research Institute, San Antonio, Texas

Flight Assignment—Sl-1/2, SL-3, SL-4

Results: A new instrument for inflight space operations and research was demonstrated; previous unproven mechanisms of weight losses under weightlessness were demonstrated; and it was proven that the human body, properly fed, could sustain long duration missions without significant obligatory mass loss.

M 078 Bone Mineral Measurement

Objective: Determine the occurrence of bone mineral changes due to weightlessness.

Principal Investigator—J. M. Vogel, University of California School of Medicine, Davis, California

Coinvestigator—M. W. Whittle, NASA-JSC

Hardware Contractor—U.S. Public Health Service, San Francisco, California

Flight Assignment—SL-1/2, SL-3, SL-4

Results: It was concluded that mineral losses occurred from the bones of the lower extremities during missions of up to 84 days. In general, they followed the loss patterns observed in a heterogeneous group of bed-rested subjects.

M 092 Lower Body Negative Pressure

Objective: Evaluate space flight cardiovascular deconditioning and establish the time course of any changes.

Principal Investigator—R. L. Johnson, NASA-JSC

Coinvestigator—J. W. Ord, USAF Medical Corps, Clark AFB, Philippine Islands

Hardware Contractors—MSFC; Martin Marietta Aerospace Corp., Denver

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Vectorcardiograms taken on all crewmen during the Skylab flights showed several consistent changes apparently related to space flight. Principal among the changes were

temporal intervals, vector magnitudes and their orientations, and certain derived parameters, presumably resulting from altered autonomic neutral inputs upon the myocardial conduction system or major fluid shifts known to have occurred in flight.

All observed measurements were well within accepted limits of normal and were considered to represent adaptative phenomena rather than pathological conditions.

M 093 Vectorcardiogram

Objective: Measure electrocardiographic potentials during weightlessness and the immediate postflight period to obtain precise measurements of the changes that occur.

Principal Investigator—N. W. Allebach, U.S. Naval Aerospace Medical Institute, Pensacola, Florida

Coinvestigator—R. F. Smith, School of Medicine, Vanderbilt University, Nashville, Tennessee

Hardware Contractors—MSFC; Martin Marietta Aerospace Corp., Denver

Flight Assignment—SL-1/2, SL-3, SL-4

Results: No adverse electrocardiographic changes, with the exception of arrhythmias, were observed in the Skylab crews that could be attributed to long exposure to a weightless environment or to the other stresses of extended space flight. There was no evidence of myocardial ischemia or changes in the electrocardiogram that would suggest vasoregulatory abnormalities. The vectorcardiographic techniques utilized in the experiment added both accuracy and precision to the data acquisition and facilitated both scientific investigation and monitoring for crew safety.

M 111 Cytogenetic Studies of Blood

Objective: Determine pre- and postflight chromosome aberration frequencies in the peripheral blood leukocytes of the Skylab crew members and provide in-vivo radiation dosimetry.

Principal Investigator—L. H. Lockhart, University of Texas Medical Branch, Galveston, Texas

Coinvestigator—P. C. Gooch, Brown & Root-Northrop, Houston, Texas

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Data did not seem to indicate that the external sources of radiation to which the crews had been exposed in orbit resulted in any aberration increase.

M 112 Man's Immunity In-vitro Aspects

Objective: Assay changes in humoral and cellular immunity as reflected by the concentrations of plasma and blood cell proteins, blastoid transformations, and synthesis of ribonucleic (RNA) and desoxy-ribonucleic acids (DNA) by the lymphocytes.

Principal Investigator—S. E. Ritzmann, University of Texas Medical Branch, Galveston, Texas

Coinvestigator—W. C. Levin, University of Texas Medical Branch, Galveston, Texas

Contractors—MSFC; McDonnell Douglas Astronautics Co., Eastern Division, St. Louis

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Changes noted, in general in the preliminary evaluation, were minor and were not expected to be of any clinical significance.

M 113 Blood Volume and Red Cell Life Span

Objective: To determine the effect of orbital missions on the plasma volume and the red blood cell populations, particularly changes in red cell mass, red cell destruction rate, red cell life span, and red cell production rate.

Principal Investigator—P. C. Johnson, Jr., Baylor University College of Medicine, Houston, Texas

Contractors—MSFC; McDonnell Douglas Astronautics Co., Eastern Division, St. Louis

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The Skylab data, taken in its totality with previous flight data, confirm that a decrease in red cell mass is a constant occurrence in space flight. After the initial loss, there is at least a 30-day delay before the red cell mass begins to reconstitute itself.

M 114 Red Blood Cell Metabolism

Objective: Determine if any metabolic or membrane changes occur in the human red blood cell as a result of exposure to the space flight environment.

Principal Investigator—C. E. Mengel, University of Missouri School of Medicine, Columbia, Missouri

Contractors—MSFC; McDonnell Douglas Astronautics Co., Eastern Division, St. Louis

Flight Assignment—SL–1/2, SL–3, SL–4

Results: It was concluded that there were no evidences of lipid peroxidation, that the biochemical effect known to be associated with irreversible red cell damage and the changes observed in glycolytic intermediates and enzymes cannot be directly implicated as indicating red cell damage from exposure to the space flight environment.

M 115 Special Hematologic Effects

Objective: Examine critical physiochemical blood parameters relative to the maintenance of a stable equilibrium between certain blood elements and evaluate the effects of space flight on these parameters.

Principal Investigator—S. L. Kimzey, NASA–JSC

Coinvestigator—C. L. Fischer, Eisenhower Memorial Hospital, Palm Springs, California

Contractors—MSFC; McDonnell Douglas Astronautics Co., Eastern Division, St. Louis

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Until questions about the specific cause and impact of the red-cell shape change on cell survival in-vivo have been resolved, individuals with diagnosed hematologic abnormalities should not be considered as prime candidates for missions, especially long-duration missions.

M 131 Human Vestibular Function

Objective: Evaluate the requirement for an artificial gravitational force for space flight and compare vestibular response in space with preflight baseline data.

Principal Investigator—A. Graybiel, Naval Aerospace Medical Research Laboratories, Pensacola, Florida

Coinvestigators—E. Miller, Naval Aerospace Medical Research Laboratories, Pensacola, Florida, and J. L. Homick, JSC

Hardware Contractor—MSFC

Flight Assignment—SL–1/2, SL–3

Results: Prevention of motion sickness in any stressful environment involves selection, adaptation, and the use of drugs. There is a lack of laboratory tests to predict accurately susceptibility to motion sickness in weightlessness. Susceptibility to motion sickness in the weightless phase of parabolic flight is promising but has not been validated.

M 133 Sleep Monitoring

Objective: Evaluate quantity and quality of sleep during prolonged space flight.

Principal Investigator—J. D. Frost, Jr., Baylor School of Medicine, Houston, Texas

Coinvestigators—W. H. Shumate, JSC; C. R. Booher, JSC; J. G. Salamy, Technology, Inc., Houston, Texas

Hardware Contractors—MSFC; Martin Marietta Aerospace Corp., Denver

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The experiments indicated that man was able to obtain at least adequate sleep over prolonged periods of time in space and during regularly scheduled eight-hour sleep periods. The most notable changes in the sleep patterns occurred in the postflight period, perhaps suggesting that readaptation to one-g is somewhat more disruptive to sleep than the adaptation to zero-g.

M 151 Time and Motion Study

Objective: Evaluate the relative consistency between ground-based and inflight task performance as conducted by astronauts and as measured by time and motion determinations.

Principal Investigator—J. F. Kubis, Fordham University, Bronx, New York

Coinvestigator—E. J. McLaughlin, NASA–OMSF

Hardware Contractor—MSFC

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Inflight task performance was relatively equivalent among the three Skylab crews. Behavioral performance continued to improve from beginning to end of all Skylab missions. Performance adaptation was very rapid. There was no evidence of performance deterioration that could be attributed to the effects of long-duration exposure to the Skylab environment.

M 171 Metabolic Activity

Objective: Evaluate man's metabolic effectiveness in space.

Principal Investigator—E. L. Michel, NASA-JSC

Coinvestigator—J. A. Rummel, NASA-JSC

Hardware Contractor—MSFC

Flight Assignment—SL-1/2, SL-3, SL-4

Results: From experiment results, it was hypothesized that inflight exercise had a beneficial effect not only in the maintenance of a normal inflight response to exercise and well-being but also in reducing the period of time required for readaptation post flight. However, this hypothesis would have to be evaluated by proper experimentation.

M 172 Body Mass Measurement

Objective: Validation of a mass measuring device large enough to contain a man.

Principal Investigator—W. E. Thornton, NASA-JSC

Coinvestigator—J. W. Ord, USAF Medical Corps, Clark AFB, Philippine Islands

Hardware Contractors—MSFC; Southwest Research Institute, San Antonio, Texas

Flight Assignment—SL-1/2, SL-3, SL-4

Results: See results of M074 Specimen Mass Measurement.

General Summation of Skylab Biomedical Experience

• Biomedical results show that man can adapt and function effectively in weightless environment for extended periods.

• Daily inflight personal-exercise regimens coupled with appropriate dietary intake and adequate sleep, work, and recreation periods are essential for maintaining crew health and well-being.

• No untoward physiological changes were noted that would preclude longer duration manned space flights; however, further research is required to understand the mechanisms responsible for many observed changes.

• Remedial or preventive measures may be required for mission durations in excess of 9 to 12 months, e.g., bone demineralization countermeasures.

• Ideally, further observations of man in Earth orbit for an uninterrupted period of six months should precede a Mars-type mission.

BIOLOGY EXPERIMENTS

S 015 Zero-g Single Human Cells

Objective: Study the influence of zero gravity on living human cells and tissue cultures.

Principal Investigator—P. O'B. Montgomery, Dallas County Hospital District, Dallas, Texas

Coinvestigators—J. Paul, Dallas County Hospital District, Dallas, Texas; P. Kruse, Jr., Noble Foundation; and L. Hayflick, Stanford University, Palo Alto, California

Hardware Contractors—JSC; Dallas County Hospital, Dallas, Texas

Flight Assignment—SL–3

Results: Minor unexplained differences were found in biochemical constituents of the used flight and control media. These changes were apparently not significant. Within the limits of the experimental design, zero-g environment produced no detectable effects on Wistar-38 human embryonic lung cells in tissue culture.

S 071 (Passive) Circadian Rhythm—Pocket Mice

Objective: Study the stability of the circadian rhythm of a mammalian system under conditions of space flight.

Principal Investigator—R. G. Lindberg, Northrop Corp., Hawthorne, California

Hardware Contractors—JSC; Northrop Corp., Electronics Division, Norwood, Massachusetts

Flight Assignment—SL–3

Results: The experiment was not successful because of equipment failure, which prevented the acquisition of telemetry data.

S 072 (Passive) Circadian Rhythm—Vinegar Gnat

Objective: Examine the phenomenon of temperature compensation in the circadian rhythm of an insect.

Principal Investigator—C. Pittendrigh, Stanford University, Palo Alto, California

Hardware Contractors—JSC; Northrop Corp., Electronics Division, Norwood, Massachusetts

Flight Assignment—SL–3

Results: The experiment failed because of equipment failure similar to that of S 071, which prevented the acquisition of telemetry data.

STUDENT EXPERIMENTS

ED 11 Atmospheric Absorption of Heat

Objective: Determine the attenuation of visible and near infrared radiant energy through the Earth's atmosphere at various locations and under varying atmospheric conditions.

Principal Investigator—J. B. Zmolek, 12th Grade, Lourdes High School, Oshkosh, Wisconsin

Science Advisors—D. R. Norris, NASA–JSC; E. E. Comer, NASA–MSFC

Flight Assignment—SL–1/2

Results: Data are being analyzed in preparation for a final report.

ED 12 Volcanic Study

Objective: Perform infrared surveys from Skylab of volcanoes to support data from ground instrumentation, gathered to establish a methodology for predicting volcanic activity.

Principal Investigator—T. A. Crites, 9th Grade, Kent Junior High School, Kent, Washington

Science Advisors—D. L. Amsbury, NASA–JSC; E. E. Comer, NASA–MSFC

Flight Assignment—SL–1/2

Results: Results have not yet been reported.

ED 21 Libration Clouds

Objective: Photograph the two libration clouds on the Moon's orbit at the Lagrangian Points, L_4 and L_5, of the Earth-Moon system (points within the Earth-Moon system at which particles experience zero force).

Principal Investigator—A. Hopfield, 9th Grade, Princeton Day School, Princeton, New Jersey

Science Advisors—J. T. Humphreys, NASA–MSFC; R. M. MacQueen, High Altitude Observatory, National Center for Atmospheric Research, Boulder, Colorado

Flight Assignment—SL–3

Results: No definite results are available.

ED 22 Objects Within Mercury's Orbit

Objective: Photograph objects (Vulcan hoped for) within the orbit of the planet Mercury.

Principal Investigator—D. C. Bochsler, 9th Grade, Silverton Union High School, Silverton, Oregon

Science Advisors—J. T. Humphreys, NASA–MSFC; R. M. MacQueen, High Altitude Observatory, National Center for Atmospheric Research, Boulder, Colorado

Flight Assignment—SL-1/2

Results: No new objects have been identified between Mercury and the Sun.

ED 23 Ultraviolet from Quasars

Objective: Obtain spectra from quasars in the ultraviolet region.

Principal Investigator—J. C. Hamilton, 11th Grade, Aiea High School, Aiea, Hawaii

Science Advisors—K. G. Henize, NASA-JSC; J. T. Humphreys, NASA-MSFC

Flight Assignment—SL-1/2

Results: Data from this experiment are still being analyzed.

ED 24 X-Ray Stellar Classes

Objective: Determine the general characteristics and location of celestial X-ray sources.

Principal Investigator—J. W. Reihs, 11th Grade, Tara High School, Baton Rouge, Louisiana

Science Advisors—J. T. Humphreys, NASA-MSC; M. Zombeck, American Science and Engineering, Inc., Cambridge, Massachusetts

Flight Assignment—SL-4

Results: No data available on this experiment. Results, when known, will be on solar X-ray data, an alternative to this experiment.

ED 25 X-Rays from Jupiter

Objective: Detect X-rays from Jupiter and search for a correlation of the X-ray emission with both solar activity and jovian decametric radio emission.

Principal Investigator—J. L. Leventhal, 11th Grade, Berkeley High School, Berkeley, California

Science Advisors—J. T. Humphreys, NASA-MSFC; M. Zombeck, American Science and Engineering, Inc., Cambridge, Massachusetts

Flight Assignment—SL-3

Results: Target observations were unobtainable on both the *Skylab 3* and *Skylab 4* missions.

ED 26 Ultraviolet from Pulsars

Objective: Study and photograph pulsars in the ultraviolet wavelengths.

Principal Investigator—N. W. Shannon, 11th Grade, Dekalb High School, Atlanta, Georgia

Science Advisors—K. G. Henize, NASA-JSC; J. T. Humphreys, NASA-MSFC

Flight Assignment—SL-1/2

Results: Spectral photographs are being studied, but no conclusions have been reached at this time.

ED 31 Bacteria and Spores

Objective: Observe under controlled conditions the survival, growth, and mutations of bacterial spores in the Skylab environment.

Principal Investigator—R. L. Staehle, 11th Grade, Harley School, Rochester, New York

Science Advisors—G. R. Taylor, NASA–JSC; S. B. Hall, NASA–MSFC

Hardware Contractor—MSFC (in house)

Flight Assignment—SL–1/2

Results: Bacterial growth showed definite changes in behavior in the Skylab environment. Study continues to determine whether the changes are environmental or genetic.

ED 32 In-vitro Immunology

Objective: Determine the effects of zero-g on these representative life processes: Part A, Chemotaxis; Part B, Antigenicity.

Principal Investigator—T. A. Meister, 12th Grade, Bronx High School of Science, Jackson Heights, New York

Science Advisors—S. L. Kimzey, NASA–JSC; R. E. Allen, NASA–MSFC

Hardware Contractor—MSFC (in house)

Flight Assignment—SL–3

Results: Analyses and comparison with the ground control samples showed that results were consistent.

ED 41 Motor-Sensory Performance

Objective: Measure changes in motor-sensory performance resulting from prolonged space flight and compare Skylab performance data with existing baseline data and those obtained during pre- and postflight analysis.

Principal Investigator—K. L. Jackson, 11th Grade, Clear Creek High School, Houston, Texas

Science Advisors—W. E. Feddersen, NASA–JSC; R. E. Allen, NASA–MSFC

Hardware Contractor—MSFC (in house)

Flight Assignment—SL–4

Results: A final report on this experiment has not been completed.

ED 52 Web Formation

Objective: Observe the web-building process and detailed structure of the web of the common cross spider (Araneus Diadematus) in both a normal environment and the Skylab environment.

Principal Investigator—J. S. Miles, 11th Grade, Lexington High School, Lexington, Massachusetts

Science Advisors—J. B. MacLeod, NASA–JSC; R. L. Gause, NASA–MSFC

Hardware Contractor—MSFC (in house)

Flight Assignment—SL–3

Results: Although the final report has not been completed at this time, initial study verifies that spiders use a gravity sensing organism to size the thread used in spinning a web.

ED 61 Plant Growth

Objective: Observe and record differences in root and stem growth and orientation of radish seeds that were germinated in the Skylab environment compared with seeds germinated and developed in a normal environment.

Principal Investigator—J. G. Wordekemper, 9th Grade, Central Catholic High School, West Point, Nebraska

Science Advisors—C. H. Walkinshaw, NASA–JSC; L. A. Gross, NASA–JSC

Hardware Contractor—MSFC (in house)

Flight Assignment—SL–4

Results: Analysis is continuing preparatory to preparing a final report.

ED 62 Plant Phototropism

Objective: Assess whether or not phototropism can serve as a substitute for geotropism for radish seeds germinated and developed in the Skylab environment.

Principal Investigator—D. W. Schlack, 11th Grade, Downey High School, Downey, California

Science Advisors—C. H. Walkinshaw, NASA–JSC; L. A. Gross, NASA–JSC

Hardware Contractor—MSFC (in house)

Flight Assignment—SL–4

Results: A final report is in the process of being written.

ED 63 Cytoplasmic Streaming

Objective: Observe the effects of zero-g on cytoplasmic streaming in plants.

Principal Investigator—C. A. Peltz, 10th Grade, Arapahoe High School, Littleton, Colorado

Science Advisors—C. H. Walkinshaw, NASA–JSC; C. A. Cothran, NASA–MSFC

Hardware Contractor—MSFC (in house)

Flight Assignment—SL–3

Results: Elodea plants used in this experiment did not survive. The hypothesis advanced in the final report is that this may have been caused by the plants' waste products and lack of carbon dioxide due to circulation problems in the agar.

ED 72 Capillary Study

Objective: Demonstrate capillary tubes and capillary wicks in the Skylab environment.

Principal Investigator—R. G. Johnston, 12th Grade, Alexander Ramsey High School, St. Paul, Minnesota

Science Advisors—J. B. MacLeod, NASA–JSC; R. L. Gause, NASA–MSFC

Flight Assignment—SL–4

Results: Fluid loss occurred, which threatened the experiment. However, film data and sketches of the experiment are still being studied.

ED 74 Mass Measurement

Objective: Demonstrate the methods of mass measurement utilized on baseline Skylab systems.

Principal Investigator—V. W. Converse, 12th Grade, Harlem High School, Rockford, Illinois

Science Advisors—J. B. MacLeod, NASA–JSC; R. R. Head, NASA–MSFC

Flight Assignment—SL–3

Results: An excellent film demonstration of mass measurement in zero-g was obtained. Results correlated well with the theoretical data.

ED 76 Neutron Analysis

Objective: Measure the ambient neutron flux in the Orbital Workshop and attempt to identify the contribution from each of three sources: Earth-albedo neutrons, solar neutrons, and cosmic ray secondary neutrons.

Principal Investigator—T. C. Quist, 12th Grade, Thomas Jefferson High School, San Antonio, Texas

Science Advisors—D. E. Robbins, NASA–JSC; C. L. Peacock, NASA–JSC

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Although the study is continuing, preliminary results indicate that ambient neutron fluxes may be significantly higher than previously predicted.

ED 78 Liquid Motion in Zero Gravity

Objective: Observe the motion of a gas bubble in a fluid excited by a simple mechanical system of calibrated driving force of simple frequency.

Principal Investigator—W. B. Dunlap, 10th Grade, Austintown Fitch High School, Youngstown, Ohio

Science Advisors—J. B. MacLeod, NASA–JSC; R. R. Head, NASA–MSFC

Results: An experiment hardware failure negated this experiment.

CREW OPERATIONS EXPERIMENTS

M 487 Habitability/Crew Quarters

Objective: Evaluate the features of the Skylab living quarters, provisions, and support facilities that affect the crew's comfort, safety, and operational effectiveness.

Principal Investigator—C. C. Johnson, Jr., NASA–JSC

Hardware Contractor—McDonnell Douglas Astronautics Co., St. Louis

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Habitability requirements for spacecraft, except in the areas of mobility and restraint, are similar to those on Earth.

M 509 Astronaut Maneuvering Equipment

Objective: Evaluate, with a "test bed" maneuvering unit, the utility of several astronaut maneuvering techniques that differ in the degree of man-machine integration.

Principal Investigator—C. E. Whitsett, Jr., USAF Space and Missiles System Office, Los Angeles, California

Coinvestigators—B. McCandless II, and D. C. Schultz, NASA–JSC

Hardware Contractor—Martin Marietta Corp., Denver

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The operation of the astronaut maneuvering unit was considered successful.

M 516 Crew Activities/Maintenance Study

Objective: Evaluate man-machine relations by gathering data concerning the crew's capability to perform work in the zero-g environment throughout long-duration missions.

Principal Investigator—R. L. Bond, NASA–JSC

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Man can conduct inflight maintenance tasks as effectively in orbit as on Earth if given the proper tools, restraints, accessibility, and procedures.

T 013 Crew/Vehicle Disturbance

Objective: Measure the effects of various crew motions on the dynamics of manned spacecraft, specifically the torques, forces, and vehicle motions produced by the astronauts' body motions.

Principal Investigator—B. A. Conway, LaRC

Hardware Contractor—Martin Marietta Corp., Denver Division

Flight Assignment—SL–3, SL–4

Results: Results indicate that crew motion disturbances in a manned spacecraft can provide appreciable inputs to the spacecraft attitude-control system.

T 020 Foot-Controlled Maneuvering Unit

Objective: Provide information pertaining to the design and use of astronaut maneuvering systems by conducting inflight and ground-based evaluations of an unstabilized experimental device.

Principal Investigator—D. E. Hewes, LaRC

Hardware Contractor—Martin Marietta Corp., Denver Division

Flight Assignment—SL–3, SL–4

Results: Preliminary results indicate that hands-free operation and other design features of the foot-controlled maneuvering unit are feasible for incorporation into a future system.

ATM SOLAR EXPERIMENTS

S 052 White Light Coronagraph

Objective: The solar coronagraph views the corona out to 3 million miles (six solar radii) in visible light. Measure polarization, shape, and intensity of the solar corona by photographs taken at rates up to one every 13 seconds.

Principal Investigator—R. M. MacQueen, High Altitude Observatory, Boulder, Colorado

Coinvestigator—E. Hildner, National Center for Atmospheric Research, Boulder, Colorado

Hardware Contractor—High Altitude Laboratory with subcontractor Ball Brothers Research Corp., Boulder, Colorado

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The Skylab coronagraph obtained observations comparable to the best ground-based eclipse observation at least daily for eight and one-half months with few gaps. During this period, coronal evaluation on time scales including months, weeks, days, hours, and even minutes were observed. The most rapid change in coronal form, called coronal transients, occurred at an unexpectedly high frequency of one every few days. Diversity of behavior of coronal transients was noted.

S 054 X-Ray Spectrographic Telescope

Objective: Obtain time development of X-ray producing events (flares and active regions) in the various X-ray wavelengths.

Principal Investigator—R. Giacconi, American Science and Engineering, Inc., Cambridge, Massachusetts

Hardware Contractor—American Science and Engineering, Inc., Cambridge, Massachusetts

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Good resolution of the coronal X-ray structure was obtained. Data are still being analyzed.

S 055 Ultraviolet Spectrometer

Objective: Observe temporal changes in the extreme ultraviolet radiation emitted by several types of solar regions.

Principal Investigator—E. M. Reeves, Harvard College Observatory, Cambridge, Massachusetts

Hardware Contractor—Harvard College Observatory, Cambridge, Massachusetts

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Some data have been reduced to photographic form. Clear, detailed loops of ionized particles streaming away from the Sun's surface more than 41 000 km into space have been obtained. Some details of structure, composition, and active processes revealed in the ultraviolet photographs were the first seen by man. Data reduction and analyses are continuing.

S 056 Dual X-Ray Telescope

Objectives: Take X-ray photographs in six bands from 6–33Å; observe the total X-ray emission of the Sun in the wavelength region from 2.5–20Å in 10 channels.

Principal Investigator—J. E. Milligan, NASA–MSFC

Coinvestigator—R. X. Meyer, The Aerospace Corp., El Segundo, California

Hardware Contractors—GSFC; MSFC

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Data obtained from the experiment have been analyzed based on the assumption that the magnetic fields in the chromosphere and lower corona were force-free. Although the data analyzed are consistent with the force-free field model, a more extensive analysis of the available data is required to definitely establish the nature of the X-ray arches obtained in the experiment observations.

S 082 Ultraviolet Spectrograph/Heliograph

Objective: Photograph the Sun in selected ultraviolet wavelengths.

Principal Investigator—R. Tousey, Naval Research Laboratory, Washington

Hardware Contractor—Naval Research Laboratory with subcontractor Ball Brothers Research Corp., Boulder, Colorado

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Structural patterns in the chromosphere, corona holes, and active regions of large flares were photographed. Line spectra on and off the solar disc and across the limb were recorded, and an image of the full solar disc was observed. Data studies are continuing.

EARTH RESOURCES EXPERIMENTS

S 190A Multispectral Photographic Facility

Objective: Evaluate high-quality, repetitive multispectral photography from space for detailed analysis in the Earth-resources disciplines.

Principal Investigator—K. J. Demel, NASA–JSC

Hardware Contractor—ITEK Corp., Lexington, Massachusetts

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The multispectral photographic facility performance was satisfactory.

S 190B Earth Terrain Camera

Objective: Obtain high-resolution data of small areas to aid interpretation of data gathered by EREP remote sensors.

Principal Investigator—K. J. Demel, NASA–JSC

Hardware Contractors—Actron Industries, Inc., Monrovia, California; North American Rockwell, El Segundo, California

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The Earth terrain camera performed very well. The photography obtained is being used in conjunction with experiment S 190A data and other sensor outputs to perform land-use inventories, including studies of soil erosion, timberline location, snow extent and water equivalency, plankton production, fishing productivity, and African drought areas.

S 191 Infrared Spectrometer

Objective: Produce multispectral imagery of visible solar and thermal infrared spectra to assess Earth surface composition and condition.

Principal Investigator—T. L. Barnett, NASA–JSC

Hardware Contractors—Block Engineering Co., Inc., Cambridge, Massachusetts, for IR Sensor; Martin Marietta Aerospace Group, Denver, for Viewfinder/Tracking System

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Data obtained by this experiment are being used to evaluate the dynamics of upper air flow and to improve stratospheric structure models that might prove useful for weather forecasting.

S 192 Multispectral Scanner

Objective: Evaluate quantitatively the applicability of spectral data for Earth resources sensing.

Principal Investigator—C. L. Korb, NASA–JSC

Hardware Contractor—Honeywell Radiation Center, Boston, Massachusetts

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Skylab S 192 data provide a useful tool for synoptic appraisal of land-water cover types and environmental analysis.

S 193 Microwave Radiometer/Scatterometer, Altimeter

Objective: To simultaneously measure radar differential backscattering cross section and passive microwave emissivity of land and sea on a global scale.

Principal Investigator—D. Evans, NASA–JSC

Hardware Contractor—General Electric Co., Philadelphia, Pennsylvania

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Data from this experiment are being used for studies of means and methods to improve remote sensing techniques. Studies of storm systems and the dynamics of the upper air flow are being made to improve weather forecasting. Sea-state studies, wind-field studies, and determination of sea surface brightness temperatures are being conducted. During the last manned Skylab mission an around-the-world altimeter data pass was made to provide previously unavailable data on the Earth.

S 194 L-Band Radiometer

Objective: Measure thermal radiation in the microwave (L-band) range.

Principal Investigator—D. Evans, NASA–JSC

Hardware Contractor—Airborne Instruments Laboratory Division, Cutler-Hammer, Inc.' Deer Park, Long Island, New York

Flight Assignment—SL–1/2

Results: Data from this experiment are being used for analysis of snow fields to improve radiation models and energy transfer processes. Data collected over the western United States are being used to determine soil and snowpack moisture content for use in crop planning and predicting the effects of snow melt.

SCIENTIFIC EXPERIMENTS

S 009 Nuclear Emulsion

Objective: Study charge spectrum of primary cosmic rays with emphasis on heavy nuclei.

Principal Investigator—M. M. Shapiro, Naval Research Laboratory, Washington

Hardware Contractor—Naval Research Laboratory, Washington

Flight Assignment—SL–1/2

Results: The experiment operated normally for approximately the first two-thirds of the visit, after which the detector package would not move to the closed position. However, by improvisation, the experiment was continued.

S 019 Ultraviolet Stellar Astronomy

Objectives: Obtain a large number of stellar spectra down to 1400 angstroms (UV spectra beyond limits of ground-based instruments). Obtain spectra of early-type stars and photographs of Milky Way fields.

Principal Investigator—K. G. Henize, NASA–JSC, and Northwestern University, Evanston, Illinois

Hardware Contractor—Northwestern University, Evanston, Illinois

Flight Assignment—SL–1/2

Results: A preliminary review of this experiment film indicated that the spectra quality was good and fully recoverable by spectrophotometry but that some film fogging had occurred. Computer programs for quantitative data reduction were in the final stages of development.

SOLAR PHYSICS EXPERIMENTS

S 020 Ultraviolet X-Ray Solar Photography

Objective: Photograph extreme UV and X-ray emissions of the Sun in the 10- to 200-angstrom wavelengths.

Principal Investigator—R. Tousey, Naval Research Laboratory, Washington

Hardware Contractor—Naval Research Laboratory, Washington

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The experiment was originally planned to be carried out from the solar scientific airlock; however, because of the parasol deployment, experiment operations were performed during EVA. Revised functional objectives were successfully completed and one of the major original objectives, spectra of a solar flare, was also obtained.

S 063 Ultraviolet Airglow Horizon Photography

Objective: Photograph the twilight airglow and Earth's ozone layer simultaneously in the visible and ultraviolet wavelengths.

Principal Investigator—D. M. Packer, Naval Research Laboratory, Washington

Hardware Contractor—Martin Marietta Corp., Denver

Flight Assignment—SL-1/2, SL-3, SL-4

Results: A preliminary visual review of the film indicated some large variations in image quality, although color photography appeared to be very good. Experiment success would require some film processing enhancements and microdensitometry.

S 073 Gegenschein/Zodiacal Light

Objective: Measure the surface brightness and polarization of the night glow over a large portion of the celestial sphere in the visible light spectrum and determine the extent and nature of the spacecraft corona during daylight.

Principal Investigator—J. L. Weinberg, Dudley Observatory, Albany, New York

Hardware Contractor—Dudley Observatory, Albany, New York

Flight Assignment—SL-1/2, SL-3, SL-4

Results: The experiment performed normally, except for one instance in which shaft and trunnion positioning control was lost (Skylab 2).

S 149 Particle Collection

Objective: Determine the mass distribution of micrometeorites in near-Earth space.

Principal Investigator—C. L. Hemenway, Dudley Observatory, Albany, New York

Hardware Contractor—Dudley Observatory, Albany, New York

Flight Assignment—SL-1/2, SL-3, SL-4

Results: Full study and calibration of the S 149 materials will take a number of years, but initial results show promise of determining accurately the near-Earth population of cosmic dust particles over a wide mass range.

S 150 Galactic X-Ray Mapping

Objective: Survey a portion of celestial sphere for galactic X-ray sources in the 0.2 KeV to 10 KeV energy range.

Principal Investigator—W. L. Kraushaar, University of Wisconsin, Madison, Wisconsin

Hardware Contractor—University of Wisconsin, Madison, Wisconsin

Flight Assignment—SL-4

Results: The experiment collected X-ray data for only 110 minutes before the experiment high voltage switched off because of low gas pressure in the X-ray sensor. The planned operating time was 265 minutes.

S 183 Ultraviolet Panorama

Objective: Obtain wide-field-of-view photographs of individual stars and extended star fields in the ultraviolet range.

Principal Investigator—G. Courtes, Laboratoire d'Astronomie Spatiale du CRNS, Marseille, France

Hardware Contractor—French Government

Flight Assignment—SL-1/2

Results: The equipment malfunctioned once. However, after a new film cassette was inserted, equipment operated properly.

S 228 Trans-Uranic Cosmic Rays

Objective: Provide detailed knowledge of relative abundance and energies of the nuclei in cosmic radiation.

Principal Investigator—K. A. Anderson, University of California, Berkeley, California

Hardware Contractor—University of California, Berkeley, California

Flight Assignment—SL-1/2, SL-4

Results: Detector assemblies were deployed and retrieved by the SL-4 crew. Results are being analyzed.

S 230 Magnetospheric Particle Composition

Objective: Measure fluxes and composition of precipitating magnetospheric ions and trapped particles.

Principal Investigator—D. L. Lind, NASA-JSC

Coinvestigators—J. Geiss and W. Stettler, University of Bern, Bern, Switzerland

Hardware Contractor—Engineering Division, JSC

Flight Assignment—SL-3, SL-4

Results: Deposits similar to those on the D 024 samples were also found on the S 230 surfaces, but the data were still usable for primary experiment objectives. Processing of the preliminary data from the first two sets of foil sections indicated that the foils collected precipitated magnetospheric particles as expected. The majority of the particles participating in the aurora were identified to be of solar wind origin. Preliminary results also showed no indications of interstellar gas atoms and revealed that fluxes of epithermal noble gas ions at low latitudes are very small.

TECHNOLOGY AND MATERIALS PROCESSING EXPERIMENTS

D 008 Radiation in Spacecraft

Objectives: Advance active and passive dosimetry instrumentation. Test theoretical computer codes. Accumulate detailed information of SC radiation environment as supplement to NASA system.

Principal Investigator—A. D. Grimm, USAF Weapons Laboratory, Kirtland AFB, New Mexico

Coinvestigator—J. F. Janni, USAF Weapons Laboratory, Kirtland AFB, New Mexico

Hardware Contractors—AVCO Electronics, Cincinnati, Ohio; Century Electronics and Instruments, Inc., Tulsa, Oklahoma

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Doses to third-visit crewmen were greater than those to the previous crews because of the longer visit, longer duration of EVA, and a slight increase in dose rates as the use of food, water, and other expendables reduced overall radiation shielding of habitation areas. However, all doses were less than 25 percent of the third-visit guidelines.

D 024 Thermal Control Coatings (Airlock Module)

Objective: Expose selected thermal control coatings to space environment in order to compare results with ground-based simulations and to determine mechanisms of degradation caused by space radiation.

Principal Investigator—W. L. Lehn, Air Force Materials Laboratory, Wright-Patterson AFB, Ohio

Coinvestigator—University of Dayton Research Institute, Dayton, Ohio

Hardware Contractors—Air Force Materials Laboratory, Wright-Patterson AFB, Ohio; Goodyear Aerospace Corp., Akron, Ohio

Flight Assignment—SL–1/2, SL–3, SL–4

Results: Sample trays returned from the first two manned missions were so badly contaminated that a radiation degradation analysis could not be performed. Major objectives of the experiment were also affected by contamination of the samples returned on the last mission. In future manned space flights contamination control must receive special attention in order to prevent loss of valuable data.

M 415 Thermal Control Coatings (Instrument Unit)

Objective: Determine degradation effects of prelaunch, launch, and space environments on absorptivity/emissivity characteristics of thermal control coatings.

Principal Investigator—E. C. McKannan, NASA–MSFC

Flight Assignment—SL–1/2

Results: Loss of the solar array system wing requires thermal design modifications to minimize electrical power consumption. CSM temperatures were maintained within acceptable limits.

M 479 Zero-g Flammability

Objective: Determine extent of surface flame propagation, surface and bulk flame propagation rates under zero convection, self-extinguishment properties, and extinguishment by vacuum and water spray.

Principal Investigator—J. H. Kimzey, NASA–JSC

Flight Assignment—SL–4

Results: Data on toxicity, contamination, cleaning, timeline, and hardware performance were provided.

M 512 Materials Processing Facility

Objective: Explore space manufacturing applications of molten phenomena, such as molten metal flow, freezing patterns, thermal stirring, fusion across gaps, and surface tension, by performing five experimental tasks and Experiment 479.

Principal Investigator—P. G. Parks, NASA–MSFC

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The facility and the returned samples were identical to the training hardware and samples. The welding went extremely well. The materials processing facility was used to conduct experiments M 479, M 551, M 552, M 553, and M 555.

M 551 Metals Melting

Objectives: Study the behavior of molten metals in microgravity. Characterize the structures formed in metals melted and rapidly solidified in zero gravity. Test means of joining metals by electron beam welding in zero gravity.

Principal Investigator—R. M. Poorman, NASA–MSFC

Flight Assignment—SL–1/2

Results: Ground specimens contained large elongated grains and a wide chill zone. The Skylab specimen contained more equiaxed fine grains and a more symmetrical pattern of grain structure. The finer grain structure observed in the space specimen was attributed to constitutional supercooling, which results when a solid freezes with a composition slightly different from that of the liquid from which it forms.

M 552 Exothermic Brazing

Objectives: Test and demonstrate a method of brazing components in space repair and maintenance operations. Study surface wetting and capillary flow effects in weightless molten metals.

Principal Investigator—J. R. Williams, NASA–MSFC

Hardware Contractor—Whittaker Corp., Los Angeles, California

Flight Assignment—SL–1/2

Results: In the same time and at the same temperature conditions, nickel dissolved more rapidly in liquid silver-copper alloys in space than on Earth. The experiment indicated that this occurred not because the nickel was more soluble in space, but because the speed of dissolution was greater. This suggests that saturated liquid metal solutions can be more easily produced and true solubility more easily determined in space than on Earth.

M 553 Sphere Forming

Objective: Demonstrate the effects of zero gravity on fundamental solidification phenomena.

Principal Investigator—E. A. Hasemeyer, NASA–MSFC

Hardware Contractor—Arthur D. Little, Inc., Cambridge, Massachusetts

Flight Assignment—SL–1/2

Results: Gun problems resulted in the specimen being pear-shaped instead of spherical following gun cutoff. Incomplete melting occurred, and sometimes the spike would retract and the sphere would stick on the ceramic. At about the same time the gun problems were occurring, the time required to create a vacuum in the system seemed tremendously long. Apparently, outgassing in the gun was causing the vacuum problem.

M 555 Gallium Arsenide Crystal Growth

Objective: Grow single crystals of gallium arsenide from solution in order to produce material of exceptionally high chemical and crystalline perfection.

Principal Investigators—M. Rubenstein, Westinghouse Electric Corp., Pittsburgh, Pennsylvania; M. C. Davidson, NASA–MSFC

Flight Assignment—SL–1/2

Results: The experiment was successfully carried out. Knowledge of the role of gravity in materials processing has made substantial progress.

M 518 Multipurpose Furnace System

Objective: Enhance the capabilities of existing Skylab hardware by providing means to perform experiments on solidification, crystal growth, and other processes involving phase changes in materials.

Principal Investigator—H. A. Ray, NASA–JSC

Hardware Contractor—Westinghouse Electric Corp., Pittsburgh, Pennsylvania

Flight Assignment—SL–4

Results: The furnace system performed well and no malfunctions were encountered. Experiments M 556, M 557, M 558, M 559, M 560, M 561, M 562, M 563, M 564, M 565, and M 566 were performed using the multipurpose electric furnace system or the material processing facility. All samples processed in the furnace were returned to Earth. Results from some of the processes were far superior to the results obtained on Earth.

M 556 Vapor Growth of II—VI Compounds

Objective: Determine the degree of improvement that can be obtained in the perfection and chemical homogeneity of crystals grown by chemical vapor transport under weightless conditions in space.

Principal Investigator—H. A. Wiedemeier, Rennselaer Polytechnical Institute, Troy, New York

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–3, SL–4

Results: Mixed crystals of compound, semiconductor germanium selenide and germanium telluride were grown by chemical transport through a temperature gradient in a transport agent, iodine vapor, from polycrystalline sources of the two component materials. The growth process was carried out in sealed quartz ampoules contained in the sample cartridges. The experiment was considered a success.

M 557 Immiscible Alloy Compositions

Objective: Determine the effects of near zero-g on the processing of material compositions that normally segregate on Earth.

Principal Investigator—J. L. Reger, TRW Systems Group, Redondo Beach, California

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–3, SL–4

Results: It was demonstrated that a completely stable dispersion of the two immiscible liquids, which were very unstable on Earth, can be prepared in space. Since the important parameters of immiscible liquids, such as viscosity and density differences, are similar to those found for common liquid-metal immiscible systems, the metallic systems should also be very stable in low gravity.

M 558 Radioactive Tracer Diffusion

Objective: Measure self-diffusion and impurity diffusion effects in liquid metals in space flight, and characterize the disturbing effects, if any, due to spacecraft accelerations.

Principal Investigator—A. O. Ukanwa, Howard University, Washington

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–3

Results: A marked decrease in zinc 65 movement along the length of a cylinder of liquid zinc in space was apparently caused by the absence of convective mixing. The radial distribution observed in the Skylab samples also indicated that convective mixing was negligible in space.

M 559 Microsegregation in Germanium

Objective: Determine the degree of microsegregation of doping impurities in germanium caused by convectionless directional solidification under conditions of weightlessness.

Principal Investigator—F. A. Padovani, Texas Instruments, Inc., Dallas, Texas

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL-3

Results: Space-grown crystals were compared with identical crystals resolidified on Earth. Microsegregation in space is one-half to one-fifth that on Earth in the bulk material, which implies a reduced diffusion or mass transport of the solute through the host material during solidification.

M 560 Growth of Spherical Crystals

Objective: Grow doped germanium crystals of high chemical homogeneity and structural perfection and study their resulting physical properties in comparison with theoretical values for ideal crystals.

Principal Investigator—H. U. Walter, University of Alabama in Huntsville, Huntsville, Alabama

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL-3, SL-4

Results: Single crystals with extremely low density of defects were obtained. Even though the crystals were small, very large crystals could be prepared by this approach. The technique would seem to be ideal for processing of highly reactive and high melting temperature materials. Since no mechanical feedthroughs are required, the technique could be most readily adapted to high-pressure or encapsulated growth.

M 561 Whisker-Reinforced Composites

Objective: Produce void-free samples of silver or aluminum, reinforced with oriented silicon-carbide whiskers.

Principal Investigator—T. Kawada, National Research Institute for Metals, Tokyo, Japan

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL-3, SL-4

Results: The experiment produced void-free samples of silver, reinforced with oriented silicon-carbide whiskers. Sintered rods of silver containing distributions of unidirectionally oriented silicon-carbide whiskers, one micron in diameter by one millimeter long, were melted in the furnace. Pressure was exerted to force voids from the melt and promote wetting of the whiskers by the matrix material.

M 562 Indium Antimonide Crystals

Objective: Produce doped semiconductor crystals of high chemical homogeneity and structural perfection and to evaluate the influence of weightlessness in attaining these properties.

Principal Investigator—H. C. Gatos, Massachusetts Institute of Technology, Cambridge, Massachusetts

Coinvestigator—A. F. Witt, Massachusetts Institute of Technology, Cambridge, Massachusetts

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–3, SL–4

Results: High-quality single crystals of indium antimonide, doped with tellerium, were precision machined and etched to fit into heavy quartz ampoules, sealed, and enclosed in metal cartridges. Half of each crystal (7.62 cm in length) was melted in the furnace and regrown at the rate of 1.27 cm per hr using the unmelted half as seed.

M 563 Mixed III—V Crystal Growth

Objective: Determine how weightlessness affects directional solidification of binary semiconductor alloys and, if single crystals are obtained, determine how their semiconducting properties depend on alloy composition.

Principal Investigator—W. R. Wilcox, Seaver Science Center, University of Southern California, Los Angeles, California

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–3, SL–4

Results: Alloys of indium antimonide and gallium antimonide in varying proportions were placed in separate, fused silica ampoules, encased in cartridges, melted in the furnace, and directionally solidified at the slowest available rate.

M 564 Metal and Halide Eutectics

Objective: Produce highly continuous, controlled structures in samples of the fiberlike NaF–NaCl and platelike Bi–Cd and Pb–Sn eutectics, and measure their physical properties.

Principal Investigator—A. S. Yue, University of California, Los Angeles, California

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–3

Results: The experiment produced controlled structures in samples of fiberlike, fluoride-sodium chloride eutectic, and measured their physical properties. Three ingots of the eutectic, 1.27 cm in diameter and 10.16 cm long, were grown by melting the alloys and then cooling them directionally at the slowest available rate.

M 565 Silver Grids Melted in Space

Objective: Determine how pore sizes and pore shapes change in grids of fine silver wires when they are melted and resolidified in space.

Principal Investigator—A. Deruytherre, Katholieke Universiteit, Heverlee, Belgium

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–3

Results: The action of diffusion and of the remaining convection due to the variations in

the surface tensions appeared to be reduced in space from the rapid leveling of concentration gradients on Earth experiments.

M 566 Copper-Aluminum Eutectic

Objective: Determine the effects of weightlessness on the formation of lamellar structure in eutectic alloys when directionally solidified.

Principal Investigator—E. A. Hasemeyer, NASA–MSFC

Hardware Contractor—Westinghouse Electric Corp., Baltimore, Maryland

Flight Assignment—SL–3, SL–4

Results: Three aluminum-copper alloy rods 0.64 cm in diameter were partially melted and directionally solidified.

T 003 Inflight Aerosol Analysis

Objective: Measure aerosol particle concentration and size distribution inside spacecraft and assess adequacy of air distribution, circulation, and filtration.

Principal Investigator—W. Z. Leavitt, U.S. Department of Transportation (DOT), Cambridge, Massachusetts

Hardware Contractors—DOT; Bendix Corp., Ann Arbor, Michigan

Flight Assignment—SL–1/2, SL–3, SL–4

Results: The equipment operated properly and data cards are being analyzed.

T 025 Coronagraph Contamination Measurement

Objectives: Determine the presence of an induced particulate atmosphere surrounding the orbital assembly. Measure changes in the atmosphere due to thruster firings, waste dumps, and vehicle orientation.

Principal Investigator—J. M. Greenberg, Dudley Observatory, Albany, New York

Coinvestigator—G. P. Bonner, NASA–JSC

Hardware Contractor—Martin Marietta Corp., Denver

Flight Assignment—SL–1/2, SL–3, SL–4

Results: All EVA for this experiment was satisfactory, except for one occasion when the 35-mm camera EVA viewfinder became loose.

T 027 ATM Contamination Measurement

Objective: Determine the change in optical properties of various surfaces due to contaminants near the spacecraft on a real-time basis plus postflight analysis. Measure sky brightness background caused by solar illumination of contaminants.

Principal Investigator—J. A. Muscari, Martin Marietta Corp., Denver

Hardware Contractor—Martin Marietta Corp., Denver

Flight Assignment—SL–1/2

Results: Valuable quantitative deposition information was supplied, which was used daily for mission support and contamination prediction calculations.

COMET KOHOUTEK EXPERIMENT

Objective: Provide long-term viewing, near-perihelion viewing, astronaut response, and payload optimization, allowing Kohoutek to be monitored in the ultraviolet and visible-light ranges regardless of its angular separation from the Sun.

Project Scientist—W. C. Snoddy, MSFC

Experiment Integration Engineer—R. J. Barry, Bendix Corp., Burbank, California

Results: Preliminary results indicate that the experiment was highly successful.

APPENDIX 4—EXTRAVEHICULAR EXPERIMENT OPERATIONS

[From Johnson Space Center, *Skylab Mission Report*, Supplement 3, *Flight Crew Contributions to the Skylab Mission*, July 1974]

Experiment		Operations Performed	Visit	Remarks
Number	Title			
D024	Thermal Control Coatings	Sample trays deployed and retrieved.	Second and third	
S020	X-Ray/Ultraviolet Solar Photography	Instrument attached to Apollo telescope mount truss, operated, and retrieved.	Third	Operated during extravehicular activities because of parasol in solar scientific airlock.
S149	Particle Collection	Experiment unit attached to Apollo telescope mount and cassettes exposed. Unit retrieved upon completion.	Second and third	Solar-side exposures obtained by extravehicular activity because of parasol in solar scientific airlock.
S201 and S201K	Extreme Ultraviolet Electronographic Camera	Camera attached to Apollo telescope mount truss, operated, and retrieved.	Third	Added to obtain data on Comet Kohoutek and other celestial objects.
S228	Transuranic Cosmic Rays	Detector assemblies deployed and retrieved.	Third	
S230	Magnetospheric Particle Composition	Collector assemblies deployed and retrieved.	Second and third	
T025 and T025K	Coronagraph Contamination Measurement	Camera attached to Apollo telescope mount truss, operated, and retrieved.	Third	Operated during extravehicular activity because of parasol in solar scientific airlock.

APPENDIX 5—EXPERIMENT REPAIR AND MAINTENANCE

[From Johnson Space Center, *Skylab Mission Report*, Supplement 3, *Flight Crew Contributions to the Skylab Mission*, July 1974]

Experiment	Abnormal condition	Corrective action
	Unplanned Tasks	
Apollo Telescope Mount		
White Light Coronagraph (S052)	Contamination on occulting disc caused bright spots on television monitor.	Contamination brushed off disc during extravehicular activity.
X-Ray Spectographic Telescope (S054)	Drive mechanism on aperture door failed.	Door manually opened by removing release pins during extravehicular activity.
	Filter wheel jammed between two filter positions.	Wheel moved to open position during extravehicular activity.
Ultraviolet Scanning Polychromator-Spectroheliometer (S055A)	High-voltage tripoff caused by oversensitivity of detector to background radiation levels.	Main high-voltage switch configured to override for manned operation and to enable unattended operations.
	Aperture door-ramp latch binding.	Door-ramp latch removed during extravehicular activity.
Extreme Ultraviolet Coronal Spectroheliograph (S082A)	Aperture door-ramp latches binding.	Door pinned open during extravehicular activity.
Chromospheric Extreme Ultraviolet Spectrograph (S082B)	Exposure timer operating erratically.	Replacement timer installed.
	Cover on hydrogen-alpha 2 telescope aperture operating intermittently.	Cover pinned open during extravehicular activity.
Image Scope Television Monitor (S082A/B)	Monitor inoperative.	New television monitor supplied and installed successfully.

Experiment Repair and Maintenance—Continued

Experiment	Abnormal condition	Corrective action
	Unplanned Tasks	
Earth Resources Experiment Package		
Multispectral Scanner (S192)	Improperly seated cooler/detector.	Reseated and realigned. Alignment readings increased from 43 percent to 46 percent.
	Incorrect prelaunch attenuator adjustments.	Special procedure uplinked and crew adjusted attenuator in flight.
	Detector did not provide desired resolution of thermal data.	Modified thermal detector supplied and installed.
Microwave Radiometer/Scatterometer and Altimeter (S193)	Electrical short caused erratic antenna motion.	Antenna pinned in zero-degree pitch position during extravehicular activity, restoring operation of antenna in roll axis.
Biomedical		
Sleep Monitoring (M133)	Cap electrodes dried out.	Rejuvenation kits used on second and third visits.
Mark 1 Exerciser	Mark 1 exerciser spring broke.	Spring replaced.
Specimen Mass Measurement Device (M074)	Electronics module failed on wardroom specimen mass measurement device.	Module replaced with electronic module from waste management compartment unit. Spare electronic module supplied and installed during next visit.
Corollary		
Nuclear Emulsion (S009)	Motor failed, preventing opening and closing of detector package.	Motor resupplied and replaced.

Experiment Repair and Maintenance—Continued

Experiment	Abnormal condition	Corrective action
	Unplanned Tasks	
Articulated mirror system	Tilt control jammed on first visit.	Crew freed tilt adjustment gears and reported new indicator "zero" position.
	Mirror surface was contaminated on second visit.	New mirror installed by third visit crew.
	Mirror position indicator failed on third visit.	Crew positioned mirror by counting turns of control knob.
Ultraviolet Panorama (S183)	Film plate jammed in carrousel.	Malfunction procedure used for carrousel alignment.
	Electrical failure in protective circuit, which shut off power to electronics package before exposure sequence.	Jumper wires connected between test connector and camera connector pins.
Contamination Measurements (T027/S073)	Photometer head in nonretractable position due to shaft drive circuit failure.	Photometer system ejected into space, permitting antisolar scientific airlock use in other experiments.
Student		
Neutron Analysis (ED76)	Detector deactivation slide jammed.	Detector partly dismantled to free deactivation slide.
	Planned Tasks	
Apollo Telescope Mount		
Persistence Image Scope	Fuzzy image, poorly defined bright spots and horizontal bright lines on persistence image scope.	Proper operation restored after contacts were cleaned and batteries changed.
Earth Resources Experiment Package		
Multispectral Photographic Cameras (S190A)	No film motion sensing at camera station 6.	Camera station 6 magazine replaced with spare.

Experiment Repair and Maintenance—Concluded

Experiment	Abnormal condition	Corrective action
	Planned Tasks	
	Dust particles on optics and film emulsion buildup on platens.	Cleaned with optical cleaning kits.
Tape recorder	Metal oxide buildup on recording heads.	Contamination removed from recording heads and tape rollers.
Biomedical		
Sleep Monitoring (M133)	Improper operation on indicator lights.	Cable between electronic box and cap replaced.
	Lack of telemetry data.	Two experiment cables replaced with spares.
Lower Body Negative Pressure (M092)	Blood pressure measuring system cuff failed.	Cuff replaced with spare.

APPENDIX 6—SYSTEM REPAIRS AND MAINTENANCE

[From Johnson Space Center, *Skylab Mission Report*, Supplement 3, *Flight Crew Contributions to the Skylab Mission*, July 1974]

System	Abnormal condition	Corrective action
	Unplanned Tasks	
Structure		
Orbital Workshop micrometeorite shield (thermal control)	Shield torn off during launch, resulting in high interior Workshop temperature.	Skylab parasol deployed through solar scientific airlock on first visit.
		Twin-pole sunshade deployed during extravehicular activity on second visit.
Electrical power		
Orbital Assembly solar array system	Solar-array system wing 2 broken off during launch and wing 1 failed to deploy.	Wing 1 deployed during EVA on first visit.
Orbital Assembly charger/battery/regulator module 15	Stuck relay in regulator prevented battery from being charged.	Crewman freed stuck relay during first visit by striking skin of spacecraft with hammer in vicinity of relay during EVA.
Attitude control		
Orbital Assembly rate-sensing system	Deterioration in performance of rate gyros during first visit.	Rate gyro "six-pack" installed in multiple docking adapter on second visit. Installation required extravehicular operations.
Environmental control		
Thermal control system	Leakage of coolant fluid from coolant loop.	Fluid replenished on third visit.
Refrigeration system	Failed primary and secondary refrigeration system loop bypass valves in partial radiator position caused low loop temperature and loss of control.	Connector J5 disconnected to permit simultaneous use of primary and secondary loops and to prevent automatic switchover.

System Repairs and Maintenance—Continued

System	Abnormal condition	Corrective action
	Unplanned Tasks	
Apollo telescope mount control and display panel cooling system	Gas bubbles in cooling fluid caused flow rate fluctuations.	Spare liquid/gas separator installed in place of system filter.
Airlock module primary coolant loop	Contamination caused temperature control valve to stick in cold position.	Valve resumed operation during troubleshooting.
Life support		
Orbital Workshop hatch check valves	Check valves leaked.	Check valve orifices taped.
Orbital Workshop vent valve	Vent valves remained open after close commands sent.	Valves purged and cleaned; valves then closed.
150-psi nitrogen pressure regulator	Nitrogen pressure regulator was 10 to 15 psi low.	Placed on a 5-day duty cycle; operated normally.
Urine receptacle suction line	Rubber washer loose.	New washer supplied and installed by crew.
Communications		
Transmitter	Transmitter C inoperative.	Crewman reset circuit breaker on panel 200 and operations were normal.
Airlock Module tape recorder	Tape slipped off capstan.	Crew repositioned tape on capstan.
Television camera	Television camera color wheel was not rotating, causing loss of lower part of picture and partial color.	Crew removed lens and started wheel manually to remove contamination in gearing.
Teleprinter	Printout difficult to read.	Teleprinter head cleaned.
	Planned Tasks	
Life support		
Molecular sieves A and B partial pressure carbon dioxide	Erratic readings.	A and B sensors replaced. O-ring on molecular sieve B partial pressure carbon dioxide inlet and cap replaced.

System Repairs and Maintenance—Concluded

System	Abnormal condition	Corrective action
	Planned Tasks	
Condensate dump	Dump probe iced up.	Dump probe replaced.
Waste management compartment water dispenser	Low water flow.	Replaced with spare.
Waste management compartment squeezer	Leaked around seal.	Seal replaced.
Airlock Module electrical power system		
Fine sensor control panel	Panel 392 failed test.	Sensor replaced with spare.
Communications		
Television input station	Broken connector pin on television input station 642.	Replaced with spare.
Television monitor	No video on television monitor.	Monitor and monitor cable replaced.
Television power cable	Coaxial lead failed in power cable.	Power cable replaced.
Airlock Module tape recorder	Three recorders failed.	Replaced with spares.
Teleprinter	Paper feed mechanism inoperative.	Teleprinter head assembly replaced with spare unit.
Speaker-intercommunications assembly	Switch failures on two units.	Assemblies replaced with spares.
Video tape recorder	Recorder failed to transmit recorded signals.	Electronics unit and transport unit replaced with spares.

APPENDIX 7—TASKS IDENTIFIED AS POSSIBLE FOR SPACE LABORATORY

[From Douglas Aircraft Company, Inc., Summary Report SM-48822, "Report on the Development of the Manned Orbital Research Laboratory (MORL) System Utilization Potential." See January 1966 entry.]

RESEARCH

Astronautics

- Determination of orbital atmospheric densities (free molecular flow regime) in all areas of mission interest*
- Determination of radiation environment in all areas of mission interest

  Particular emphasis on electron flux at synchronous altitudes*
- Determination of micrometeoroid environment in all areas of mission interest*

Biotechnology

- Qualification of proposed MORL atmosphere for long-term habitability*
- Evaluation of aeroembolism effects upon decompression to pure O_2 suit atmosphere*
- Determination of all detrimental atmospheric contaminants and toxicity levels*
- Evaluation of methods of identifying and continuously monitoring all trace contaminants at levels significantly lower than ever attempted before*
- Assessment of long-term exposure to modified (semisterile) bacteriological environment*
- Assessment of biological and psychological effects of long-term use of recycled and reclaimed (urine) water
- Establishment of human requirements and operational parameters for spinning (artificial gravity) mode

Control Systems

- Determination of accurate long- and short-term disturbance profiles
- Determination of horizon radiometric signature (gradients profile)
- Assessment of long-term exposure of optical devices and bearings to the space environment
- Determination of hypergolic propellant long-term storage and ignition characteristics under orbit-environment conditions*

*MORL study tasks for which orbital flight experience and development support might be provided by Apollo Applications Program.

System Repairs and Maintenance—Concluded

System	Abnormal condition	Corrective action
	Planned Tasks	
Condensate dump	Dump probe iced up.	Dump probe replaced.
Waste management compartment water dispenser	Low water flow.	Replaced with spare.
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*MORL study tasks for which orbital flight experience and development support might be provided by Apollo Applications Program.

- Assessment of high-speed space-particle impact on system components (loaded propellant tanks, combustion chamber, etc.)*
- Assessment of vacuum sealing and joining of metals (valves)*

Power

- Determination of long-term (years) stability of Pu–238 isotope fuel under high- and low-temperature conditions
- Determination of maximum practical reduction of O^{17} and O^{18} isotopes in PuO_2 fuel form
- Evaluation of effects on neutron source strength of fuels using purified O_2
- Determination of fuel-capsule material creep as a function of temperature and stress for time periods over five years
- Determination of PuO_2 fuel helium release rates as a function of temperature and time
- Determination of thermal conductivity of packed beds of fuel particles
- Establishment of chemical reaction rates between the diffusion barrier and fuel capsule materials
- Determination of oxidation-cladding plastic flow as a function of temperature and stress
- Assessment of oxidation cladding compatibility with various soils
- Determination of thermal conductivity of representative soils, particularly at high (1400 K [2000°F]) temperatures
- Determination of long-term dissolution rates of fuel in sea water
- Determination of fuel-capsule-material brittle/ductile transition temperatures, energy absorption as a function of strain rate, and strength and creep after impact
- Determination of fuel-block-material strength and plastic flow as a function of time and temperature
- Determination of fuel-block-material oxidation rate when protected by an emissivity coating

ADVANCE TECHNOLOGY

Astronautics

- Verification of recommended deployment system used to separate laboratory and counterweight for artificial gravity spinup
- Assessment of feasibility of using simpler linkages

*MORL study tasks for which orbital flight experience and development support might be provided by Apollo Applications Program.

- Determination of structural damping properties of cables when subjected to prolonged space environment
- Determination of induced disturbances introduced by internal mass motion during the rotating mode
- Assessment of human tolerance to wobble motions to determine wobble-damping control requirements

Biotechnology

- Evaluation of humidity vapor water purification techniques to determine whether charcoal bed will eliminate atmospheric contaminants
- Development of a flight-qualified mass-spectrometer-gas-chromatograph combination to measure trace contaminants at significantly lower levels than has been attempted before
- Evaluation of whether thermal desorption of molecular sieve bed is possible at 420 to 435 K (300 to 325°F), rather than 455 K (360°F), to reduce system complexity
- Determinations of accurate metabolic rates so that spacesuit airflow fans can be efficiently sized
- Evaluation of whether the Bosch hydrogenation reactor can operate in a low output mode so that power can be made available for critical experiments
- Determination of (1) the volume of laboratory and food wastes to be expected, (2) the density of wastes after freeze drying, and (3) the long-term compatibility of fecal wastes with food and laboratory wastes and collection sphere material
  Evaluation of decontamination and cleanup techniques in case of illness*
- Evaluation of long-term maximum sound tolerance levels for EC/LS rotating machinery and air ducts*
  Development of high-efficiency, low-specific-speed fans
  Determination of duct configuration for minimum sound propagation
- Evaluation of cabin ventilation in zero-g*
- Resolution of micrometeoroid-penetration leak detection problems
- Development of physical/psychological testing equipment compatible with orbital environment
  Determination of physical/psychological monitoring and conditioning criteria*
- Development of techniques for integrating behavioral testing with routine station operation and maintenance procedures
- Development of automated biomedical measurements
- Determination of long-term physical and psychological effects of food packaging and processing methods

*MORL study tasks for which orbital flight experience and development support might be provided by Apollo Applications Program.

- Development and testing of onboard zero-g laundry facilities
- Assessment of man's ability in zero-g to perform station-keeping operations, maintenance, and experimentation*
- Development of techniques for crewman positive motion control
- Identification of flight crew procedures with emphasis on communication requirements; need for restraints, special tools, and work aids; special requirements for controls and displays; and optimum layout of onboard equipment and facilities
- Assessment of man's performance capabilities in extravehicular spacesuit operations*
- Establishment of realistic, long-term radiation exposure criteria, particularly critical for synchronous missions*
- Development of effective partial body shielding

Flight Electronics

- Development and qualification of a high-power, low-loss, solid-state rf switch for use over a frequency range of 250 to 2300 mc

Control Systems

- Development and qualification of control-moment gyro system sized to MORL-class requirements
- Evaluation of control-moment gyro system's ability to counteract disturbance torques (orbital tests required)
- Development of long-life bearing techniques and maintainability features for control-moment gyros
- Evaluation of the performance of total, integrated inertial reference system, including the inertial reference components, various experiment packages, and the space crew
  Determination of detailed computational requirements for the inertial reference system (to determine whether a new special purpose computer is required)
- Evaluation of improved accuracy of single axis platforms*
- Evaluation of the performance of the proposed rigid inertial-reference base concept
- Development of extravehicular maintenance techniques and procedures to bring the reliability of the two-axis star tracker to acceptable levels*
- Evaluation of man-machine interface to ensure successful execution of experiments utilizing the star tracker, inertial reference system, displays, and data processing equipment
- Simulation of proposed gyrocompassing technique for maintaining X-axis in orbit plane

*MORL study tasks for which orbital flight experience and development support might be provided by Apollo Applications Program.

- Evaluation of performance of completely integrated stabilization and control subsystem in a specially designed simulation facility
- Evaluation of proposed horizon-sensor maintenance techniques
- Determination of horizon sensor accuracy*
- Determination of performance characteristics of inertial-rate integrating gyros in long-term, zero-g environment*
- Evaluation of gyromotor bearing life in a zero-g environment*
- Determination of applicability of long-life, air-bearing gyros to MORL
- Development of long-life bellows (1000 + cycles) capable of storing hypergolic propellants for extended periods*
- Evaluation of corrosion due to fuel and oxidizer*
- Assessment of inflight reaction-control system component maintenance*
- Assessment of electronic circuit design, packaging, and testing for improved maintainability/reliability

Structures

- Development of optimum radiator surface coatings for EC/LS and power systems
- Evaluation of techniques and equipment for in-orbit EC/LS and power-system radiator tube repair
- Assessment of the effectiveness of radiation shielding by onboard equipment*
- Evaluation of the optical properties of the outer surface for temperature control* Assessment of degradation due to orbital environment*
- Assessment of micrometeoroid damage to windows*
- Assessment of internal-material advanced aging and breakdown, formation of combustion products and characteristics, and quantities of volatile products emitted*
- Evaluation of space exposure effects on static and dynamic seals*
- Development and qualification of experimental and operational handling arms and airlock operating and sealing mechanisms*

Power

- Evaluation of long-term compatibility, as a function of temperature, of fuel and reaction products with fuel capsule materials
- Evaluation of Xe-He gas mixture helium loss through selective leakage

*MORL study tasks for which orbital flight experience and development support might be provided by Apollo Applications Program.

- Determination of fuel block coating emissivity as a function of time and temperature in a vacuum environment
  Determination of the adherence of coatings during thermal cycling
- Development of super alloy coatings with an emissivity of 0.9 or better for heat source exchanger

ADVANCE DEVELOPMENT

Biotechnology

- Development of waster electrolysis cells with extended membrane life
- Confirmation of cell stop-start capability
- Evaluation of the long-term effectiveness of trace contaminant removal techniques
- Development of flight-qualified ultraviolet lights used for control of atmospheric bacteria
- Qualification of water separator performance in zero-g
- Qualification of interface heat exchanger (between power system and heat transport circuit) to establish leak prevention capability of internal vent passage technique

Flight Electronics

- Development of an S-band transmitter to satisfy TV transmission characteristics
- Development and orbital testing of external TV cameras and their associated pan and tilt mechanism
- Evaluation of the theoretically optimized modulation parameters of the telemetry modulator by breadboard testing

Power

- Assessment of plutonium production schedules and availability priorities to ensure fuel availability
- Assessment of facilities required to convert plutonium into fuel form on a commercial basis and produce fuel capsules
- Development of a fuel capsule "window" that is selectively porous to helium only
- Evaluation of foil and solid insulations to determine thermal conductivity as a function of altitude and time in vacuum
- Determination of neutron source strength of commercially produced fuel as a function of time
  Determination of effects of initial impurities and reaction products

SUPPORTING DEVELOPMENT

Biotechnology

- Development of polarographic oxygen-partial-pressure sensors to improve sensor life, or development of a completely new concept
- Development of "dry" electrolysis units to eliminate use of free fluid electrolyte in atmosphere supply system

Control Systems

- Investigation of alternate control-moment gyro configurations to provide additional torquing capability for laboratory maneuvering
- Determination of the applicability of alternate inertial-reference systems
- Evaluation of alternate alignment concepts and techniques for the two-axis star tracker
- Evaluation of airlock devices for inflight maintenance of the two-axis star tracker, rather than the present extravehicular maintenance
- Evaluation of alternate techniques for aligning the X-axis to the orbit plane
- Investigation of backup, manual, optical-alignment techniques for the inertial reference systems*
- Evaluation of potentially more efficient, low-level thrustors and advance reaction-control propulsion systems
- Evaluation of screen ullage positioning devices for reaction control system propellant expulsion
- Evaluation of new electronic circuit techniques; i.e., microintegrated circuits

Power

- Evaluation of reentry stability of shaped fuel blocks through wind tunnel tests
  Evaluation of the heating rates of shaped fuel blocks
- Determination of a model for fuel capsule deformation after reentry impact
- Determination of the impact depth and Earth coverage of fuel blocks after reentry
- Determination of the high-temperature creep strength of nickel and its alloys when the material is deprived of oxygen—evaluation of the strength of preoxidized samples and the use of argon doped with small percentages of oxygen

*MORL study tasks for which orbital flight experience and development support might be provided by Apollo Applications Program.

- Investigation of fuel capsule fabrication to (1) obtain leak-tight, maximum-strength welds; (2) determine methods of filling the capsule with fuel, closing the filter plug, and leak checking; and (3) determine methods of applying oxidation cladding to the diffusion barrier on the fuel capsules
- Evaluation of improved alternator designs
- Assessment of the need for (1) improved long-term, high-temperature thermocouples; (2) thermocouple inflight recalibration; and (3) other temperature measuring techniques (optical sensors or variations in the electrical resistance of gases at high temperature)

APPENDIX 8—SKYLAB CONTRACTORS, RESPONSIBILITIES, AND COSTS

(Partial List)

[From U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Skylab: Hearing on Skylab Mission*, 93rd Cong., 1st sess., 23 May 1973]

Major Skylab Contractors

Contractor	Responsibility	Contract Amount (millions)
	JSC	
Rockwell International	Command and service module	$354.3
General Electric	Automatic checkout equipment reliability and quality assurance system engineering	29.7
Martin Marietta	Payload and experiments integration and spacecraft support	105.4
The Garrett Corp	Portable astronaut life support assembly	11.9
International Latex	Space Suits	16.9
ITEK	S190—Multispectral photo facility	2.7
Black Engineering	S191—Infrared spectrometer	2.0
Cutler Hammer Airborne Instrument Lab	S194—L-band radiometer	1.5
General Electric	S193—Microwave radiometer/scatterometer	11.3
Honeywell	S192—10-band multispectral scanner	10.8
	HQ	
Martin Marietta	Program support	11.1
	MSFC	
General Electric	Electrical support equipment and logistics support	25.0
McDonnell Douglas	S–IVB stage	25.7
Martin Marietta	Payload integration and multiple docking adapter assembly	215.5
Rockwell International (Rocketdyne Division)	Saturn engine support—Saturn V and Saturn IB	10.3
IBM	Apollo telescope mount digital computer and associated items	29.2
Chrysler	S–IB stage	30.0
	S–IB systems and integration	7.0
McDonnell Douglas, Huntington Beach	Orbital Workshop	383.3
McDonnell Douglas, St. Louis	Airlock	267.7
General Electric	Launch vehicle ground support equipment	12.6
IBM	Instrument unit	30.7

Skylab Contractors, Responsibilities, and Costs—Concluded

Major Skylab Contractors

Contractor	Responsibility	Contract Amount (millions)
Boeing	S–IC stage	.9
	System engineering and integration	7.4
American Science and Engineering	X-ray spectrographic telescope—S054	8.3
High Altitude Observatory	White light coronagraph—S052	14.7
Harvard	UV spectrometer—S055	34.6
Naval Research Laboratory	UV spectrograph/heliograph	40.9
Goddard Space Flight Center	Dual X-ray telescope	2.5
	KSC	
Chrysler	S–IB launch operations support	23.2
Boeing	Saturn V launch vehicle and launch complex 39, launch operations	14.4
Rockwell International	Command and service module support	17.5
McDonnell Douglas	S–IVB launch services	58.9
IBM	Instrument unit, launch services	12.3
Delco Electronics	Navigation and guidance launch operations	.9
Martin Marietta	Multiple docking adapter support	7.2

Major Skylab Subcontractors

	JSC	
Aerojet General	CSM service propulsion system (SPS) rocket engines	$ 3.1
AiResearch	CSM environmental control systems (ECS)	5.6
Aeronca Inc.	CSM honeycomb panels	1.5
AVCO	Command module heat shields	2.5
Beech Aircraft	CSM cryogenic gas storage system	4.0
Collins Radio	CSM communications and data systems	4.7
Honeywell	CSM stabilization and control systems	3.1
Marquardt	Service module reaction control system (RCS) engines	1.1
Northrop	Command module Earth-landing system	.8
Pratt & Whitney Aircraft	CSM fuel-cell powerplants	3.2
Bell Aerospace	RCS propellant storage tanks	3.4
Simmonds Precision Products	Propellant utilization gauging system	1.3
	MSFC	
TRW	Solar array system	23.7
Fairchild Hiller	Habitability support system	19.0
Hamilton Standard Division of United Aircraft	Centrifugal urine separators	9.6
Hycom Manufacturing	Orbital workshop viewing window	.9
AiResearch	Molecular sieve	4.7

APPENDIX 9—FUNDING

(Dollars in Thousands)

Fiscal Year		Funding Breakdown		
1966				
		Apollo Applications		$ 51 247
		Space vehicles:		
	$ 51 247	Uprated Saturn I procurement	$ 1 000	
		Spacecraft modifications	7 500	
			8 500	
		Experiments:		
		Definition	34 447	
		Development	5 900	
			40 347	
		Mission support:		
		Payload integration	100	
		Operations	2 300	
			2 400	
1967				
		Apollo Applications		$ 80 000
		Space vehicles:		
	$ 80 000	Saturn IB procurement	$ 21 900	
		Saturn V procurement	1 300	
		Spacecraft modifications	14 500	
			37 700	
		Experiments:		
		Definition	10 974	
		Development	26 626	
			37 600	
		Mission support:		
		Payload integration	3 900	
		Operations	800	
			4 700	
1968				
		Apollo Applications		$126 190
		Space vehicles	$ 29 629	
Budget Plan	$253 200			
Prior year funds applied to FY 1969 Financing Plan	−127 010	Payloads and experiments	96 561	
Financing Plan	$126 190			

Funding—Continued

(Dollars in Thousands)

Fiscal Year		Funding Breakdown		
1969				
	Apollo Applications			$277 010
		Space vehicles	$ 93 600	
Budget Plan	$150 000			
Prior year funds applied to FY 1969		Payloads and experiments	183 410	
Financing Plan	127 010			
Financing Plan	$277 010			
1970				
	Apollo Applications			$308 800
		Space vehicles	$138 400	
Budget Plan	$308 800			
		Payloads and experiments	170 400	
1971				
	Skylab			$405 200
		Workshop Cluster:		
Budget Plan	$405 200	Orbital Workshop	$ 96 665	
		Multiple docking adapter	27 600	
		Airlock module	85 300	
		Apollo telescope mount	14 001	
			223 566	
		Experiment development:		
		Applications and science	35 608	
		Technology and engineering	16 337	
		Medical	6 620	
			58 565	
		Payload integration	27 803	
		Program support	15 050	
		Space vehicles:		
		Spacecraft	42 040	
		Saturn IB	25 659	
			67 699	
		Operations	12 517	

Funding—Concluded

(Dollars in Thousands)

Fiscal Year		Funding Breakdown		
1972				
	Skylab			$538 500
		Workshop Cluster:		
Budget Plan	$538 500	Orbital Workshop	$158 525	
		Multiple docking adapter	31 248	
		Airlock module	77 720	
		Apollo telescope mount	10 908	
			278 401	
		Experiment development:		
		Applications and science	23 368	
		Technology and engineering	22 724	
		Biomedical	3 650	
			49 742	
		Payload integration	32 591	
		Program support	31 823	
		Space vehicles:		
		Saturn V	4 100	
		Spacecraft	92 706	
		Saturn IB	39 582	
			136 388	
		Operations	9 555	
1973				
	Skylab			$502 000
Budget Planning	$502 000			
1974				
	Skylab			$233 300
Budget Planning	$233 300			

Source: Information supplied by F. B. Hopson, JSC, Administrative and Program Support Directorate.

APPENDIX 10

OFFICIAL U.S. INTERNATIONAL AERONAUTICAL FEDERATION WORLD RECORDS

Mission/Date	Commander and Crew	Record	Numbers
F.A.I. World Records—Mercury Flights			
MR–3 5/5/61	Alan B. Shepard, Jr.	Altitude without Earth Orbit	186.6 km (116 mi)
F.A.I. World Records—Gemini Flights			
Gemini V 8/21–29/65	L. Gordon Cooper, Jr. Charles Conrad, Jr.	Distance with Earth Orbit, 2–4 Astronauts	5 326 133.6 km (3 309 506 mi)
Gemini V 8/21–29/65	L. Gordon Cooper, Jr. Charles Conrad, Jr.	Duration with Earth Orbit, 2–4 Astronauts	190 hrs 56 min
Gemini VII 12/4–13/65	Frank Borman James A. Lovell, Jr.	Distance with Earth Orbit, 2–4 Astronauts	9 204 573.8 km (5 719 457 mi)
Gemini VII 12/4–13/65	Frank Borman James A. Lovell, Jr.	Duration with Earth Orbit, 2–4 Astronauts	330 hrs 35 min
Gemini X 7/18–21/66	John W. Young Michael Collins	Greatest Altitude with Earth Orbit, 2–4 Astronauts	766 km (476 mi)
Gemini XI 9/12–15/66	Charles Conrad, Jr. Richard F. Gordon, Jr.	Greatest Altitude with Earth Orbit, 2–4 Astronauts	1368.98 km (850.65 mi)
F.A.I. World Records—Apollo Flights			
Apollo 7 10/11–22/68	Walter M. Schirra, Jr. R. Walter Cunningham Donn F. Eisele	1. Greatest Mass Lifted to Altitude 2. World Class for Greatest Mass Lifted to Orbit, 2–4 Astronauts	14 771.6 kg (32 566 lbs)
Apollo 8 12/21–27/68	Frank Borman James A. Lovell, Jr. William A. Anders	1. Greatest Mass Lifted to Altitude 2. Highest Altitude 3. World Class for Greatest Mass Lifted to Orbit, 2–4 Astronauts 4. World Class for Highest Altitude, 2–4 Astronauts 5. Duration of a Lunar Mission	128 002.4 kg (282 197 lbs) 377 349.38 km (203 752.37 nm) 128 002.4 kg (282 197 lbs) 377 349.38 km (203 752.37 nm) 147 hrs 42 sec

		6. Duration in Lunar Orbit, 2–4 Astronauts	20 hrs 6 min 49 sec (10 orbits)
		7. Total time in Space, 1 Astronaut	572 hrs 10 min 16 sec
Apollo 9	James A. McDivitt	1. Longest Duration Outside Spacecraft (EVA)	47 min 1 sec
03/03–13/69	David R. Scott	2. Longest Duration in Group Flight, Linked	21 hrs 36 min 31 sec
	Russell L. Schweickart	3. Greatest Mass in Group Flight, Linked	28 428.9 kg (62 675 lbs)
		4. Greatest Distance in Group Flight, Linked	602 488.9 km (325 318 nm)
		5. Longest Duration in Group Flight	26 hrs 32 min 59 sec
Apollo 10	Thomas P. Stafford	1. Duration of a Lunar Mission	192 hrs 03 min 23 sec
05/18–26/69	John W. Young	2. Duration in Lunar Orbit	31 orbits
	Eugene A. Cernan		
Apollo 11	Neil A. Armstrong	1. Duration of Stay on the Surface of the Moon	21 hrs 36 min 21 sec
07/16–24/69	Michael Collins	2. Greatest Mass Landed on the Moon	7326.9 kg (16 153.2 lbs)
	Edwin E. Aldrin, Jr.	3. Duration of Stay Inside Spacecraft on Lunar Surface	19 hrs 49 min 28 sec
		4. Duration of Stay Outside Spacecraft on Lunar Surface	2 hrs 31 min 40 sec
		5. Greatest Mass Lifted to Lunar Orbit from Lunar Surface	2689.1 kg (5928.6 lbs)
		6. Duration of Stay Outside Spacecraft (World Absolute)	2 hrs 31 min 40 sec
Apollo 12	Charles Conrad, Jr.	1. Duration of a Lunar Mission	244 hrs 36 min 25 sec
11/14–24/69	Richard F. Gordon, Jr.	2. Duration of Stay in Lunar Orbit	88 hrs 56 min 01 sec
	Alan L. Bean	3. Duration of Stay in Lunar Surface	31 hrs 31 min 12 sec
		4. Duration of Stay Outside the Spacecraft	25 hrs 06 min 49 sec
		5. Duration of Stay on Lunar Surface for Crewmen	14 hrs 02 min 25 sec
		6. Total Continuous Time Outside the Spacecraft for One Crewman	3 hrs 52 min 06 sec
		7. Total Accumulated Time Outside the Spacecraft for One Crewman	7 hrs 37 min 37 sec

Official U.S. International Aeronautical Federation World Records—Continued

F.A.I. World Records—Apollo Flights

Mission/Date	Commander and Crew	Record	Numbers
Apollo 13 04/11–17/70	James A. Lovell, Jr. Fred W. Haise, Jr. John L. Swigert, Jr.	Total Accumulated Time in Space for One Crewman	715 hrs 04 min 57 sec
Apollo 14 01/31–02/9/71	Alan B. Shepard, Jr. Edgar D. Mitchell Stuart A. Roosa	1. Total Duration of Stay Outside Spacecraft (EVA) by One Astronaut for a Single Mission	9 hrs 12 min 27 sec
		2. Total Duration of Stay Outside Spacecraft on Lunar Surface for Single Mission (Total Accumulation for All Crewmen) (World Class for Lunar Mission)	17 hrs 33 min 29 sec
		3. Maximum Distance Traveled on Lunar Surface Away from Spacecraft (World Class for Lunar Mission)	1453.8 m (4770 ft)
Apollo 15 07/26–08/7/71	David R. Scott Alfred M. Worden James B. Irwin	1. Total Time Outside Spacecraft on Lunar Surface for One Crewman During One Mission	18 hrs 18 min 26 sec
		2. Maximum Radial Distance Traveled Away from Spacecraft on Lunar Surface	5020 m (16 470 ft)
		3. Greatest Mass to Lunar Orbit from Earth	34 599.1 kg (76 278 lbs)
Apollo 16 04/16–27/72	John W. Young Thomas K. Mattingly II Charles M. Duke, Jr.	1. Duration of Stay in Lunar Orbit	125 hrs 46 min 50 sec
		2. Duration of Stay on Lunar Surface	71 hrs 02 min 13 sec
		3. Duration of Stay Outside Spacecraft for All Crewmen on a Single Mission	39 hrs 04 min 03 sec
		4. Greatest Mass Landed on Surface of Moon	8259 kg (18 208 lbs)
		5. Greatest Mass Lifted from Lunar Surface	4966.3 kg (10 949 lbs)
Apollo 17 12/07–19/72	Eugene A. Cernan Ronald E. Evans Harrison H. Schmitt	1. Total Time Outside Spacecraft for One Crewman on a Single Mission (World Absolute)	21 hrs 31 min 44 sec

		2. Total Time Outside Spacecraft for One Crewman on a Single Lunar Mission (World Class—Lunar Mission)	21 hrs 31 min 44 sec
		3. Total Time in Lunar Orbit (World Class—Lunar Mission)	147 hrs 41 min 13 sec
		4. Maximum Distance Traveled Radially Away from Spacecraft on the Lunar Surface	7628.8 m (25 029 ft)
		5. Duration of a Lunar Mission	301 hrs 51 min 57 sec
		F.A.I. World Records—Skylab Flights	
SL-1/SL-2	Charles Conrad, Jr.	1. Absolute Duration of Flight	28 days 00 hrs 49 min 49 sec
05/25-06/22/73	Joseph P. Kerwin	2. Duration in Earth Orbit	28 days 00 hrs 49 min 49 sec
	Paul J. Weitz	3. Duration in Linked Configuration	27 days 06 hrs 48 min 07 sec
		4. Absolute Distance Traveled	18 536 730.9 km (10 009 034 nm)
		5. Distance Traveled in Linked Configuration	18 059 390.9 km (9 751 291 nm)
		6. Total Absolute Time in Space, 1 Astronaut	49 days 03 hrs 38 min 36 sec
		7. Total Time in Space for Orbital Mission	38 days 23 hrs 02 min 11 sec
		8. Greatest Mass Linked	88 054.5 kg (194 127 lbs)
SL-3	Alan L. Bean	1. Absolute Duration of Flight	59 days 11 hrs 09 min 04 sec
07/28-09/25/73	Owen K. Garriott	2. Duration in Earth Orbit	59 days 11 hrs 09 min 04 sec
	Jack R. Lousma	3. Absolute Distance Traveled	39 309 605.6 km (21 225 489 nm)
		4. Duration in Linked Configuration	59 days 00 hrs 09 min 42 sec
		5. Distance Traveled in Earth Orbit	39 309 605.6 km (21 225 489 nm)
		6. Absolute Time in Space, 1 Astronaut	69 days 15 hrs 45 min 29 sec
		7. Distance Traveled in Linked Configuration	39 007 368.4 km (21 062 294 nm)
		8. Total Time in Earth Orbit	59 days 11 hrs 09 min 04 sec
		9. Total Absolute Time in Earth Orbit for a Single Astronaut	59 days 11 hrs 09 min 04 sec

Official U.S. International Aeronautical Federation World Records—Concluded

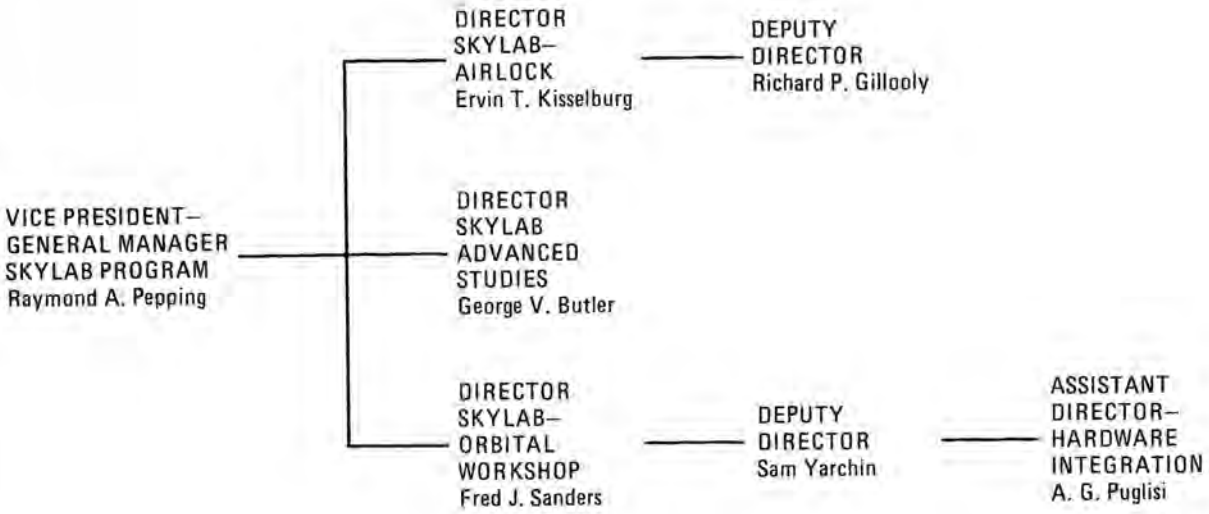
F.A.I. World Records—Skylab Flights

Mission/Date	Commander and Crew	Record	Numbers
SL–4	Gerald P. Carr	1. Absolute Duration of Flight	84 days 01 hr 15 min 30.8 sec
11/16/73–	William R. Pogue	2. Duration in Earth Orbit	84 days 01 hr 15 min 30.8 sec
02/8/74	Edward G. Gibson	3. Duration in Linked Configuration	83 days 12 hrs 32 min 12 sec
		4. Absolute Distance Traveled	55 474 039.4 km (29 953 585 nm)
		5. Distance Traveled in Earth Orbit	55 127 746.9 km (29 766 602 nm)
		6. Total Absolute Time in Space	84 days 01 hr 15 min 30.8 sec
		7. Total Time in Earth Orbit	84 days 01 hr 15 min 30.8 sec

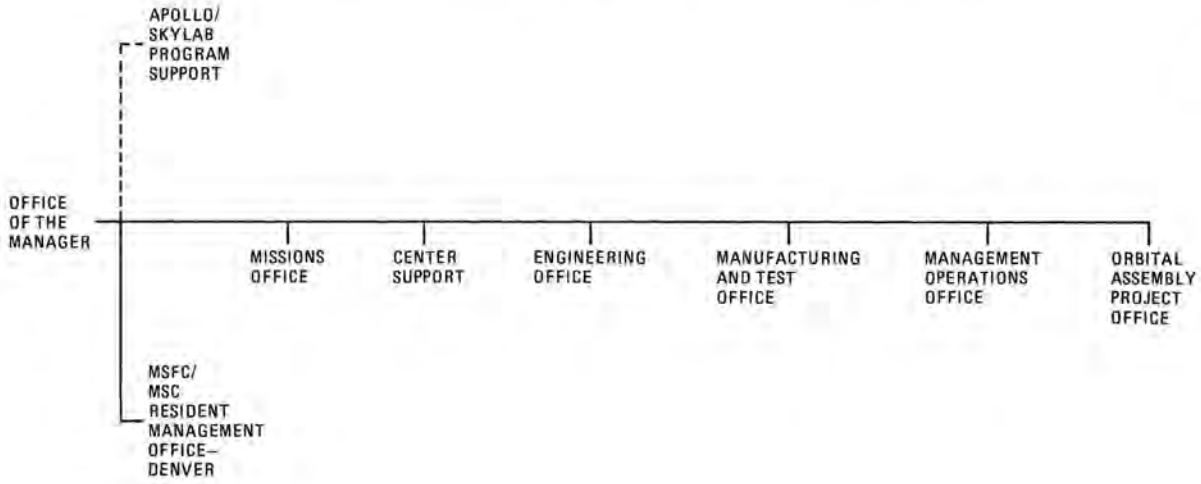
Prepared by Carl R. Huss, Data Systems and Analysis Directorate, Johnson Space Center.

APPENDIX 11—ORGANIZATION CHARTS

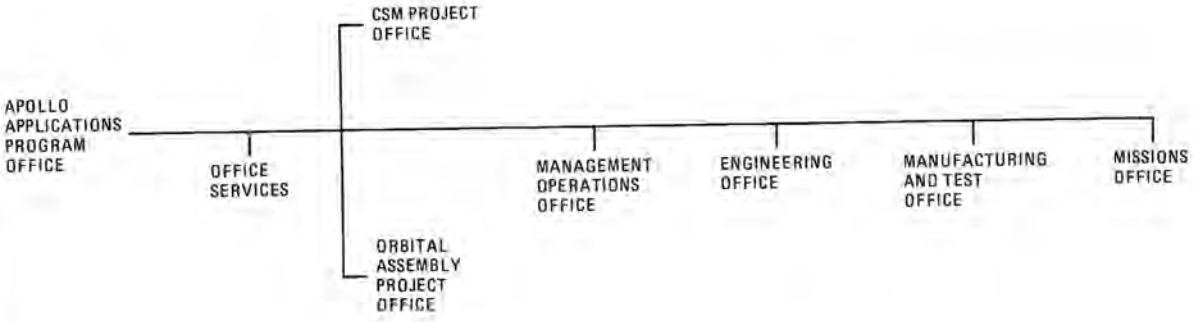
McDONNELL DOUGLAS CORPORATION—SKYLAB ORGANIZATION



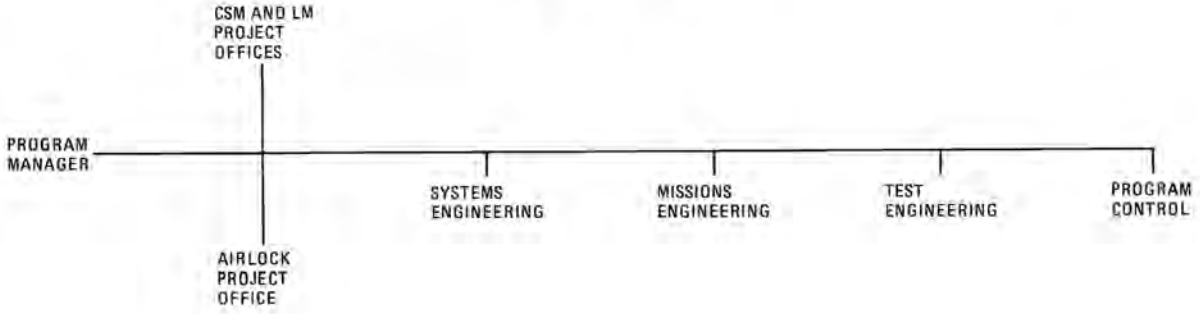
JOHNSON SPACE CENTER—SKYLAB PROGRAM OFFICE
[as of 1971]



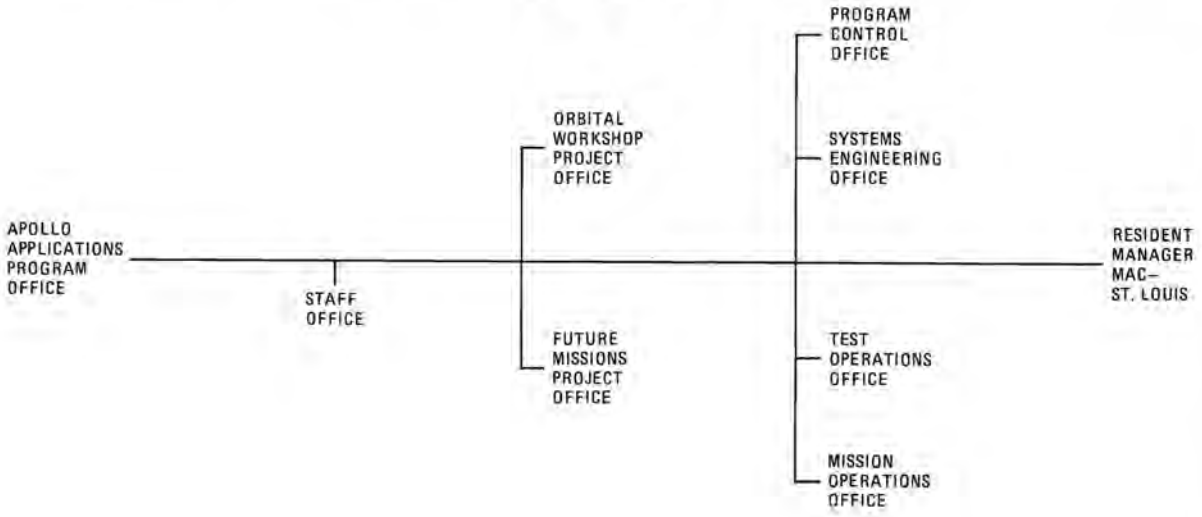
JOHNSON SPACE CENTER—APOLLO APPLICATIONS PROGRAM OFFICE
[as of 1969]



JOHNSON SPACE CENTER—APOLLO APPLICATIONS PROGRAM OFFICE
[as of 1968]

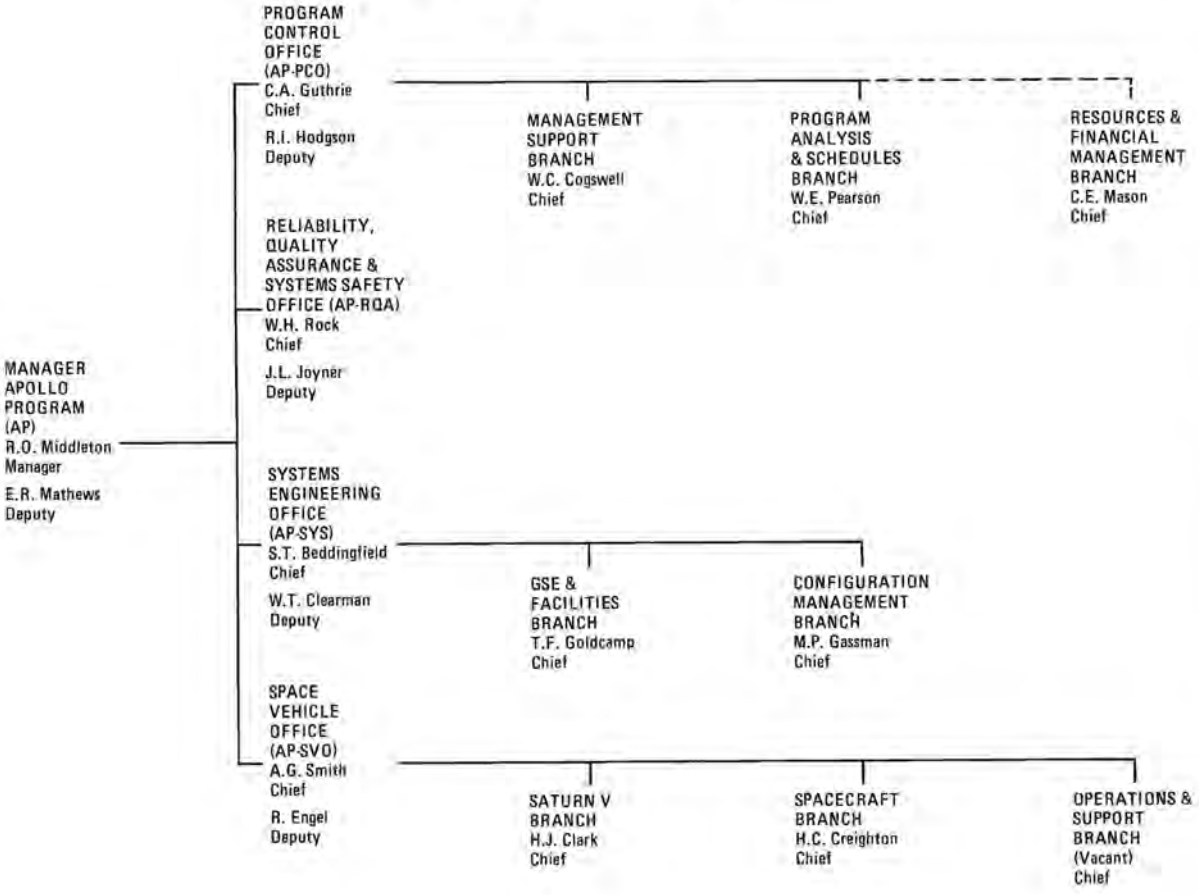


JOHNSON SPACE CENTER—APOLLO APPLICATIONS PROGRAM OFFICE
[as of 1966]

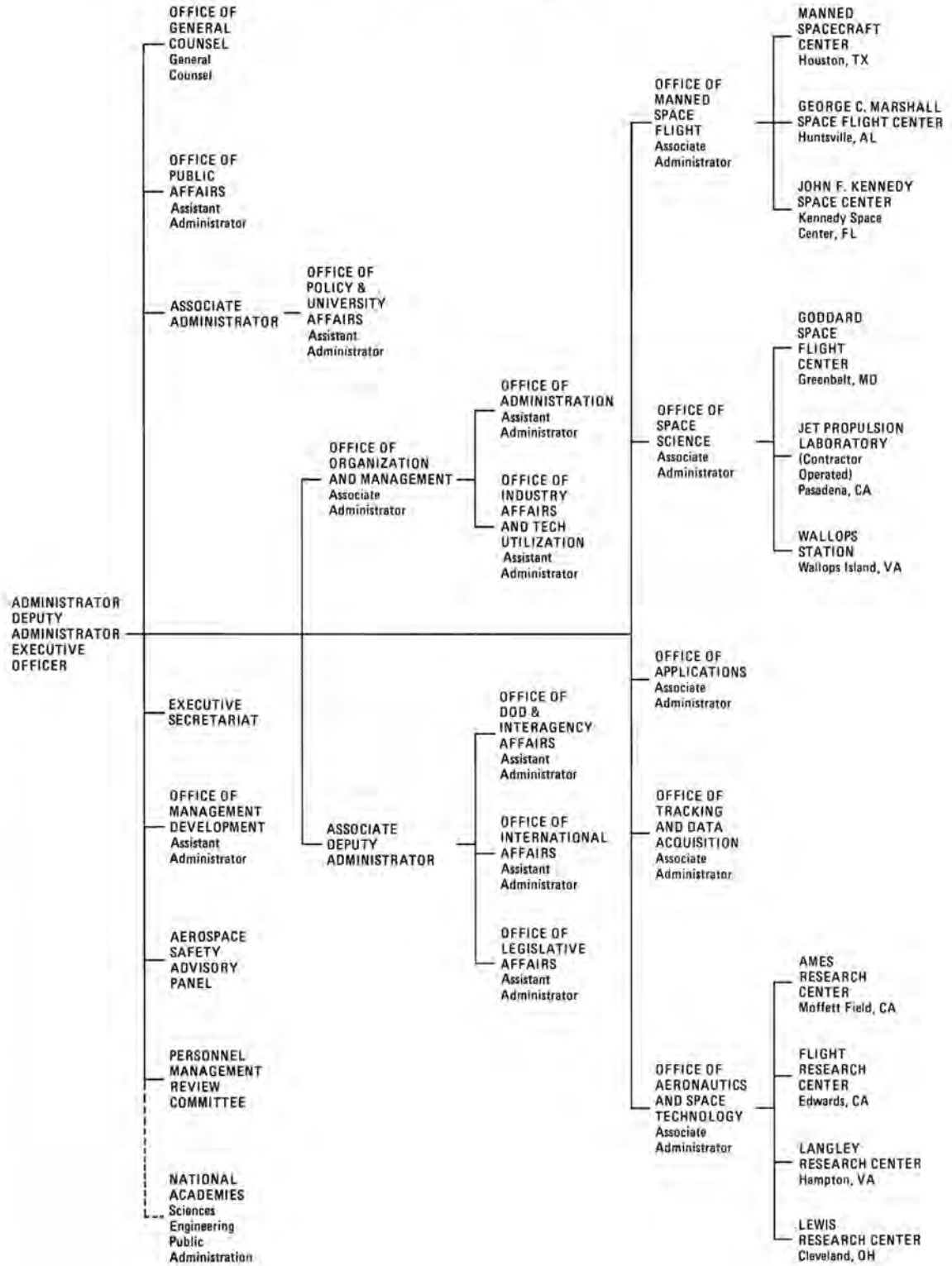


APOLLO APPLICATIONS PROGRAM ORGANIZATIONAL ELEMENTS
[as of 1967]

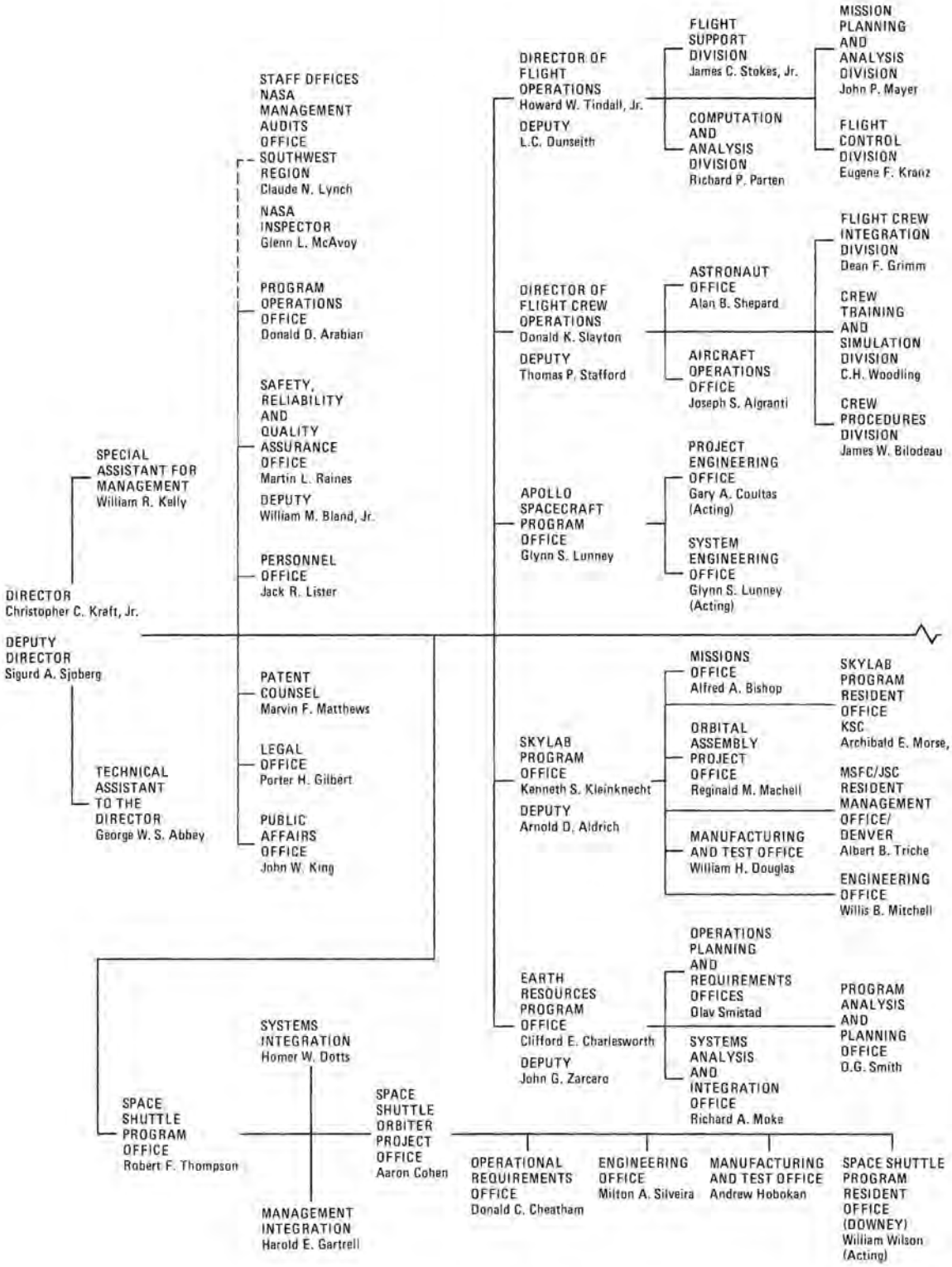
KENNEDY SPACE CENTER
[as of January 1969]



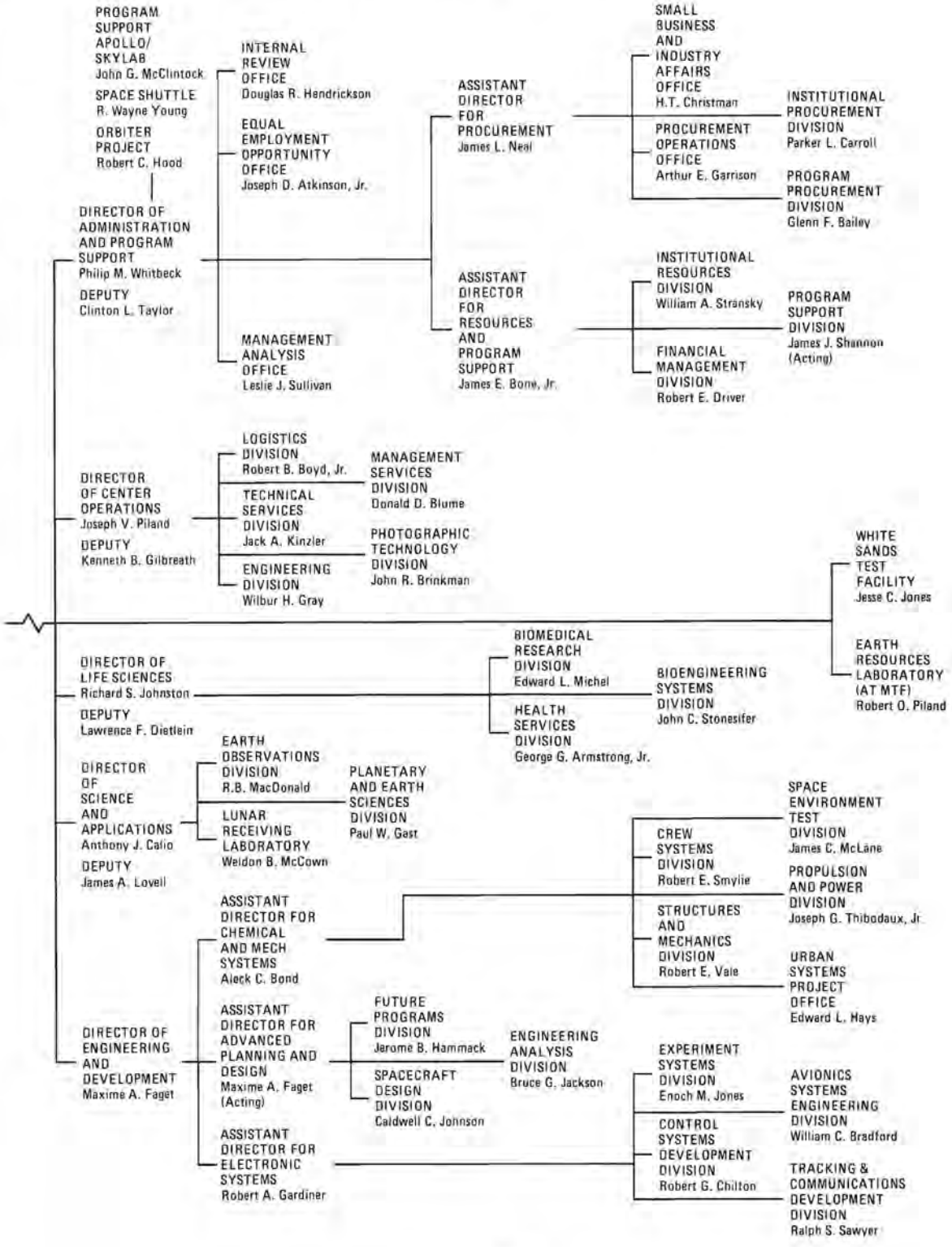
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
[as of 30 June 1972]



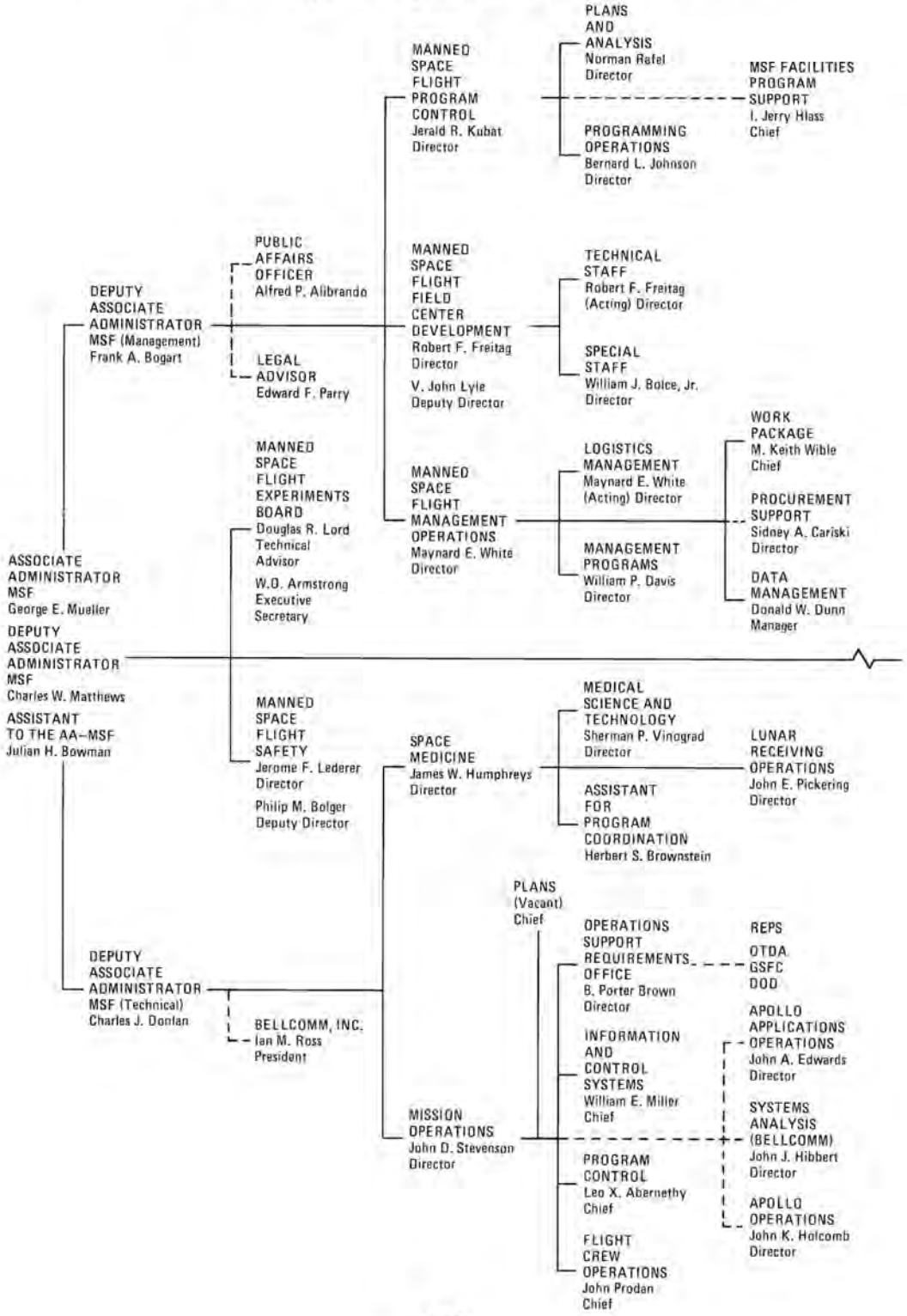
LYNDON B. JOHNSON SPACE CENTER
[as of March 1973]



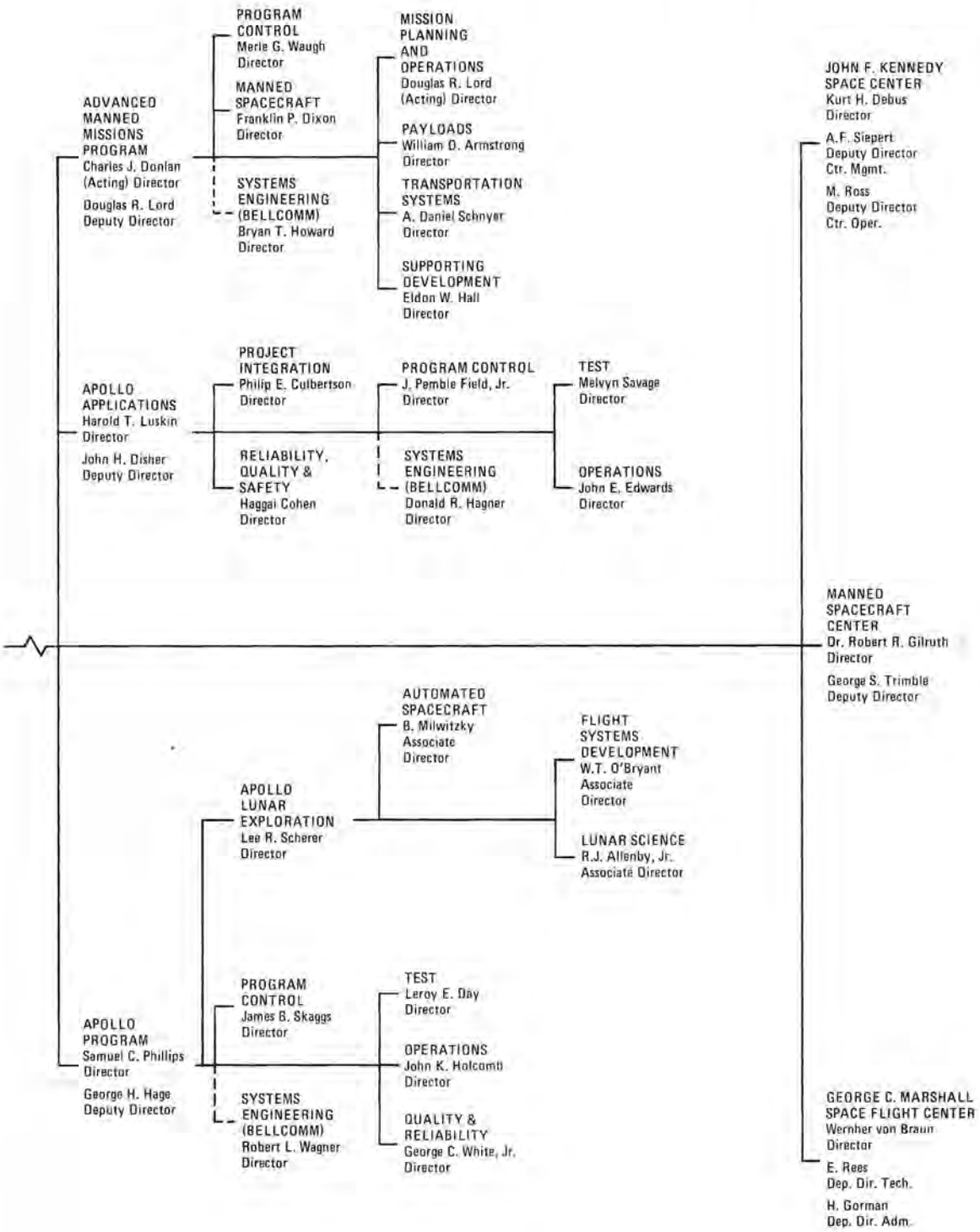
LYNDON B. JOHNSON SPACE CENTER—CONT.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION—MANNED SPACE FLIGHT ORGANIZATION
[as of September 1968]



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION—MANNED SPACE FLIGHT ORGANIZATION—CONT.



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