NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE SHUTTLE MISSION STS-51

PRESS KIT
JULY 1993

ACTS / ORPHEUS - SPAS
ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE
ORBITING AND RETRIEVABLE FAR AND EXTREME ULTRAVIOLET SPECTROMETER - SHUTTLE PALLET SATELLITE MISSION

STS-51 INSIGNIA

STS057-S-001 **--** *Designed by the crewmembers, the STS-57 insignia depicts the space shuttle Endeavour maneuvering to retrieve the European Space Agency's microgravity experiment satellite EURECA. Spacehab, the first commercial space laboratory, is depicted in the cargo bay, and its characteristic shape is represented by the inner red border of the insignia. The three gold plumes surrounded by the five stars trailing EURECA are suggestive of the U.S. astronaut logo. The five gold stars together with the shape of the orbiter's mechanical arm form the mission's numerical designation. The six stars on the American flag represent the U.S. astronauts who comprise the crew. With detailed input from the crewmembers, the final artwork was accomplished by artist Tim Hall.*

The NASA insignia design for space shuttle flights is reserved for use by the astronauts and for other official use as the NASA Administrator may authorize. Public availability has been approved only in the form of illustrations by the various news media. When and if there is any change in this policy, which we do not anticipate, it will be publicly announced.

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RELEASE: 93-121

ACTS DEPLOYMENT HIGHLIGHTS STS-51 MISSION

The deployment of a satellite which will serve as a testbed for technology leading to a new generation of communication satellites and the deployment and retrieval of a U.S./German free-flying scientific observation satellite highlight NASA's Shuttle Mission STS-51.

The mission, which is scheduled for mid-July, 1993, also will see Space Shuttle Discovery and her five-person crew conduct a variety of experiments on the effects of microgravity on various plants and materials along with other payloads which will perform photographic observations during the mission.

The Advanced Communications Technology Satellite (ACTS) program provides for the development and flight test of high-risk, advanced communications satellite technology. Using sophisticated antenna beams and advanced on-board switching and processing systems, ACTS will pioneer new initiatives in communications satellite technology.

The Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer - Shuttle Pallet Satellite (ORFEUS-SPAS) mission is the first of a series of missions using the German built ASTRO-SPAS science satellite. ASTRO-SPAS is a spacecraft designed for launch, deployment and retrieval by the Space Shuttle.

Once deployed from the Shuttle by its Remote Manipulation System (RMS), ASTRO-SPAS operates quasi-autonomously for several days in the Shuttle vicinity. After completion of the free flight phase, the satellite is retrieved by the RMS and returned to Earth. ORFEUS-SPAS is an astrophysics mission, designed to investigate very hot and very cold matter in the universe.

On the fifth day of the mission, two STS-51 crew members will perform a 6-hour extravehicular activity (EVA), or spacewalk, as part of a continuing series of test spacewalks NASA is conducting to increase experience with spacewalks and refine spacewalk training methods.

In addition to performing tasks that investigate a spacewalker's mobility in general, the astronauts will evaluate several tools that may be used during the servicing of the Hubble Space Telescope (HST) later this year on mission STS-61, including a power socket wrench, a torque wrench, foot restraint, safety tethers and tool holder.

Leading the STS-51 crew will be Mission Commander Frank Culbertson who will be making his second space flight. The pilot for the mission is William Readdy, making his second flight. The three mission specialists for this flight are Daniel Bursch (MS-1), James Newman (MS-2) and Carl Walz (MS-3), all three of whom will be making their first flight.

The mission duration for STS-51 is planned for 9 days with a scheduled landing at the Kennedy Space Center, Fla.

This will be the 17th flight of Space Shuttle Discovery and the 57th flight of the Space Shuttle system.

(END OF GENERAL RELEASE; BACKGROUND INFORMATION FOLLOWS.)

MEDIA SERVICES INFORMATION

NASA Select Television Transmission

NASA Select television is available on Satcom F-2R, Transponder 13, located at 72 degrees west longitude; frequency 3960.0 MHz, audio 6.8 MHz.

The schedule for television transmissions from the orbiter and for mission briefings will be available during the mission at Kennedy Space Center, Fla.; Marshall Space Flight Center, Huntsville, Ala.; Ames-Dryden Flight Research Facility, Edwards, Calif.; Johnson Space Center, Houston and NASA Headquarters, Washington, DC. The television schedule will be updated to reflect changes dictated by mission operations.

Television schedules also may be obtained by calling COMSTOR 713/483-5817. COMSTOR is a computer data base service requiring the use of a telephone modem. A voice update of the television schedule is updated daily at noon Eastern time.

Status Reports

Status reports on countdown and mission progress, on-orbit activities and landing operations will be produced by the appropriate NASA newscenter.

Briefings

A mission press briefing schedule will be issued prior to launch. During the mission, status briefings by a Flight Director or Mission Operations representative and when appropriate, representatives from the science team, will occur at least once per day. The updated NASA Select television schedule will indicate when mission briefings are planned.

STS-51 QUICK-LOOK

Launch Date/Site:	July 1993, Kennedy Space Center - Pad 39B
Launch Time:	TBD
Orbiter:	Discovery (OV-103) - 17th Flight
Orbit/Inclination:	160 nautical miles/28.45 degrees
Mission Duration:	8 days, 21 hours, 59 minutes
Landing Time/Date:	TBD
Primary Landing Site:	Kennedy Space Center, FL
Abort Landing Sites:	Return to Launch Site - KSC, FL Transatlantic Abort landing - Banjul, The Gambia Ben Guerir, Morocco Moron, Spain Abort Once Around - Edwards AFB, Calif.
Crew:	Frank Culbertson, Commander (CDR) William Readdy, Pilot (PLT) Jim Newman, Mission Specialist 1 (MS1) Dan Bursch, Mission Specialist 2 (MS2) Carl Walz, Mission Specialist 3 (MS3)

Cargo Bay Payloads & Activities:
Advanced Communication Technology Satellite/Transfer Orbit Stage (ACTS/TOS)
Orbiting Retrievable Far and Extreme Ultraviolet Spectrometer - Shuttle Pallet Satellite (ORFEUS-SPAS)
Limited Duration Space Environment Candidate Materials Exposure (LDCE)

In-Cabin Payloads:
Air Force Maui Optical Site (AMOS)
Auroral Photography Experiment-B (APE-B)
Commercial Protein Crystal Growth (CPCG)
Chromosome and Plant Cell Division in Space (CHROMEX)
High Resolution Shuttle Glow Spectroscopy-A (HRSGS-A)
IMAX
Investigations into Polymer Membrane Processing (IPMP)
Radiation Monitoring Equipment-III (RME-III)

STS-51 PAYLOAD AND VEHICLE WEIGHTS

	Pounds
Orbiter (Discovery) empty and 3 SSMEs	173,117
Advanced Communications Satellite/Transfer Orbit Stage	26,756
ACTS Support Equipment	6,394
ORFEUS/SPAS	7,070
LDCE/GAS can	770
APE	41
CHROMEX	69
CPCG	70
HRSGS	91
IMAX Camera System	320
IPMP	20
RME	7
DSOs/DTOs	162
Total Vehicle at SRB Ignition	4,525,219
Orbiter Landing Weight	203,639

STS-51 SUMMARY TIMELINE

Flight Day 1
Ascent burns
OMS-2 (160 n.m. x 161 n.m.)
Remote Manipulator System checkout
CHROMEX check
CPCG activation
RME activation
ACTS/TOS deploy
RCS, OMS Separation burns (161 n.m x173 n.m)

Flight Day 2
OMS, RCS burns (158 n.m. x 159 n.m.)
ORFEUS/SPAS checkout
ORFEUS/SPAS release
RCS Separation burns (158 n.m. x 159 n.m.)
CHROMEX check
Cabin depress to 10.2 psi

Flight Day 3
Stationkeeping burns (158 n.m. x 159 n.m.)
IPMP activation
CHROMEX check

Flight Day 4
EMU checkout
Stationkeeping burns (158 n.m. x 159 n.m.)
RME check

Flight Day 5
Extravehicular activity preparations
Extravehicular activity (six hours)
Stationkeeping burns (158 n.m. x 159 n.m.)
CHROMEX check

Flight Day 6
Stationkeeping burns (158 n.m. x 159 n.m.)
APE setup
HRSGS setup
CHROMEX check
LDCE operations

Flight Day 7
Stationkeeping (158 n.m. x 159 n.m.)
LDCE operations
APE operations
HRSGS operations
HRSGS stow
CHROMEX check
RME check

Flight Day 8
ORFEUS/SPAS rendezvous
ORFEUS/SPAS berth
CHROMEX check
DTO 412: Fuel Cell shutdown

Flight Day 9
Cabin repress to 14.7 psi
Flight Control Systems checkout
Reaction Control System hot-fire
AMOS
CHROMEX check
Cabin stow
DTO 412: Fuel Cell restart

Flight Day 10
De-orbit preparations
De-orbit burn
Entry
Landing

SPACE SHUTTLE ABORT MODES

Space Shuttle launch abort philosophy aims toward safe and intact recovery of the flight crew, Orbiter and its payload. Abort modes include:

- Abort-To-Orbit (ATO) -- Partial loss of main engine thrust late enough to permit reaching a minimal 105-nautical mile orbit with orbital maneuvering system engines.

- Abort-Once-Around (AOA) -- Earlier main engine shutdown with the capability to allow one orbit around before landing at Edwards Air Force Base, Calif.

- Transatlantic Abort Landing (TAL) -- Loss of one or more main engines midway through powered flight would force a landing at either Banjul, The Gambia; Ben Guerir, Morocco; or Moron, Spain.

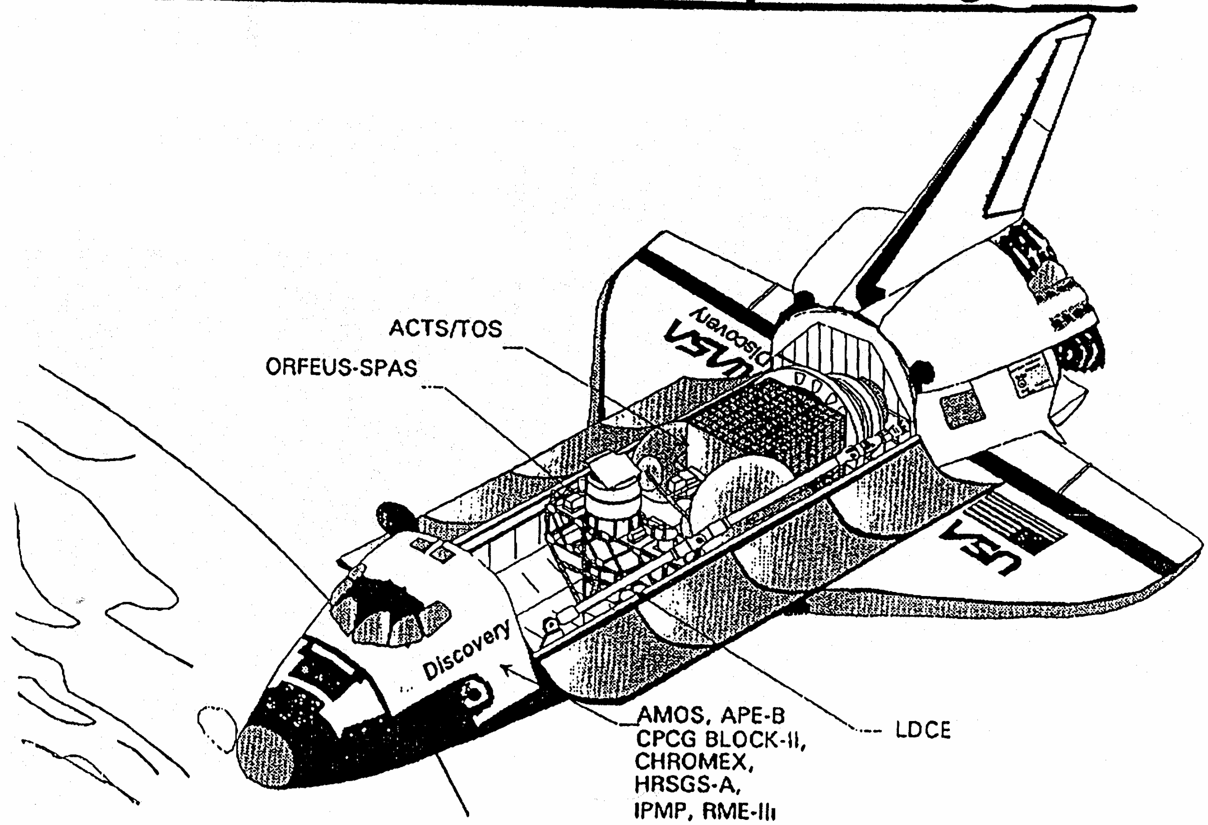
- Return-To-Launch-Site (RTLS) -- Early shutdown of one or more engines, and without enough energy to reach Banjul, would result in a pitch around and thrust back toward KSC until within gliding distance of the Shuttle Landing Facility.

STS-51 contingency landing sites are the Kennedy Space Center, Edwards Air Force Base, Banjul, Ben Guerir and Moron.

STS-51 CREW RESPONSIBILITIES

Task/Payload	Primary	Backup
ACTS/TOS	Walz	Bursch
ORFEUS/SPAS	Newman	Newman
Middeck experiments:		
APE	Walz	Newman
CHROMEX	Newman	Readdy
CPCG	Bursch	Culbertson
IMAX	Readdy	Walz
IPMP	Newman	Bursch
HRSGS	Newman	Walz
AMOS	Readdy	Bursch
RME	Walz	
DTOs/DSOs:		
EVA	Walz (EV1)	Newman (EV2)
IV	Readdy	
ET Photo	Walz	Newman
Fuel Cell	Readdy	Culbertson
PGSC	Newman	Walz
Thermal Print (TIPS)	Newman	Walz
ALBRT	Culbertson	Bursch
Laser Range (hand)	Readdy	Bursch
Laser Range (cargo bay)	Bursch	Readdy
GPS	Walz	Newman
PCMMU	Newman	Walz
VRCS	Readdy	Newman
Exercise	Culbertson	All
Entry ortho tolerance	Newman	Walz
Visual vestibular	Newman	
Posture	Readdy	Walz
Skeletal/muscle	Readdy	All
Gastro function	Bursch	Newman
Blood IV	Readdy	Bursch
ENH stand	Culbertson	Newman, Walz
Other Responsibilities:		
Photography/TV	Readdy	Walz,
Culbertson		
Earth observations	Readdy	Culbertson
In-flight Maintenance	Walz	Readdy
Medic	Readdy	Bursch

NASA Space Shuttle Program
STS-51 Cargo Configuration



ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS) HARDWARE

The Advanced Communications Technology Satellite (ACTS) provides for the development and flight test of high-risk, advanced communications satellite technology. Using advanced antenna beams and advanced on-board switching and processing systems, ACTS will pioneer new initiatives in communications satellite technology.

ACTS provides new communications satellite technology for:

- Operating in the Ka-band (30/20 GHz) where there is 2.5 GHz of spectrum available (five times that available at lower frequency bands)

- Very high-gain, multiple hopping beam antenna systems which permit smaller aperture Earth stations

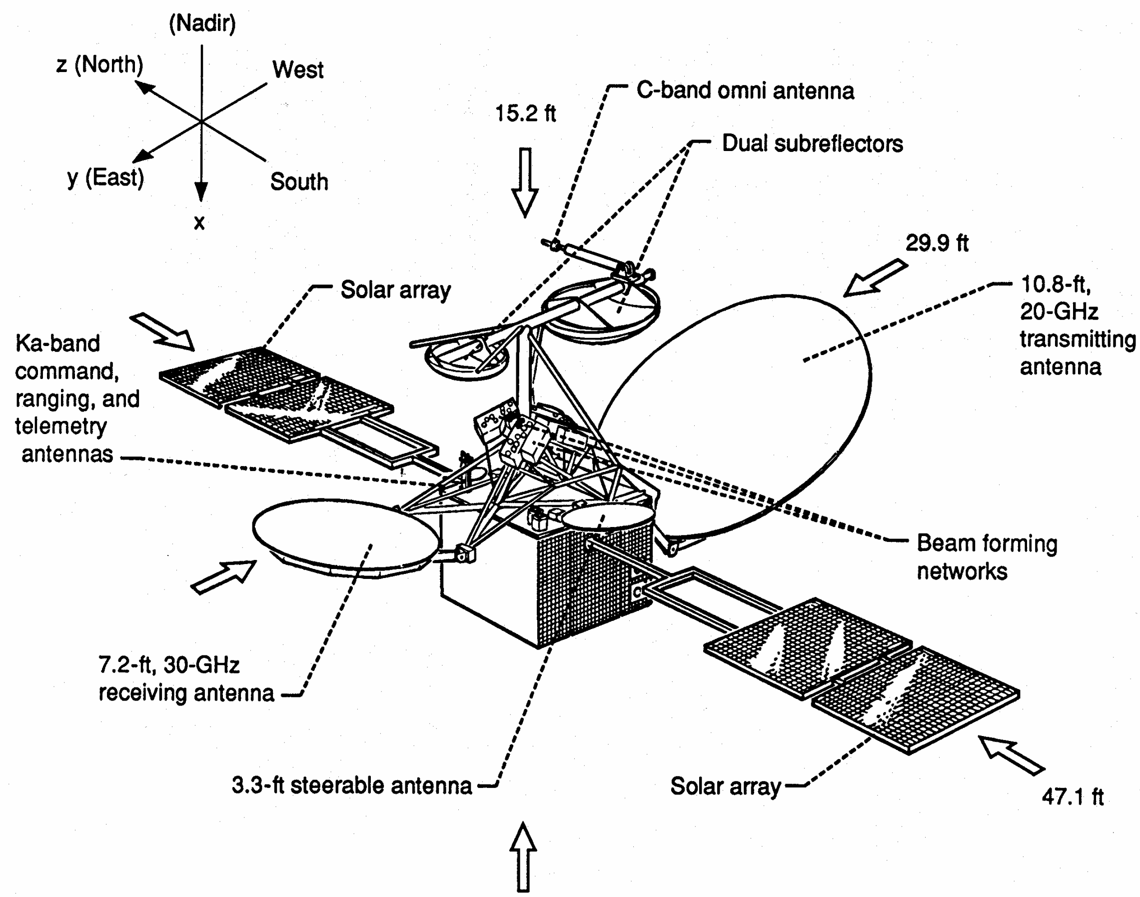
- On-board baseband switching which permits interconnectivity between users at an individual circuit level

- A microwave switch matrix which enables gigabit per second communication between users.

These technologies provide for up to three times the communications capacity for the same weight as today's satellites (more cost effective), much higher rate communications between users (20 times that offered by conventional satellites), greater networking flexibility and on-demand digital services not currently available from communications systems today. The development and flight validation of this advanced space communications technology by NASA's ACTS will allow industry to adapt this technology to their individual commercial requirements at minimal risk. It also will aid the U.S. industry in competing with European and Asian companies which have, in the last decade, developed significant capabilities for producing communications satellites and associated ground equipment.

ACTS technologies, which are applicable for a variety of frequency bands, will potentially lower the cost or technical threshold so that such new services as remote medical image diagnostics, global personal communications, real-time TV transmissions to airliners, direct transmission of reconnaissance image data to battlefield commanders and interconnection of supercomputers will be feasible. Technology spin-off is already occurring.

Motorola currently is adapting the ACTS Ka-band and on-board switching technologies for their $3 billion Iridium satellite system, which will provide global voice/data communications services. Norris Communications also is proceeding with a Ka spot-beam communications satellite.



Spacecraft on-orbit configuration showing overall dimensions.

ACTS OVERALL DESCRIPTION

ACTS is comprised of a spacecraft bus with basic housekeeping functions and a payload, known as the multi-beam communications package (MCP).

At launch, ACTS weighs 6,108 pounds including the propellants and the spacecraft adapter and clamp band which remain with the Transfer Orbit Stage (TOS) upon separation. When in the stowed configuration in the Shuttle payload bay, ACTS' overall height is 15.9 feet (5 m) from the spacecraft separation plane to the tip of the highest antenna.

During the transfer orbit phase, the spacecraft is spin stabilized, and the antenna reflectors and solar array panels are retracted and stowed to provide better load support for these appendages. During the on-orbit mission phase, the spacecraft is three-axis stabilized with the large antenna reflectors facing the Earth and the solar array panels rotating once per day to track the Sun. On-orbit, ACTS measures 47.1 feet (14 m) from tip to tip of the solar arrays and 29.9 feet (9 m) across the main receiving and transmitting antenna reflectors.

Spacecraft Bus

The spacecraft bus structure is a rectangular box with a cylindrical center structure that houses the apogee kick motor (AKM). The multi-beam antenna subsystem is mounted to the Earth facing panel of the spacecraft bus. The North and South sides are each divided into three panels. These panels are used to mount most of the spacecraft bus and MCP electronics equipment. The spacecraft bus provides support functions for the MCP such as electrical and mechanical mounting surfaces, attitude control, electrical power, thermal control, command reception, telemetry transmission and ranging and propulsion for station keeping maneuvers.

Multi-beam Communications Package

The multi-beam communications package performs receiving, switching, momentary storage, selectable coding and decoding, amplifying and transmitting functions for Ka-band time division multiple access (TDMA) communications signals. The multi-beam antenna (MBA) has fixed beams and hopping spot beams that can be used to service traffic needs on a dynamic basis. (A hopping spot beam is an antenna beam on the spacecraft that points at one location on the ground for a fraction of a millisecond. It sends/receives voice or data information and then the beam electronically "hops" to a second location, then a third and so on. At the beginning of the second millisecond the beam again points at the first location.)

In addition, the receiving antenna provides signals to the autotrack receiver which generates input error signals to the attitude control system for spacecraft pointing operations. Beam forming networks (BFN) utilize hopping beams to provide independent coverage of the East and West scan sectors, plus coverage for isolated locations outside of either sector. The MBA also has three fixed spot beams. A steerable beam antenna has been incorporated into ACTS to provide antenna coverage of the entire disk of the Earth as seen from l00 degrees west longitude and to any aircraft or low Earth orbit spacecraft, including the Space Shuttle, within view of the ACTS.

ACTS Deployment Sequence

ACTS will be deployed from Discovery's cargo bay approximately 8 hours after launch on orbit six. The TOS burn which will inject ACTS into a geosynchronous transfer orbit. The spacecraft apogee kick motor will inject ACTS into a drift orbit. Finally, ACTS will be placed in a geostationary orbit at 100 degrees west longitude over the equator, approximately in line with the center of the United States. A geostationary orbit is one where a satellite takes 24 hours to complete one revolution, thus appearing to remain motionless above a single place on the Earth.

About 2 hours before deployment from the orbiter, the astronauts perform a sequence of events beginning with preliminary TOS checks, unlatching the TOS cradle and elevating the ACTS/TOS flight element to a 42 degree angle for deployment. The crew will fire the "Super*Zip" separation system, and six springs on the TOS aft cradle will push the flight element out of the cargo bay.

The TOS motor firing is controlled by an on-board timer and occurs 45 minutes following deployment from the orbiter or about 8 hours and 45 minutes after STS-51 launch. The approximately two-minute burn will place ACTS in a geotransfer orbit. The apogee kick motor burn to inject ACTS into drift orbit will take place 42 1/2 hours after deployment, approximately 50 1/2 hours into the mission. The 7-day drift will allow ACTS to move toward its final station location of 100 degrees west longitude. Firing of the spacecraft's thrusters will bring the perigee and apogee radii increasingly closer to the geostationary orbit.

Upon reaching geostationary orbit, ACTS will transition from a spinning to a three-axis stabilized spacecraft configuration and deploy its solar arrays and antennas.

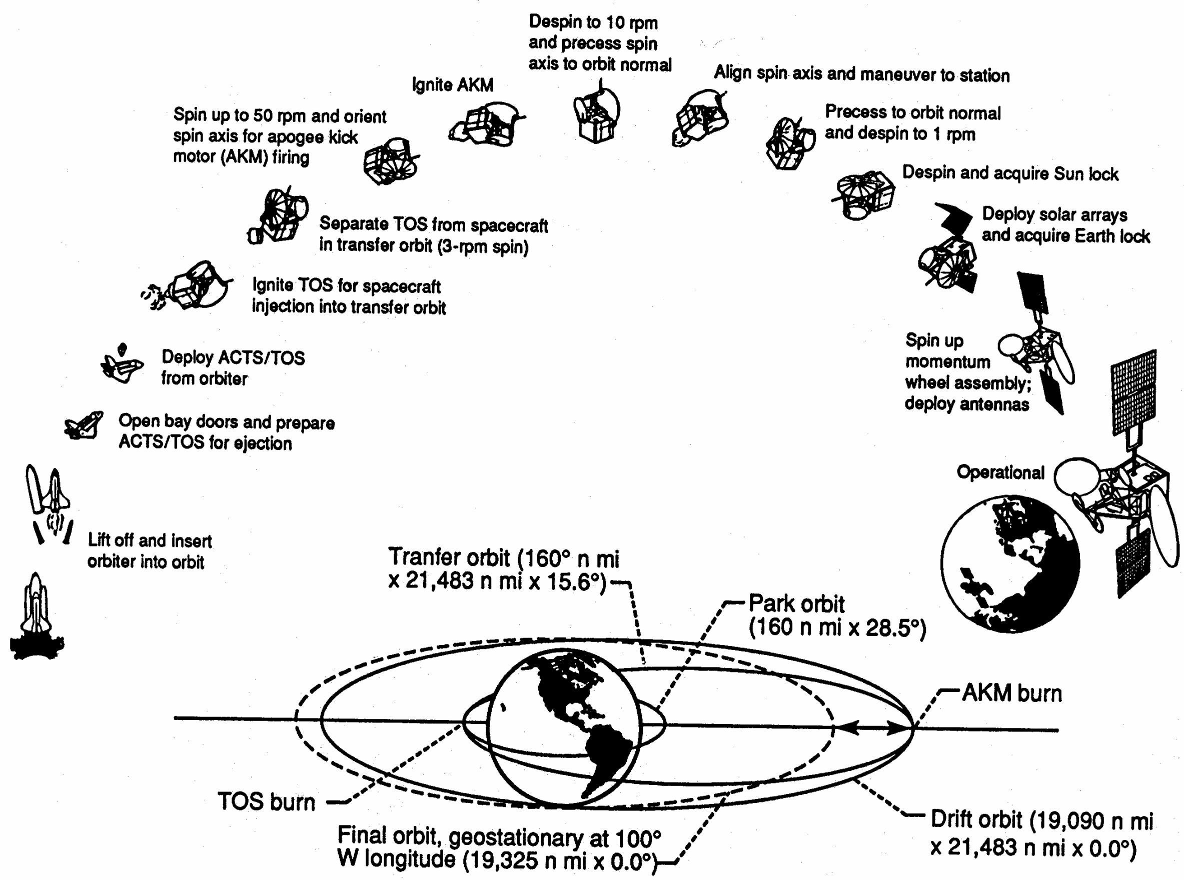
ACTS experiments will begin 12 weeks after launch following the placement of the spacecraft on-station and spacecraft checkout. ACTS is designed to have a minimum life of 2 years but will have enough station keeping fuel for a 4- year-plus mission.

ACTS Ground Systems and Support

The facilities and support to be used for the ACTS mission phases include the Guam and Carpentersville, NJ, C-band telemetry, tracking and command stations and the ACTS ground segment.

Tracking, Telemetry and Command

The ACTS mission telemetry, tracking and command (TT&C) control and monitor functions are distributed between two geographically separate locations: Lewis Research Center, Cleveland and the Martin Marietta Satellite Operations Center (SOC), East Windsor, NJ. The SOC is used to control the ACTS housekeeping functions during both the transfer orbit and the on-station phases.



ACTS mission events sequence.

During the transfer orbit phases, the SOC controls the ACTS through the C-band ground stations. During the on-station phase, command parameters generated at the SOC are routed via landlines to Lewis to be uplinked to the ACTS via Ka-band. Status information is displayed at the Lewis ACTS master ground station for both the transfer orbit and on-station phases.

ACTS Ground Segment

The ACTS ground segment is comprised of the ACTS master ground station, the satellite operations center and the experimenter terminals.

ACTS Master Ground Station

The ACTS master ground station is located at the NASA Lewis Research Center. It includes:

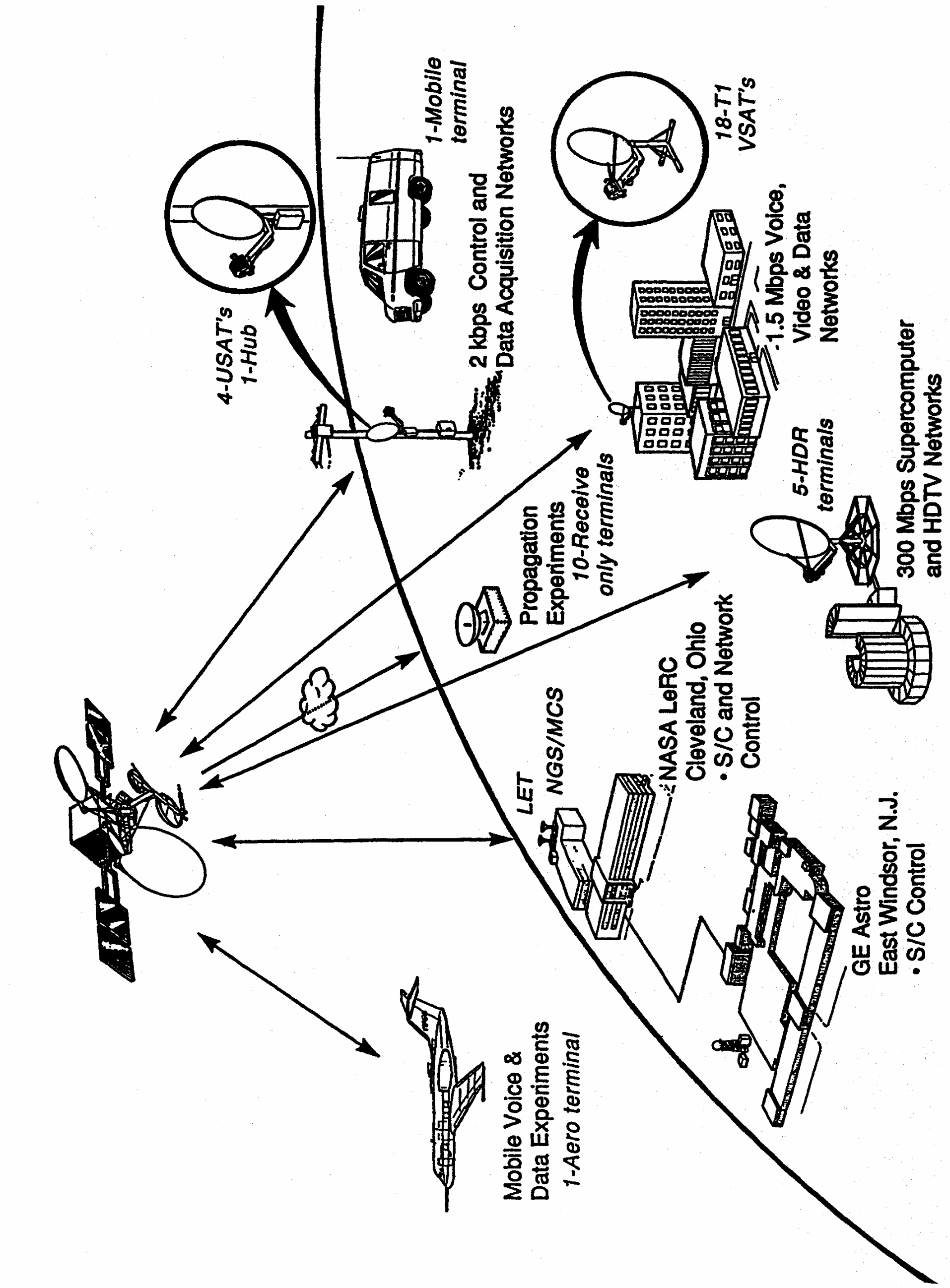
- The NASA ground station (NGS), which consists of a Ka- band radio frequency terminal, two traffic terminals and a reference terminal. It up-converts signals for the baseband processor mode of operations to 30 GHz for transmission to ACTS and amplifies and down-converts the 20 GHz baseband processor modulated signals received from ACTS. Modulation and demodulation of the baseband communications signals are performed in the NASA ground station. It also transmits and receives signals in support of the command, ranging and telemetry functions for ACTS.

- The master control station provides network control for the spacecraft baseband processor and backup to the satellite operations center for configuring the multi-beam communications package. The master control station also enables experiment execution and telemetry collection.

- The microwave switch matrix-link evaluation terminal provides the capability for the on-orbit testing of the microwave switch matrix and the multi-beam antenna. It also will conduct wideband communications experiments.

- The command, ranging and telemetry equipment interfaces with the NASA ground station at intermediate frequency and exchanges command, ranging and telemetry information to and from the master control station, the G. E. SOC and the microwave switch matrix-link evaluation terminal.

The SOC has primary responsibility for generating flight system commands and for analyzing, processing and displaying flight system telemetry data. Orbital maneuver planning and execution also are handled by the SOC. The primary housekeeping function is performed at the SOC which is linked via land line to the Ka-band command, ranging and telemetry equipment at the ACTS master control station.



Typical ACTS system operating scenarios.

The Ka-band experimenter network consists of a variety of ground stations to be operated by industry, universities and government organizations. These ground stations have varying communication services ranging from High Data Rate (HDR) at 1 gigabit per second, to Very Small Aperture Terminal (VSAT) at 1.5 megabits per second, aeronautical and ground mobile voice and data at 500 kilobits per second and Ultra Small Aperture Terminal (USAT) data at 4800 bits per second.

TRANSFER ORBIT STAGE FOR THE STS-51 MISSION

The Transfer Orbit Stage (TOS) will boost NASA's Advanced Communications Technology Satellite from low-Earth orbit into geosynchronous transfer orbit with a maximum altitude of 21,519 nautical miles (34,624 km). This will be the second mission of the Transfer Orbit Stage and the first time it has flown on a Space Shuttle mission.

The Transfer Orbit Stage was first used in September 1992 as the upper stage booster for NASA's Mars Observer mission. Following launch on an expendable rocket, the TOS successfully propelled the spacecraft on a trajectory from Earth orbit to the red planet.

The Space Systems Projects Office at NASA's Marshall Space Flight Center, Huntsville, Ala., manages the TOS program for NASA. That role involves ensuring TOS compliance with over all mission requirements, including those for integration with the launch vehicle and satellite and flight safety requirements.

Transfer Orbit Stage Description

The Transfer Orbit Stage, built by Martin Marietta Astronautics Group in Denver, for Orbital Sciences Corp., Dulles, Va., is a single-stage, solid-propellant rocket system. It is the latest addition to NASA's upper stage fleet, which includes a range of vehicles to boost satellites or spacecraft in the second step of their journey to geostationary orbit or toward interplanetary destinations.

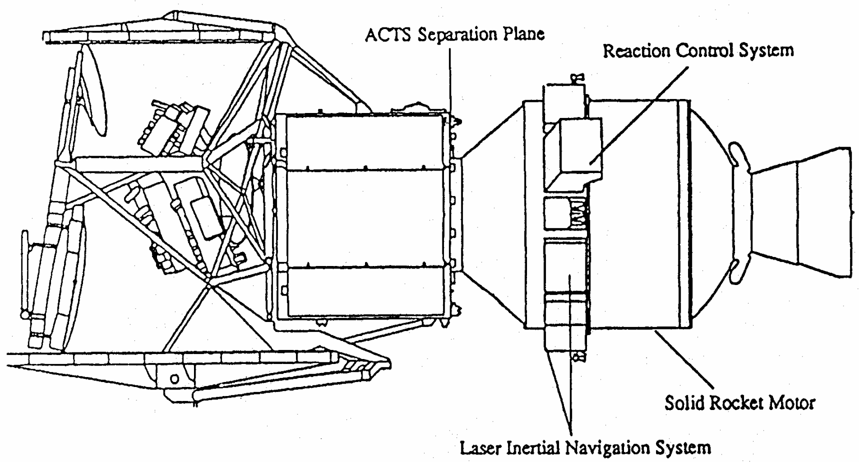
TOS, constructed primarily of high-strength aluminum alloy, weighs 20,780 pounds (9,426 kg) including solid propellant fuel. It is almost 11 feet (3.3 m) long and about 7.5 feet (2.3 m) in diameter. The satellite, weighing 6,108 pounds (2,771 kg), is mounted on top of the Transfer Orbit Stage. Portions of both the satellite and TOS are covered with gold foil multi-layered insulation for thermal protection from the Sun.

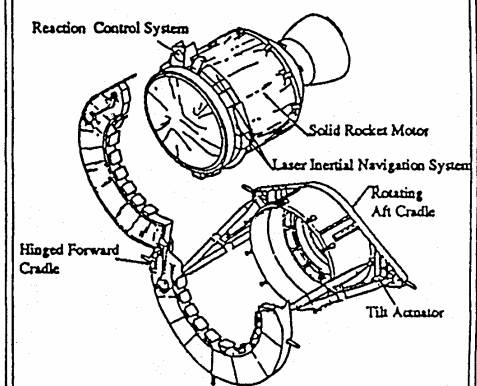
Major elements of the TOS system are a solid rocket main propulsion system, a navigation and guidance system, a reaction control system which is used to adjust TOS attitude or local pointing and an airborne support equipment cradle that holds the satellite and upper stage in the Shuttle cargo bay and facilitates deployment from the orbiter.

The ORBUS-21 solid rocket motor main propulsion system, manufactured by United Technologies Chemical Systems Division, San Jose, Calif., will give the primary thrust for the 110 seconds of powered flight. To provide the 59,000 pounds of thrust (262,445 Newtons) to inject the satellite into its transfer orbit, the motor will use 18,013 pounds (8,171 kg) of the solid rocket propellant HTPB (hydroxyl terminated polybutadiene).

Pitch (maneuvering upward or downward) and yaw (turning to the left or right) will be controlled during the burn by gimbaling the nozzle of the solid rocket motor with two thrust vector control actuators. Roll control is provided by the reaction control system during motor burn.

TOS Configuration





TOS and Airborne Support Equipment

TOS guidance and control avionics are based on a laser inertial navigation system manufactured by Honeywell, Inc., Clearwater, Fla. It acts as the brains of the vehicle, computing location and providing signals to the propulsion system to maintain the proper trajectory. All TOS operations are performed autonomously with no ground commanding required. The guidance system uses laser gyroscopes with no moving parts, thus reducing chances for malfunctions in space. A telemetry and encoder unit records performance data from all on-board electronics and sends it to ground control at KSC.

The reaction control system thruster assembly, manufactured by UTC/Hamilton Standard Division, Windsor Locks, Conn., correctly positions the TOS and its payload, based on information from the laser inertial navigation system. The three-axis control system uses 12 small maneuvering rockets, which rely on decomposed hydrazine as their propellant, to fine-tune the orientation of the vehicle and its payload before solid rocket motor ignition.

The reaction control system also slowly turns the satellite-TOS for thermal control to avoid overheating from the sun. The reaction control system makes final attitude adjustments before TOS separation from the satellite.

The equipment needed to adapt the satellite-TOS to the Space Shuttle is called the airborne support equipment. This equipment is manufactured by Martin Marietta. Prior to deployment, the TOS rests in the aft cradle and is clamped firmly in the Shuttle's cargo bay by the forward cradle.

ACTS/TOS deployment scenario

During the STS-51 mission, Discovery crew members will initiate a predeployment checkout to ensure that all critical TOS systems are healthy and ready to deploy. The upper forward cradle, similar to a clamp, will then be unlatched and rotated open. The satellite-booster will be elevated 45 degrees out of the cargo bay. If any problems are detected in the combined payload up to this point, it can be lowered, relatched and returned to Earth at the end of the mission. If no anomalies are detected, a pyrotechnic system will release the satellite- TOS and springs on the cradle will gently nudge it out of the orbiter. The satellite-TOS will coast for 45 minutes while the Shuttle maneuvers to a safe distance, 11.7 miles (18.8 km) away, to avoid a possible collision or damage from the TOS solid rocket exhaust plume.

Once the Transfer Orbit Stage has positioned the satellite in the proper attitude, the TOS solid rocket motor will fire for 110 seconds, accelerating to the 22,800-mph velocity (36,685 km/hr) necessary to boost the satellite into its geosynchronous transfer orbit. Then the Transfer Orbit Stage will make final attitude adjustments as the satellite speeds toward apogee, the point farthest from the Earth in its orbit.

Shortly after rocket burnout, the satellite will separate from the TOS and the TOS will make a perpendicular turn to avoid being in the satellite's path. Later, thrusters and a solid rocket motor on the satellite itself will fire to place the satellite into its final geosynchronous orbit. The actual timing of the satellite burn is controlled by commands from the ground.

Extra-Vehicular Activity Tools

If a mechanical problem with the TOS airborne support equipment were to develop prior to or after deployment of the satellite-TOS, two astronauts can use one or more specially designed tools to correct it. The tools were designed at Marshall Space Flight Center and tested under simulated weightless conditions in the center's Neutral Buoyancy Simulator water tank. The actual use of these devices is considered unlikely since the airborne support equipment itself is fully redundant, with all systems having built-in back-ups.

ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS) EXPERIMENTS PROGRAM

The Advanced Communications Technology Satellite Experiments Program gives industry, academic, and government organizations an opportunity to investigate new ways of communicating. In conjunction with industry, NASA has developed the ACTS and an extensive network of ground stations to test and prove pioneering communications concepts and technologies that will advance cheaper, on-demand, flexible communications.

The Experiments Program provides access to these new telecommunication tools that will be widely used in the 21st century. ACTS experimenters design, fund, and conduct investigations. NASA contributes spacecraft time, manages operations, and assists investigators in developing a final experiment plan. This partnership brings the capabilities of this unique national resource to regional telecommunications users.

The goals of the program reflect national priorities in advancing technology development and promoting U.S. competitiveness in international markets. The program will conduct technical verification experiments to prove the high- risk technology and a balanced set of experiments which evaluate the potential applications of the technology.

Experiments have been selected that meet these goals and challenge the ACTS system. The results of these investigations could yield numerous benefits to business, health care, education, national defense, and emergency/disaster relief and advance the technology in high data rate communications. The following describes ACTS's contribution to these areas and candidate experiments. (The experiments listed below have been officially accepted into the ACTS Experiments Program at press time.)

Business Advantages

Communications is an essential element of any community's infrastructure, but in business it can be the factor that promotes profit or inhibits growth. Expanded communication capacities such as fax machines and electronic information networks have revolutionized the way the business is conducted around the world. The ACTS Experiments Program provides an opportunity for business to test new technologies that may lead to more efficient ways to operate and create new services.

With the advent of ACTS, a new generation in communications technology will bring benefits to business. ACTS-type technologies will increase efficiency and lower the cost of business communications by enabling real-time communications and the use of smaller satellite dishes. It can augment fiber-optic networks to extend communications capacity to remote areas, creating new telecommunications users and enhancing the "information superhighway" with Earth-space linkages.

EXPERIMENTS

The ACTS Program has developed and will validate, by flight testing, high risk advanced communication satellite technologies. The validation of these technologies is to be accomplished through the ACTS Experiments Program. The ACTS flight and ground systems will be made available to the public and private sectors (industry, universities and government agencies) for evaluation, experimentation and demonstration of key technologies and their applications after launch. A formal 2-year Experiments Program currently is planned, including:

- demonstrate the commercial viability and market acceptability of new voice, data and video networks and service with ACTS
- verify the on-orbit performances of the advanced technology components of the ACTS flight system
- demonstrate and evaluate the system networking aspects of the switching and processing technology
- characterize the Ka-band transmission medium and develop techniques to combat signal fade and attenuation

To date, some 60 experiments have been approved to use the ACTS system. These experiments represent 86 principal investigators and co-investigators from over 61 different organizations.

The following table breaks down the application experiments category into a number of sub-categories and lists the number of experiments currently planned for each.

Application Experiments Categories

Business Networks	7
Medical	3
Integrated Services Digital Network	4
Public Switched Network	3
Education	1
Video/Teleconferencing	1
DOD Strategic/Tactical	2
Gigabit Networks	3
High Definition TV	1
Supervisory Control and Data Acquisition	1
Land Mobile	6
Aeronautical Mobile	1
Science	3
Network Protocol	1
TOTAL	**37**

American Express
Availability Comparison Between Ku and Ka Satellite Technologies

American Express is interested in testing the ACTS very- small aperture terminal (VSAT) technology to determine if it will be a viable future business option for transactions. ACTS will operate as a data channel between facilities in Phoenix, Ariz., and Mexico City, Mexico. American Express has an existing Ku-band link between these sites and wants to compare the performance of the ACTS Ka-band T-1 VSAT (capable of higher data rates, 1.544 Mbps, with a smaller terminal) to its current system. Contact: Thomas Marshall, 602/492-4321.

Southern California Edison
Low Cost SCADA Network
Affiliated Organizations: Weber State University, Wasatch Research

Southern California Edison (SCE) is working with NASA Lewis Research Center to build and test an ultra-small aperture terminal (USAT) that operates at Ka-band for use in a supervisory control and data acquisition (SCADA) network. Weber State University will conduct the tests of the terminal with both Ku- and Ka-band antennas and will compare performance.

The spotbeam antenna technology of ACTS makes it possible to use smaller terminal apertures. SCE is investigating the Ka-band USAT to determine its suitability for use with electric utilities and other industries. Contact: Dr. Roosevelt Fernandes, 818/812-7305.

Ohio University
Disaster Recovery, Backup, and Communications Augmentation Experiment Using ACTS
Affiliated Organizations: Huntington Bank, SUNGARD Recovery Services, Inc., Unisys Corporation, Ascom Timeplex, Inc.

Ohio University will conduct tests with ACTS to help Huntington Bank recover from a "simulated" natural or other disaster, thus protecting it against a total loss of communications. ACTS will transmit financial data such as deposits, account balances and transfers of funds. The experiment will determine the reliability of the data link and the ability to switch over to a backup communications system within an acceptable period of time as well as the economical advantages of using such a system. Contact: Dr. Don Flournoy, 614/593-4866.

COMSAT World Systems
Prototype INTELSAT Operations
Affiliated Organization: INTELSAT

This experiment will provide operational experience with ACTS technology to potential service providers, earth station owners, and users, emphasizing the use of Ka-band and onboard signal processing. The reliability and transmission quality of Ka-band will be compared with C- and Ku-bands to determine feasibility of future use. Contact: A. M. Goldman Jr., 202/863-6601.

Jet Propulsion Laboratory
ACTS Aeronautical Experiment
Affiliated Organizations: Air Force Rome Labs, Boeing Defense and Space Group,
GE Electronics Laboratory, Texas Instruments

The Jet Propulsion Laboratory (JPL) will demonstrate a 4.8 kbps voice and data link between an aircraft and a fixed terminal using phased-array antennas. This experiment will evaluate ACTS spotbeam technology, the ACTS Mobile Terminal (AMT), and phased-array antennas for use in aeronautical communications. Aeronautical communications could be an important new growth area in the telecommunications industry. Contact: Brian Abbe, 818/354-3887.

Baseline Land-mobile Experiments

JPL will conduct multiple mobile communications experiments demonstrating various applications involving voice, data, and slow-scan video. They will evaluate the commercial viability of system concepts and perform propagation measurements. The main purpose is to evaluate K/Ka-band feasibility for mobile applications. Contact: Mr. Tom Jedrey, 818/354-5187.

Dataflow Systems Direct-to-Premises
ACTS-based Video Services
Affiliated Organizations: University of California-Berkeley, Mississippi State University

Dataflow Systems will investigate two-way, direct-to- premises static and motion video services with ACTS, based on low cost, low power workstations. Such services are needed to communicate images between offices during normal business operations or in emergency situations. Some of the possible applications include: multimedia conferencing between remotely located CAD/CAE design teams, doctors in surgery, lawyers in court, and industrial process control teams. Also, use of ACTS would enable on-demand and dynamic database browsing and copying. Contact: Dr. Vason P. Srini, 415/527-7183.

Public Broadcasting Service
High Definition Television and Video Demonstration

The Public Broadcasting Service (PBS) will use ACTS to transmit high definition television (HDTV) and digital video signals from PBS to member stations. Member stations could then distribute the signals via terrestrial transmitters or cable TV. PBS will be experimenting with the High Data Rate terminal -- the only ground station available capable of transmitting HDTV signals.

In another test, PBS would transmit via ACTS from member stations to a small area to demonstrate the feasibility of local direct broadcast satellite service (DBS) within a single city or market region. Contact: Mr. Carl Girod, 703/739-5483.

COMSAT Laboratories
Integrated Services Digital Network (ISDN) Experiments

In this experiment, COMSAT will demonstrate the ability of satellite communications to provide state-of-the-art commercial telecommunications services. The experiment is designed to test the viability of providing a variety of services and teleservices via ISDN using an ACTS-type system. COMSAT will measure the performance of the ACTS ISDN technology and its network capabilities. Contact: Moorthy Hariharan, 301/428- 7747.

University of Florida
Narrow band ISDN Applications Using ACTS

The relationship between ISDN and satellites is complementary. ISDN provides satellite networks with a single access point into multiple ground networks. On the other hand, satellite systems provide increased geographical coverage for ISDN. ACTS's advanced features enhance this relationship by increasing flexibility of connectivity, network efficiency, and quality of service.

The University of Florida will conduct three narrow band ISDN-related investigations which can be implemented using ACTS: video teleconferencing, performance evaluation of High- Level Data Link Control (HDLC) protocol over a Ka-band satellite channel (which will study the effect of rain fade on this protocol with respect to its various control functions such as addressing, frame numbering, error recovery, and flow control), and Local Area Network interconnection. Contact: Dr. Haniph A. Latchman, 904/392-4950.

NASA Lewis Research Center
North American ISDN Users' Forum (NIUF) Demonstration
Affiliated Organizations: A consortium of users and telephony industry, including: Bellcore, Regional Bell Operating Companies, AT&T

This experiment will demonstrate ACTS ISDN services to NIUF members. It will involve the use of a T-1 VSAT transportable link back to Lewis Research Center, JPL, and other ACTS ISDN transportable nodes. The primary application demonstrated will be PC-based multimedia teleconferencing. Contact: Tom vonDeak, 216/433-3277.

NBC
Satellite News Vehicle (AMT) Experiment
T-1 VSAT Backhaul Experiment
Affiliated Organization: JPL

NBC will investigate mobile and fixed terminal capabilities for providing increased communications for people in the satellite news industry, specifically while enroute to and from news sites. The experiments will determine how many "hops" can be made between points before image quality degrades beyond acceptable levels.

The fixed experiment involves using several T-1 VSATs to provide multiple "hop" communications, transmitting the same images from point to point between different broadcast locations. The mobile experiment will evaluate the ACTS and AMT technologies for remote communications purposes, e.g., from a news bureau to a satellite news vehicle. Contact: Robert Sisko, 212/664-6186.

IDB Communications Group
Satellite News Gathering Land-Mobile Experiment/Demonstration
Affiliated Organization: JPL

IDB Communications is interested in showcasing the ACTS and AMT technologies for remote broadcast purposes. This experiment/demonstration will be a live transmission of IDB Communications' network-fed broadcast via ACTS. It will occur at the National Association of Broadcaster's Convention in 1994. Contact: David Anderson, 213/240-3726.

Bellcore
Experimentation with Satellite-based Personal Communications Services (PCS)
Affiliated Organization: JPL

The goal of this research effort is to demonstrate the capabilities of satellites for enhancement of ground-based personal communications voice and data services. The experiment will determine the ways in which local exchange network providers can interface to wireless service providers and the kinds of services that should be offered.

The applications being investigated include: two-way messaging, delivery of personalized information services, use of satellites to alert nomadic end users of incoming telephone calls. It will also test the combined capability of satellites plus Global Positioning System service to locate nomadic end users, update network databases, and route calls and/or messages to their current location. Contact: Richard Wolff, 201/829-4537.

Florida Atlantic University
ACTS Wide Bandwidth and Video Compression Experiments

The primary goal of this experiment is to demonstrate the use of ACTS for commercial video data transmission. Florida Atlantic University will use video compression techniques developed by the University and will test the reliability and feasibility of ACTS to provide this commercial service. Contact: Dr. Henry Helmken, 407/367-3452.

Martin Marietta Astrospace
Business Telecommunications for Potential Customers

Martin Marietta Astrospace will be allowing potential customers to evaluate the Ka-band frequency for business communications. Martin Marietta has purchased a ground station for its facility in East Windsor, NJ., in order to experiment with ACTS. It is identifying various areas for investigation. Contact: Frank Gargione, 609/490-2337.

HEALTH CARE ADVANTAGES

Availability of quality health care is a primary concern to people everywhere. When a patient is not able to get to health facilities or when specialists are not available for consultation, precious time is wasted. Improved and expanded telecommunications can help overcome distance barriers, improve upon local facilities, and extend medical services to more people, while maintaining reasonable costs.

The ACTS Experiments Program is working with medical personnel around the country to test delivery of health care services to remote locations and to demonstrate the use of more sophisticated mobile communications. ACTS will transmit images and information to physicians and specialists for use in diagnoses. High-resolution medical imagery from X-rays, MRIs, or CT scans can be sent to another location for review by a consulting physician. The ACTS Mobile Terminal (AMT) will also be used to transmit patient data from emergency vehicles while en route to a hospital.

EXPERIMENTS

Mayo Foundation
Application of the NASA ACTS Satellite System to the Practice of Medicine in an Integrated Group Practice
Affiliated Organizations: U.S. Army Medical Diagnostic Imaging Support

The Mayo Foundation will be using ACTS to investigate communication techniques which may eventually allow large medical centers to provide supporting medical services to small and medium-sized medical facilities in small towns and rural areas. The objective of the experiment is to demonstrate that the provision of quality medical diagnostic and information services to remote facilities can be cost effective and timely.

It has become essential to be able to communicate and transmit data from one medical facility to another to enhance the quality of care for individual patients and to seek consultation from experts who may be at a distant location. Mayo will be investigating a variety of medical applications including image, data, and voice transmission. They will use ACTS to transmit in real-time medical imagery and other patient test information for diagnosis. The on-demand flexibility, wide bandwidth, ISDN and high data rate capabilities of ACTS could solve many medical outreach problems. Contact: Dr. Robert Hattery, 507/284-9425.

Georgetown University School of Medicine
Remote Radiology

In this experiment, Georgetown University will transmit magnetic resonance images (MRI) and radiological images from Tripler Army Base in Hawaii to Washington, DC. Tele-education will also be provided for radiologists and radiologists-in- training. The experiment may be expanded to include transmission to South America. Contact: Dr. Seong K. Mun, 202/687-5990.

NASA Lyndon B. Johnson Space Center
Application of Small Earth Stations in Conducting Telescience and Telemedicine
Affiliated Organizations: Krug Life Sciences, University of Colorado

Johnson Space Center will use ACTS to test the utility of advanced satellite technology for conducting telemedicine, telescience, video conferencing, and high resolution image transfer. Specifically, the experiment will generate images of the interior of the eye. The images will then be transmitted to another location via ACTS for analysis. Contact: Dr. Gerald Taylor, 713/280-0469.

EMSAT: Advanced Technology for Emergency Medical Services
Emergency Medicine Land-Mobile Satellite Experiment (EMSAT)
Affiliated Organizations: JPL

EMSAT will evaluate the feasibility of mobile satellite communications for pre-hospital communications. Experiment objectives are to demonstrate and assess the transmission and reception of satellite digital voice for two-way, pre-hospital communications, one-way transmission of patient data from field paramedics to the base hospital, and telemetry of patient assessment data to the base hospital. Factors that affect pre-hospital satellite communications will be studied. Contact: Bruce P. Jackson, 818/842-0207.

University of Washington
Mobile Radiology Image Transfer
Affiliated Organization: GE Medical Systems

This experiment will link a mobile Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) van to the Department of Radiology at the University of Washington Medical Center. The mobile van will transmit digital medical images (while stationary) from various locations in the state of Washington. This investigation will allow for quality control and for diagnostic consultation and interpretation of the remotely obtained images at a major university medical center. This use of ACTS demonstrates a practical medical application of teleradiology from remote locations to medical centers. Contact: Dr. Stephen J. Carter, 206/685-2693.

ACTS/AMT Telemedicine Experiment
Affiliated Organization: JPL

This experiment involves the transmission of CT and MRI images to the University of Washington via ACTS using a portable computer with the AMT, the fixed terminal located at NASA Lewis Research Center (LeRC), and a telephone line from LeRC to the University of Washington Medical Center. The received images will be filmed with a laser camera and compared with original films. The transmissions will be performed during various weather conditions and at multiple locations throughout rural Washington state. Contact: Dr. Stephen J. Carter, 206/685-2693.

Lister Hill National Center for Biomedical Communications
National Library of Medicine
National Institutes of Health VAMA
VSAT Access to Medical Archives
Affiliated Organization: University of California at San Francisco, School of Medicine

ACTS offers the opportunity to experiment with techniques and procedures suitable for a communications environment that allows real-time access to critical medical information. Current access to medical archives at the National Library of Medicine is achievable through INTERNET. However, the transmission rate is such that real-time interaction and selection of information is not possible.

A set of experiments will test prototype systems for the rapid transfer of medical images across widely-separated geographical areas. Two possible experiments: test a prototype medical information system to provide remote access to a national medical database in real time and demonstrate a system to rapidly and accurately transfer a large volume of uncompressed digital X-Ray image files. Contact: Mr. Rodney Long, 301/496-4496.

LONG DISTANCE EDUCATION AND TRAINING

Education and training are key to increased knowledge and productivity. In this era of changes in the economy and the workplace, students and workers, with increasingly limited time and resources, will need to have better access to educational and training facilities. ACTS-type technology can provide real-time, more advanced communications capability to the classroom or the workplace. It can also tap into information networks faster and transmit that information quicker than current communications systems.

Some ACTS experimenters will be investigating the use of long-distance, real-time, interactive communications to educate people outside of major learning institutions. They will test the capability of ACTS to deliver instruction to interested students in different areas in the United States and in South America. Other experimenters will use ACTS to provide special training. ACTS-type service could create new educational networks.

EXPERIMENTS

Georgetown University
Georgetown Technical Hemispheric Intercultural Network for Knowledge (G-THINK)
Affiliated Organizations: Inter-American Development Bank, IBM, Citibank, Martin Marietta Astrospace, Loral, Andres Bello University, Catholic University, Javeriana University, Latin America Institute of Doctrinal and Social Studies, Sophia University

Georgetown University will investigate the viability of two-way, interactive distance learning, involving programs that are medical, scientific, or research in nature. ACTS will be used to demonstrate distance education to four South American sites in Columbia, Ecuador, Venezuela, and Chile.

Georgetown will also conduct distance education projects in the United States in the areas of medicine, business, teleradiology, library database access, veterinary medicine, and remote sensing. Contact: Rev. Harold C. Bradley, S. J., 202/687-3455.

NASA Kennedy Space Center
Distance Learning in the Area of Hazardous Materials and Environmental Safety
Affiliated Organizations: Lockheed Space Operations Company, University of Central Florida

This experiment involves distance learning in the area of hazardous materials and environmental safety. ACTS will link Dryden Flight Research Facility, Calif., and Kennedy Space Center, Fla., for approximately 10 hours of training to Lockheed employees. The experiment consists of distance learning classes using lecture, graphics, and videotape. It will test the quality of video and audio and effectiveness of Ka-band for distance learning. Contact: Darwin V. Brown, 407/867-7293.

Florida Agricultural and Mechanical University
Distance Learning

ACTS will be used to link the College of Pharmacy at Florida A&M University (FAMU) in Tallahassee with the FAMU Clinical Training Unit located in Miami and allow for the instruction of students. The experiment will involve two-way voice and video transmission and will be divided into two 16- week and one 13-week segments. Contact: Johnnie L. Early, 904/599-3301.

IMPROVED NATIONAL DEFENSE AND EMERGENCY/DISASTER COMMUNICATIONS

In the Persian Gulf war and the aftermath of Hurricane Andrew, the United States reaffirmed the value of advanced military and disaster communications. Secure and reliable communications provided necessary advantages to American troops in executing quick and successful air and ground attacks, while minimizing casualties. In severe contrast, lack of immediate and adequate communications capability severely hampered the relief efforts in Florida and Louisiana.

Experimenters with ACTS will gain insight into improved military and emergency/disaster communications by testing new concepts. The use of the ACTS Mobile Terminal can restore communications capability immediately. ACTS T-1 VSATs can be used to restore damaged points within the Public Switched Network.

Military and emergency communications can benefit from the real-time, higher communications capacity demonstrated by the ACTS system.

EXPERIMENTS

National Communications System
Public Switched Network (PSN) Restoration
PSN Trunking
Isolated User Access
Secure Mobile Communications
Affiliated Organizations: MITRE Corporation

The National Communications System (NCS) experiments will demonstrate the capability to restore or augment communication networks. It is the responsibility of the NCS to coordinate the planning for and provision of communications services to a set of National Security/Emergency Preparedness (NS/EP) users. NCS initiated the Commercial SATCOM Interconnectivity (CSI) program in 1983 in response to a Presidential directive stating that CONUS-based commercial satellite communication resources should be exploited to augment and restore Government communications capabilities during times of emergency. ACTS will be used to investigate new advanced satellite communications technologies.

The first three experiments examine restoration of the PSN when disrupted. The first restores communications at the point where loss of connectivity occurs or augments existing capability when needed. The second experiment provides point- to-point trunking via ACTS for NS/EP users when disruption occurs in the PSN inter-exchange carrier switches. The third experiment will demonstrate ACTS's ability to communicate with isolated users by restoring communications between local carriers in the PSN and inter-exchange carrier switches. The final experiment utilizes the AMT capability to restore communications in areas affected by disaster. Contact: Mr. Frank Dixon, 703/692-0540.

U.S. Army Space Command
Army ACTS Experiments
Affiliated Organizations: Combined Arms Center, Department of the Army/Army Space Institute, Laboratory Command/Army Space Technology Research Office, U.S. Army Communications Electronics Command, U.S. Army Information Systems Engineering Command, U.S. Army Future Battle Lab, U.S. Army Medical Diagnostic Imaging Support

The Army ACTS experiments will be incorporated into the Army Space Demonstration Program which demonstrates space systems capabilities to support AirLand Battle Doctrine. The Army will use ACTS to overcome various operational communications shortfalls. A complete set of verification experiments will be conducted to evaluate ACTS technologies and interactions with ground communication systems. The experiments will explore a variety of uses including video teleconferencing; transfer of large imagery, geographic/meteorological information, logistics, and medical databases; remote training; transmission of video, voice and data to the field; and testing of mobile communications. Contact: Pete Cafaro, 719/554-8717.

U. S. Army Topographic Engineering Center
Use of ACTS for Communicating Differential GPS
Affiliated Organization: Rockwell International

U.S. Army Topographic Engineering Center (USATEC) is conducting an experiment using the Global Positioning System (GPS). GPS uses satellite signals to calculate a position on earth and is subject to several sources of error. These errors remain relatively constant within a specific region, and a set of corrections can be generated at one location and applied to another. USATEC via ACTS will transmit these corrections to users in real-time. They will analyze time delay, transmission quality, bit error rate, and cost and convenience of terminal location and satellite acquisition. Contact: Andrew Austin, 703/355-2765.

U.S. Army Research Labs
Integrated Services Digital Network (ISDN) via Satellite
Affiliated Organization: Georgia Tech Research Institute

This experiment evaluates ACTS' ability to provide ISDN connectivity among a geographically-dispersed population of end users. It will provide real-time networking of ISDN users via satellite and multimedia desktop video teleconferencing. The ACTS system will be compared to a terrestrial DOD ISDN baseline system. Contact: Dr. Jay Gowens, 404/894-3137.

EXPANDING SCIENTIFIC RESEARCH NETWORKS

Scientific research can be greatly facilitated and augmented by improved communications capability. The majority of scientific research is conducted in remote areas that are not accessible by modern transportation or fiber-optic cable. With ACTS-type technologies, researchers could gain access to remote databases that contain needed information. Researchers would also have the ability to communicate in real-time with other scientists in the field to obtain results from experiments or to consult on a problem. Mobile communications could benefit researchers by providing a transportable link to laboratories or universities.

Experimenters in the ACTS Program will be investigating the use of new communication techniques in conducting scientific research. From operating remote laboratories to simply transmitting needed information from Arctic climates, ACTS can improve the way scientists operate and make it easier to distribute scientific results.

EXPERIMENTS

New Mexico State University
Real-Time, High-Bandwidth Data Links

ACTS will provide a high-bandwidth, real-time link to gain access and control of an astronomy telescope located at the Apache Point Observatory in south-central New Mexico by a remote user within the continental United States. The user will not have to be on-site during the observation period. The present mode of access to the observatory is through commercial, land-based telephone lines.

New Mexico State University will look to ACTS to give the user a "touch and feel" for remote access and control and to provide the high-rate capacity needed for data transmission from a new, deep-sky telescope which will produce continuous, digital data from an array of sensors. They will also test ACTS for non-real-time data networking to support observatory management, database sharing, computer conferencing, and similar services for the science community. Contact: Dr. Stephen Horan, 505/646-5870.

National Science Foundation
Antarctic Researcher Support
Affiliated Organization: University of California-Santa Barbara

ACTS would provide an advanced communications link between Palmer Station in the Antarctica and U.S. laboratories. It would also provide access to the INTERNET and high quality voice communications, allow rapid and relatively large transfer of data, and permit access to high data rate satellite information such as SAR sea-ice images. It would also allow for off-station logistics and scientific support, database management, data analysis, and open Palmer to as yet untapped educational opportunities. ACTS would contribute to increased researcher productivity thereby decreasing the number of researchers needed on-site and would provide a greatly needed link to the outside world from Palmer's remote location. Contact: Dennis Peacock, 202/357-7894.

George Washington University
Supercomputer Networking Applications
Affiliated Organizations: COMSAT Laboratories, Cray Research, NASA Goddard Space Flight Center (GSFC), Jet Propulsion Laboratory

George Washington will use ACTS to demonstrate the ability of satellites to support high data rate communications such as distributed supercomputer applications. JPL will be able to access GSFC's supercomputer facilities to enable oceanic/atmospheric modeling. Also, supercomputers will be linked to accelerate weather forecasting. The experiments can simulate Earth and space science processes, create real-time visualization of the data, and distribute the data through a wideband data communications network. Contact: Dr. Burt Edelson, 202/994-1431.

Pacific Space Center (PacSpace) and University of Hawaii
Advanced Applications to Validate ACTS Technologies
Affiliated Organizations: Argonne National Laboratory, Hawaii Space Development Authority

The State of Hawaii faces unique communication problems caused by distance. PacSpace will utilize ACTS to help solve some of these problems and to perform a range of experiments. They will use the high capacity of an ACTS ground station to support other on-going programs at the University of Hawaii, involving image processing and management, high performance computing and communications, oceanic research, and integration of advanced communications networking. Experiments will test the practicality of remote access to large image databases for scientific, military and educational information. They also will test transfer of scientific research data to central facilities. Contact: Dr. David Yun, 808/533-1539.

ADVANCING TECHNOLOGIES AND U.S. COMPETITIVENESS

The ACTS Program has and will continue to contribute to the development of advanced technologies. Since ACTS will operate at the Ka-band frequency, off-the-shelf Ka-band components are now available. The spotbeam and onboard switching and processing technologies developed for ACTS have already in part been adapted for use in planned communication systems. American research efforts in high definition television (HDTV) and in integrated services digital networks are also being advanced by ACTS technology development. Smaller ground stations that transmit at higher data rates have been created for use with ACTS. The proving ground for all of these technologies is the ACTS Experiments Program. The testing and performance of the technology could yield important results that will impact future communication systems in years to come.

ACTS technology not only advances the state-of-the-art but also strengthens U.S. competitiveness in the international telecommunications market. Since 1982, the U.S. share of the communications satellite and equipment market has shrunk in the face of increased competition from European and Japanese companies. NASA, in conjunction with industry, government and academia, developed the ACTS and its associated ground system to advance the U.S. competitive position in technologies expected to be widely used in the 21st century.

EXPERIMENTS

Advanced Research Projects Agency
High Data Rate Terminal Development and Experiments

The Advanced Research Projects Agency (ARPA), in a cooperative effort with NASA, has sponsored the development of the High Data Rate (HDR) terminal as part of a satellite research testbed network using ACTS and in support of the federal High Performance Computing and Communications (HPCC) program.

The HPCC was developed as a multi-agency effort for the purposes of extending U.S. technological leadership in high performance computing and computer communications and of providing wide dissemination and application of these technologies.

One element of the HPCC program is the development of technology for wide area gigabit (one billion bits per second) data networking. ARPA has the responsibility for coordinating the multi-agency research effort to achieve this capability. Also, ARPA has strong interests in investigating very high speed satellite/terrestrial communications for defense applications. NASA believes that satellites can render significant service in hastening the development of high data rate applications for commercial and government use.

In order to achieve mutual goals, ARPA and NASA supported the development of the HDR terminal and experiments to challenge network capabilities and promote the state-of-the-art in this area. The HDR experiments are intended to demonstrate new capabilities and the functionality of high-speed communications.

The ARPA HDR experiments will investigate the linking of satellite and fiber networks, the real-time user interaction with complex climate models created with supercomputer visualization, military applications, and the distribution of medical imagery. Experiment collaborations are currently being developed with:

Ohio Supercomputer Center
Public Broadcasting Service
National Center for Atmospheric Research
U.S. Army Future Battle Lab
Army High Performance Computer Research Center
Mayo Clinic
Georgetown University
University of Hawaii

Contact: Paul Mockapetris, ARPA, 703/696-2262.

National Telecommunications and Information Administration (NTIA)
Institute for Telecommunication Sciences
Quantify ACTS End-to-End Communication System Performance

The primary objective of NTIA's experiment is to measure and quantify the end-to-end digital communication system performance of ACTS from the end user's perspective. The experiment will also provide documented knowledge of advance communication satellite system performance. These measurements will be used to establish a baseline measure of performance of ACTS. This quantification of the ACTS system will enable performance comparisons of advanced satellites with other telecommunications technologies, e.g., public data networks and conventional communication satellite systems.

This performance data will be used by NTIA/ITS to help develop national and international telecommunication standards that will strengthen the use of advanced communication satellites in telecommunication networks. Future networks may incorporate satellites in a hybrid network design where a satellite provides back-up and restoration services as well as thin-route and mobile communications. Contact: Marjorie Weibel, 303/497-3967.

Motorola, Inc.
BBP Transmit Window Characterization
High Burst Rate Modem Evaluation
Coding Gain Evaluation

Motorola will be conducting a series of experiments to technically challenge the ACTS system. In the first experiment, it will measure the times of data arriving at the ground station while varying transmit time in order to evaluate ACTS link erosion due to orbital variations and clock accuracies.

The second experiment will test Motorola's modem technologies through the ACTS microwave switch matrix channel which is capable of higher data rates. Motorola will use advanced modulation techniques and coding to maximize bit error rate performance.

The last experiment will investigate the effect of coding on ground station transmissions. Data will be transmitted in coded and uncoded modes, and bit error rates will be measured. The data will be evaluated to determine the advantage realized by coding techniques. Contact: Kerry Lee, 602/732-2299.

COMSAT Laboratories
Demonstration of Advanced Networking Concepts
Affiliated Organization: INTELSAT

The trend toward utilizing smaller ground station antenna sizes and increasing the use of higher frequency bands has focused attention on methods for overcoming rain-induced degradation of the satellite signal. One method is to integrate a number of VSATs through a Metropolitan Area Network (MAN) into a Wide Area Diversity (WAD) Network.

The objective of this experiment is to identify whether Ka-band VSATs can achieve error performance and availability levels defined for an international ISDN connection, despite the propagation conditions in these bands, based on the networking method described above. Successful penetration of satellite-distributed communications services into existing and new markets hinges on two factors: economics and quality of service. Economy can be achieved through use of smaller Earth stations. Availability is achievable through site diversity. COMSAT Laboratories will use ACTS to test this theory. Contact: Dr. Asoka Dissanayake, 301/428-4411.

Hopping Beam TDMA Operation Observations

One of the most advanced features of ACTS is the combination of satellite baseband circuit switching, Time Division Multiple Access (TDMA), and spotbeam hopping. This experiment will test the operation of these technologies and will evaluate receive and transmit acquisition performance under normal and worst case operational conditions. Contact: Robert Ridings, 301/428-4264.

Corporate Computer Systems
High Quality Audio (AMT) Experiment
Affiliated Organizations: JPL, CBS Radio

Two mobile satellite communications experiments are planned for ACTS. The first involves interfacing the AMT with a MUSICAM Perceptual Coder and operating this system at coded 64 kbps to demonstrate high quality mono audio transmission. The second experiment interfaces the equipment with the AMT and operates at uncoded 128 kbps. The experiments also involve testing of an algorithm built into the processing capabilities of the MUSICAM Perceptual Coder. The audio coder will monitor the received signal and vary the "amount of coding" necessary to maintain the link. Contact: Dr. Larry Hinderks, 908/946- 3800.

MITRE Corporation
Protocol Evaluation for Advanced Space Data Interchange

MITRE will study the suitability of standard data communication protocols for future generations of communications satellites. The hopping spotbeam technology of ACTS, together with T-1 VSATs providing direct service to experimenters, suggests that the current method of payload data distribution, using a "bent-pipe" combined with a data distribution hub on the ground (the current Tracking and Data Relay Satellite System method), could be replaced or augmented by direct data distribution to users.

ACTS will be tested and data communication protocols evaluated to determine feasibility of an ACTS-type system for data distribution. Contact: Quoc Nquyen, 703/883-5674.

New Jersey Institute of Technology
Traffic Modeling, Channel Characterization, Coding, and Modulation on the ACTS
Affiliated Organization: Martin Marietta Astrospace

The New Jersey Institute of Technology will perform a group of technology verification experiments. It will test various traffic models for video teleconferencing data. It also will investigate the performance of ACTS at Ka-band and will test several coding and channel equalization methods. Contact: Dr. Y. Bar-Ness, 201/596-3520.

University of Maryland Center for the Commercial Development of Space
Frame Relay Experiments over ACTS: LAN Interconnection Services
Affiliated Organizations: Comsat Labs, National Telecommunications and Information Administration, National Information Technology Center, and University of Colorado

The University of Maryland will demonstrate fast packet switching communication using the ACTS T-1 VSAT network as applied to interconnection of Local Area Networks (LANs). The experiment will measure the bit error rate and performance of congestion control algorithms and confirm ACTS Frame Relay conformance to performance requirements. It will also demonstrate the capability of satellites such as ACTS to interconnect geographically dispersed LANs. Applications to be tested include file transfer, electronic mail, and interactive visualization (X-Windows) between LANs. Contact: Dr. Anthony Ephremides, 301/405-3641.

NASA Lewis Research Center
On-orbit Spacecraft Dynamics
This experiment will determine the spacecraft position (angular and range) as a function of time with respect to the Master Control Station at the NASA Lewis Research Center. Contact: Dr. Roberto Acosta, 216/433-6640.

Mini Terminal Test Bed (MTTB)
The goal of this experiment is to develop and test a communications technology testbed. The testbed will contain state-of-the-art Ka-band subsystems and components currently being designed by the NASA Lewis Research Center, Space Electronics Division. The experiment will determine the performance of these components for possible use in future communications systems. Contact: Gene Fujikawa, 216/433-3495.
Multi-beam Antenna Performance Verification
This experiment will determine the ACTS on-orbit antenna performance and will validate the LeRC Structural/Thermal/RF Analysis Program. Contact: Dr. Roberto Acosta, 216-433/6640.

Networking Technical Experiment for BBP Operations
Performance of the ACTS network control system and the adaptive rain fade compensation technique will be evaluated. Contact: Thom Coney, 216/433-2652.

Microwave Switch Matrix and Wideband Transponder Performance Evaluation
LeRC will verify the ACTS Microwave Switch Matrix (MSM) mode of operation through all of ACTS transponder paths. In addition, the experiment will verify that the MSM can support reliable high data rate communications. Also, various rain fade compensation algorithms will be developed and implemented to explore improved approaches. Contact: Don Hilderman, 216/433-3538.

Communications Link Performance
This experiment will measure co-frequency interference, adjacent frequency interference, adjacent burst interference, and uplink bit error rate performance under various conditions. It will also evaluate ground station performance and investigate clock accuracy on network performance. Contact: Dr. Jon Freeman, 216/433-3380.

ACTS Propagation Studies
The ACTS Rain Attenuation Prediction Model will be tested to verify fade occurrence and duration predictions at ACTS ground stations. The experiment also will demonstrate the capability of rain fade compensation algorithms for the NASA Ground Station in Cleveland. Contact: Dr. Roberto Acosta, 216/433-6640.

Autotrack Control Performance
This experiment will test and verify the on-orbit antenna pointing stability at peak thermal cycles. Contact: Dr. Roberto Acosta, 216/433-6640.

HBR SMSK Interference Experiment (INTEX)
LeRC will measure the bit error rate of a transmitted serial minimum shift-keyed modulated satellite signal in the presence of various types of interfering signals. Contact: Robert Kerczewski, 216/433-3434.

Compressed Digital Video Transmission
Satellite delivery of compressed digital video will be tested. The experiment also will demonstrate the effects of the ACTS system on a 25-30 Mbps broadcast quality digital television system while evaluating video compression hardware over a real channel. Contact: Wayne Whyte, 216/433-3482.

ACTS PROPAGATION EXPERIMENTS

ACTS provides an opportunity to study the characteristics of impairments to Earth-space communications at Ka-band (30/20 GHz) caused by propagation phenomena and to develop techniques to counter them. Rain is a major impediment to Ka-band communications because it causes fades in the satellite signal. It presents quite a challenge to system designers because it causes more severe fades at this frequency than in other, lower frequency bands.

Other phenomena also affect the satellite signal. Clouds and atmospheric gases -- such as water vapor and oxygen -- can also cause signal fades. Tropospheric scintillation (twinkling in the atmosphere) is another important factor. Also, the advent of smaller user terminals with their smaller operating margins increases the need for propagation data.

The ACTS Propagation Program will determine the impairments to the satellite signal caused by the various physical phenomena during the planned experiment period. The experiments will:

- provide a lasting base of 30/20 GHz propagation data for communications satellite builders,
- collect propagation data for a minimum of 2 years, and
- obtain information on the physical processes that cause signal impairments.

Researchers in this field believe that it is necessary to conduct measurements over longer periods of time to obtain valid information concerning the effects of propagation phenomena on satellite signals. ACTS provides a unique opportunity to measure the effects at Ka-band for a statistically adequate time period and in different climatic areas for which no measurements currently exist.

Lewis Research Center issued a NASA Research Announcement to solicit experiments to expand the current base of knowledge concerning propagation effects on Ka-band satellite signals. NASA sponsored the development and production of the ACTS Propagation Terminal for experimenters to use to conduct these measurements. The selected experiments consist of two defined classes.

CLASS I: In situ measurements using the propagation terminal to obtain radio wave propagation data at 20 and 28 GHz using beacons on ACTS as the signal source. Propagation terminals will be located in various climate zones in North America to gather this data.

EXPERIMENTS

Colorado State University
Ka-band Propagation Studies Using ACTS Propagation Terminal and the CSU-CHILL Multiparameter, Doppler Radar.
Contact: V. N. Bringi, 303/491-5595.

University of Alaska
ACTS Propagation Measurements in Alaska.
Contact: Dr. Charles E. Mayer, 907/474-6091.

COMSAT Laboratories
ACTS Uplink Transmit Power Control Measurement Experiment Ka-band Propagation Measurements Experiment Using the ACTS Spacecraft.
Contact: Dr. Asoka W. Dissanayake, 301/428-4411.

Stanford Telecommunications
A Proposal for ACTS Propagation Experiments.
Contact: Dr. Louis J. Ippolito, 703/438-8069.
Affiliated Organizations: New Mexico State University, NASA HQ, Code O

University of Oklahoma
Rain Attenuation Statistics for the ACTS Propagation Experiments for Central Oklahoma.
Contact: Prof. Robert E. Crane, 405/325-4419.

University of British Columbia
ACTS Ka-band Propagation Measurements in a West Coast Maritime Climate.
Contact: Dr. M. M. Z. Kharadly, 604/822-2816.

University of South Florida and Florida Atlantic University
Propagation Measurements Using ACTS.
Contact: Dr. Rudolph E. Henning (USF), 813/974-4782 or Dr. Henry Helmken (FAU), 407/367-3452.

CLASS II Measurements using either the ACTS communications channels or beacon signals to investigate other aspects of radio wave propagation on new communication services, such as multipath and blockage effects on mobile communications.

EXPERIMENTS

COMSAT Laboratories
ACTS Wide Area Diversity Experiment
Contact: Dr. Asoka Dissanayake, 301/428-4411.

John Hopkins University and University of Texas
Land-Mobile Satellite Measurements in Central Maryland and Alaska Using ACTS: Passive Antenna Tracking System and Mobile Receiver System
Contact: Dr. Julius Goldhirsh (JHU), 301/953-5042 or Wolfgard J. Vogel (UT), 512/471-8608.

Georgia Tech Research Institute
RF Propagation Effects and ACTS Satellite Channel Characterization for Very Small Aperture Terminals
Contact: Daniel Howard, 404/894-3541.

In another effort Teleglobe Canada will be participating in the ACTS Propagation Program, using its own terminal to conduct measurements. The experiment effort is not funded by the NRA, but Teleglobe Canada's data will be included in the overall Program's propagation statistics.

Teleglobe Canada
Measuring Propagation Effects Utilizing ACTS
Contact: Ara Karahisar, 514/868-8322.

ORBITING AND RETRIEVABLE FAR AND EXTREME ULTRAVIOLET SPECTROMETER - SHUTTLE PALLET SATELLITE (ORFEUS-SPAS)

OVERVIEW

The Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer - Shuttle Pallet Satellite (ORFEUS-SPAS) mission is the first in a series of missions using the German built ASTRO-SPAS science satellite. The ASTRO-SPAS program is a joint German/U.S. endeavor, based upon a memorandum of understanding between NASA and the German Space Agency, DARA.

ASTRO-SPAS is a spacecraft designed for launch, deployment and retrieval by the Space Shuttle. Once deployed from the Shuttle by its Remote Manipulation System (RMS), ASTRO-SPAS operates quasi-autonomously for several days in the Shuttle vicinity. After completion of the free flight phase, the satellite is retrieved by the RMS and returned to Earth. The ASTRO-SPAS program is very cost efficient, owing to the versatility and the retrievability of the carrier.

ORFEUS-SPAS is an astrophysics mission, designed to investigate very hot and very cold matter in the universe. The one-meter diameter ORFEUS-Telescope with the Far Ultraviolet (FUV) Spectrograph and the Extreme Ultraviolet (EUV) Spectrograph is the main payload. A secondary, but highly complementary payload is the Interstellar Medium Absorption Profile Spectrograph (IMAPS). In addition to the astronomy payloads, ORFEUS-SPAS carries the Surface Effects Sample Monitor (SESAM) and the Remote IMAX Camera System (RICS).

SCIENTIFIC OBJECTIVES

The ORFEUS-SPAS Mission is dedicated to astronomical observations at very short wavelengths, specifically the two spectral ranges Far Ultraviolet (FUV, 90-125 n.m) and Extreme Ultraviolet (EUV, 40-90 n.m). This part of the electromagnetic spectrum, which is obscured by the Earth's atmosphere for ground-based observations, bears among the highest density of spectral lines (especially from various states of hydrogen and oxygen), which are emitted or absorbed by matter of very different temperature.

ORFEUS-SPAS will add information to the understanding of the life-cycle of stars by observing some of the coldest (several degrees above absolute zero) and the hottest (more than one million degrees) matter found in our galaxy. Specific mission objectives are:

- Investigation of physical parameters in hot stellar atmospheres
- Investigation of cooling mechanisms of white dwarfs
- Determination of physical parameters of stellar accretion-disks, e.g. mass transfer rates, orbital parameters and velocity
- Shells associated with nova explosions and symbiotic stars
- Investigation of supernova remnants
- Investigation of the interstellar medium and potential star forming regions. In particular, determination of distance, density and temperature
- Studies of the intergalactic medium by observations of quasar spectra

Star formation is not yet completely understood. Stars are, however, known to be formed in dense clouds of interstellar gas and dust. Under gravitational contraction, these clouds can become dense enough to trigger star formation. ORFEUS-SPAS will observe the ultraviolet absorption lines associated with such clouds.

More generally, ORFEUS-SPAS will investigate absorption line spectra of hydrogen and other elements in a wide range of excitation states. Hydrogen is the main constituent of such clouds and can get optically excited by background star light. ORFEUS-SPAS data will allow determination of the size, distance, density and temperature of such clouds, which in turn, aids our understanding of the circumstances under which interstellar clouds collapse and new stars are born.

Once a star is formed, its evolution is mainly ruled by just one parameter, its mass. High mass stars burn energy, through nuclear fusion, more than 100,000 times faster than our sun. These processes give rise to bright ultraviolet emission and strong winds of hot ionized material. ORFEUS will study the surfaces and winds of such objects.

Low-mass stars like Earth's sun burn their energy reserves relatively slowly, not emitting large amounts of ultraviolet radiation. The outermost layers of their atmospheres can become very hot, however, due to turbulent convection which creates shock-waves. ORFEUS will measure ultraviolet spectra of such hot layers of relatively cold stars in order to contribute to an understanding of their physics.

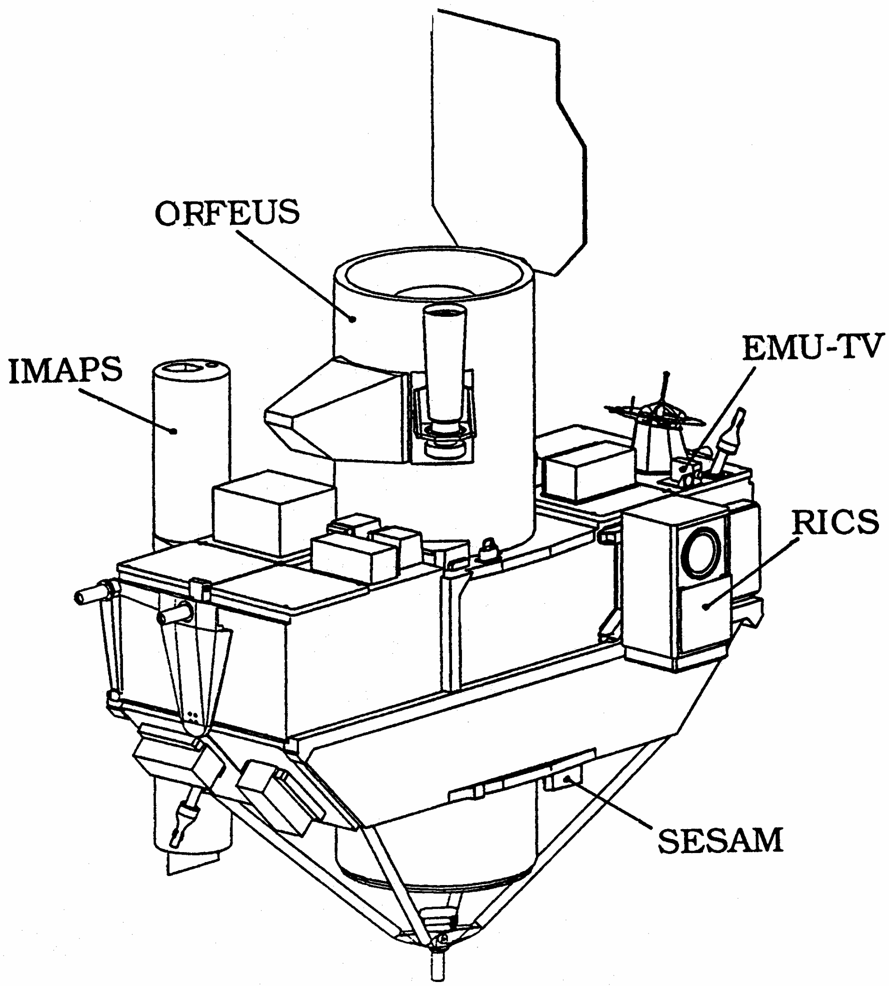
Most stars end up as compact white dwarfs. These stars take a very long time to cool down. During this time, they emit most of their energy in the ultraviolet wavelength range. Moreover, they are among the brightest EUV sources, which makes them perfect targets for ORFEUS-SPAS observations. ORFEUS data will contribute to a new understanding of the cooling mechanisms of white dwarf stars.

Once their energy reserves have been depleted, larger stars explode as supernovae and return their mass back to the interstellar medium. ORFEUS-SPAS is capable of tracing supernova remnants.

Under certain circumstances, the stars of binary systems can exchange material, forming hot accretion disks. ORFEUS observations are aimed at determination of mass exchange rates, orbital parameters and viscosity.

The physics of accretion disks is of particular interest in current astrophysical research, since there is good reason to believe that similar phenomena take place on a much larger scale in the centers of some galaxies, known as Active Galactic Nuclei (AGN). Massive black holes are believed to be surrounded by huge accretion disks. This may even be the case at the center of Earth's galaxy, the Milky Way. Dense dust clouds almost completely prevent direct observation of this region.

AGNs are inherently very bright, but because of the large distance from Earth, even the nearest ones appear very faint. Therefore, only the brightest AGN may be accessible to ORFEUS observations. Because little information is yet available on these exotic objects, even a single spectrum may lead to an important new understanding.


ORFEUS
IMAPS
EMU-TV
RICS
SESAM

THE SCIENCE PAYLOAD

The ORFEUS-SPAS science payload is provided by German and U.S. research institutions and funded through DARA and NASA.

The core instrument is the ORFEUS telescope with the FUV Echelle spectrometer and the EUV spectrometer, built into the telescope structure. The one meter diameter ultraviolet telescope has a 2.426 m focal length. An iridium coating on the primary mirror serves as a reflection enhancement for ultraviolet wavelengths. Essential stability against mechanical and thermal load deformations is provided by the carbon fiber epoxy compound tube structure.

The EUV spectrometer is directly exposed to light reflected off the main mirror. It covers the spectral range 40-115 n.m, offering a resolution of about 5000 over the whole bandwidth. In order to achieve this unprecedentedly high, resolution over such a wide band-width, a completely new design was used. A set of four novel gratings are the key to producing high quality spectra. The groove density of up to 6,000 lines per millimeter is not uniform, but varies over the gratings in a way which compensates for distortions introduced by their unusual location in the telescope beam. Novel detectors, allowing for the resolution of single photon events, can locate the distance between individual photons with a precision of about 30 micro-meter.

The FUV Echelle spectrometer is operated alternatively with the EUV spectrometer, by flipping a mirror into the beam reflected off the primary mirror. The FUV spectrometer covers the wavelength range 90-125 n.m and provides a spectral resolution on the order of 10,000. Two reflection gratings disperse the light into a spectrum, which is projected onto a two-dimensional micro channel-plate-detector. The detector is optimized for high spatial resolution.

IMAPS, the Interstellar Medium Absorption Profile Spectrograph is a separate instrument, attached to the ASTRO- SPAS framework. IMAPS was successfully flown on several sounding rocket missions. IMAPS will be operated for about 1 day during the ORFEUS-SPAS mission and during that time will observe the brightest galactic objects. IMAPS operates independently of the ORFEUS telescope. It covers the 95-115 n.m band and provides a resolution of about 240,000, which is by far the highest spectral resolution ever achieved by a space telescope. This resolution allows study of fine structure in interstellar gas lines. The individual motions of interstellar gas clouds can be determined to an accuracy of 1.6 km per second.

Another science payload is the Surface Effects Sample Monitor (SESAM), a passive carrier for state of the art optical surfaces and potential future detector materials. SESAM will investigate the impact of the space environment on materials and surfaces in different phases of a Space Shuttle mission, from launch, orbit phase to re-entry into the Earth's atmosphere. Among the SESAM samples are also witness samples to the telescope mirror, allowing for accurate calibration measurements after landing. Sample spaces are available to scientific and industrial users. Since SESAM is very efficient with respect to volume, weight and resources, it is envisaged for future ASTRO-SPAS missions as well.

The Remote IMAX Camera System (RICS) aboard ORFEUS-SPAS will take footage of the Shuttle during deployment and retrieval, to contribute to a motion picture. At the same time, RMS operations and the ORFEUS-SPAS satellite will be filmed by another IMAX camera aboard the shuttle.

The ASTRO-SPAS Carrier

ASTRO-SPAS is designed for up to 10 days of autonomous operation in the Shuttles vicinity, commanded by the mobile German SPAS Payload Operations Center (SPOC). To keep up with the extended mission capability of the Shuttle fleet, increasing the length of the ASTRO-SPAS operational phase is currently under investigation.
ASTRO-SPAS provides standardized equipment support panels, extensive onboard facilities and resources to scientific payloads. Energy is provided by a new powerful Li-SO_2 battery pack, which was space

qualified for ASTRO-SPAS. Precise attitude-control is achieved by a 3-axis stabilized cold gas system in combination with a star tracker and a specially developed space borne GPS receiver. The versatility of ASTRO- SPAS permits it to support experiments ranging from ultraviolet astronomy to infrared sensing of the Earth's atmosphere. Refurbishment between missions is achieved in less than a year.

THE SCIENCE PAYLOAD

Instrument	**Team Leader**	**Features**
Far Ultraviolet Spectrograph (FUV)	M. Grewing, G. Kraemer, Astronomisches Institut, Universitaet Tuebingen; I. Appenzeller, Landessternwarte, Heidelberg	Coverage of the 90-125 n.m wavelength range, spectral resolution of 10,000, Micro-channel Plate Detector with optimized spatial resolution
Extreme Ultraviolet Spectrograph (EUV)	S. Bowyer, M. Hurwitz, University of California at Berkeley, CA	Coverage of the 40-115 n.m wavelength range, spectral resolution of 5,000; detection of individual photons
Interstellar Medium Absorption Profile Spectrograph (IMAPS)	E. Jenkins, Princeton University, Princeton, N.J.	Coverage of 95-115 n.m wavelength range; spectroscopy of interstellar gas lines spectral resolution of about 240,000; sub-Doppler
Surface Effects Sample Monitor (SESAM)	D.-R. Schmitt, Deutsche Forschungs-anstalt fuer Luft- und Raumfahrt (DLR) Braunschweig	Carrier for optical samples to investigate degradation of surfaces and materials in space environment; 40 places for user provided samples

KEY SPACECRAFT CHARACTERISTICS

Total Weight	3,154 kg (1,905 kg available to science payload)
Dimensions	4.50 m (payload envelope), 2.50 m (front to rear)
Design Concept	Carbon fiber framework, modular equipment support panels support for a 1.2 m telescope
Power System	New modular Li-SO_2 battery pack with 10 kwh each, total of 40 kwh available to payload
Attitude Control	3-axis-stabilized cold gas system
Thrusters	12 nozzles of 100 mN thrust each
Attitude Verification	Precision star tracker and Global Positioning System (GPS) Receiver
Pointing Accuracy	Better than 5 arc seconds
Telemetry/	S-band link to Shuttle, utilizing NASA standard
Telecommand	Near Earth Transponder
Data Storage	Onboard tape recorder, 60 Gbit
Mission Control	Mobile Micro VAX based SPAS Payload Operations Center (SPOC) set up at KSC

Mission Control

ASTRO-SPAS mission control is provided by the SPOC ground station at KSC. The Shuttle is used as a relay station for the command and telemetry link. Real time telemetry data analysis and commanding is provided by the micro-VAX-based ground station. Science data are stored by an onboard tape recorder. Downlink of quick-look data is available.

Future ASTRO-SPAS Missions

The DARA/NASA ASTRO-SPAS program makes provisions for at least three more joint missions. The second mission, named CRISTA-SPAS (Cryogenic Infrared Spectrometers and Telescope for the Atmosphere), will be launched in 1994. A better understanding of the photo-chemistry and small scale dynamics of the Earth's-atmosphere are the main objectives of the CRISTA-SPAS mission.

A reflight of ORFEUS-SPAS is planned as the third ASTRO- SPAS mission. Increased mission duration and possibly improved instrument performance may allow for an extended extra-galactic observation program.

CRISTA-SPAS is planned to be reflown as the fourth ASTRO- SPAS mission. In addition, an Automated Rendezvous and Capture (ARC) mission, utilizing the ASTRO-SPAS carrier, may be flown later this decade as a joint project between the European Space Agency (ESA) and NASA. The ARC mission is designed to demonstrate automated rendezvous and capture technologies in support of the space station.

STS-51 ORFEUS/SPAS RENDEZVOUS OPERATIONS

The ORFEUS/SPAS will be released by Mission Specialist Dan Bursch using Discovery's mechanical arm on the second day of the mission.

While Bursch works with the arm to release the satellite, fellow crew member Jim Newman will oversee the mechanical operations of the ORFEUS instrument and the SPAS. The majority of commands to ORFEUS, however, will come from ground controllers.

Once Bursch has released the satellite, Commander Frank Culbertson will fire Discovery's small steering jets twice to separate from the vicinity of ORFEUS/SPAS, moving at least 13 nautical miles ahead of the satellite.

For ORFEUS/SPAS operations, science ground controllers require at least 1 1/2 hours of communications with ORFEUS/SPAS out of every 4 1/2 hours (three orbits). For these transmissions, Discovery must act as a relay station -- ground communications will reach ORFEUS/SPAS via Discovery and vice versa.

ORFEUS/SPAS will fly free of Discovery for almost 6 days. Discovery will move from being ahead of the satellite to trailing it the day before it is recaptured. The actual maneuvers to recapture the satellite will begin about 5 1/2 hours before ORFEUS/SPAS is captured, with Discovery trailing 30 n.m. behind the satellite. Discovery then will perform an engine firing to begin closing in on to a point 8 n.m. behind the satellite at a rate of about 11 n.m. per orbit. After two orbits and one fine-tuning burn once the ORFEUS/SPAS is in sight of the electronic star trackers on the Shuttle's nose, Discovery will reach the 8 n.m. point.

From 8 n.m., the final rendezvous sequence begins with the Terminal Intercept (TI) burn. The TI burn, occurring less than 2 hours before capture, will send Discovery on a final approach to ORFEUS/SPAS. As Discovery closes in, four mid-course correction firings will be done, if needed, with the Shuttle's small steering jets. The dish-shaped Ku-band antenna on the Shuttle will obtain a radar lock on the satellite.

About 1 hour, 10 minutes before capture, when Discovery is passing about 1 statute mile below ORFEUS/SPAS, Culbertson will take manual control of the rendezvous. Around that time, two laser ranging devices that measure distance and closing rate by bouncing a laser beam off of the satellite, will be used for navigation as well. One laser ranging unit is hand-held and will be pointed by Pilot Bill Readdy through the Shuttle cockpit window at ORFEUS/SPAS. A second laser ranging unit, being flown for the first time, mounted in the cargo bay of Discovery, will be remotely operated. These two units will supplement onboard radar information.

Culbertson will brake Discovery, flying with the control stick on the flight deck as it moves toward ORFEUS/SPAS, finally reaching a point a few hundred feet in front of the satellite. While Discovery is closing in, Bursch will extend the mechanical arm. With Culbertson moving Discovery to within 35 feet of ORFEUS/SPAS and holding position, Bursch will grapple the satellite and reberth it in the cargo bay for the trip back to Earth.

LIMITED DURATION SPACE ENVIRONMENT CANDIDATE MATERIALS EXPOSURE (LDCE)

The primary objective of the Limited Duration Space Environment Candidate Material Exposure (LDCE) is to introduce development composite materials to a flux atomic oxygen atoms in low-Earth orbit. The candidate materials-polymeric, coated polymeric, and light metallic composites will have undergone extensive ground based material performance testing prior to being attached to reusable test fixtures designed for multi- mission Space Shuttle use.

The LDCE, configuration C, consists of two standard 5- cubic-foot GAS cans with Motorized Door Assemblies (MDAs). A crewmember uses the Autonomous Payload Control System to control the payload

from the aft flight deck. The LDCE is a simple exposure experiment that utilizes an MDA on each can but does not contain any batteries or fluids.

CHROMOSOMES AND PLANT CELL DIVISION IN SPACE (CHROMEX-4)

Principal investigators: Dr. Abraham Krikorian, State University of New York at Stony Brook Dr. Mary Musgrave, Louisiana State University Dr. Norman Lewis, Washington State University

The upcoming flight of the CHROMEX-4 experiment is the fourth in a series of Life Sciences middeck experiments dealing with the growth of plants in microgravity.

The CHROMEX-4 payload consists of three scientific experiments. They are plant reproduction studies which are a reflight of the CHROMEX-3 experiment; plant cell developmental studies which carry the studies of CHROMEX-1 and CHROMEX-2 to another plant species; and cell wall formation and gene expression studies. The CHROMEX-4 payload also will provide the opportunity to evaluate a new nutrient support system developed at Washington State University.

The anticipated science benefits may lead to new strategies to manipulate and exploit the effect of gravity in plant growth, development, biochemistry and biotechnology. Such understandings will directly benefit the agriculture, horticulture and forestry industries which depend upon plant growth for their products.

The plants being studied on CHROMEX-4 are mouse-ear cress (Arabidopsis thaliana) and a strain of wheat (Triticum aestivum).

Arabidopsis is a small, fast-growing plant widely studied by plant scientists. It is found in the wild and cultivated for research. This plant will self pollinate during the 9-day mission and begin producing seeds. Dr. Musgrave will investigate the effects of the microgravity environment on seed production and seed forming structures of the plants.

Triticum is a superdwarf variety of wheat and has been widely studied among plant researchers. Root and shoot development, cell wall formation and gene expression studies are being conducted on these specimens by Drs. Krikorian and Lewis.

These plant specimens and their nutrient support systems are integrated with the Plant Growth Chambers (PGC) approximately 1 day before launch. The PCGs are loaded into the Plant Growth Unit (PGU). The PGU replaces one standard middeck locker and requires 28 volts of power from the orbiter. This hardware provides lighting, limited temperature control and data acquisition for post-flight analysis. The payload crew is required to perform nominal experiment activities consisting of a daily status check to monitor the PGU's systems' function.

Following the flight of these plants, the investigators will perform complete dissections of the entire plant structure and preserve the tissues by chemical fixation or flash freezing.

The PGU was developed by NASA. The experiment is sponsored by NASA's Office of Life and Microgravity Sciences and Applications.

STS-51 EXTRAVEHICULAR ACTIVITY

STS-51 crewmembers Carl Walz and Jim Newman will perform a 6-hour extravehicular activity (EVA), or spacewalk, on the fifth day of the mission as a continuation of a series of test spacewalks NASA is conducting to increase experience with spacewalks and refine spacewalk training methods.

Walz will be designated extravehicular crew member 1 (EV1) and Newman will be EV2. Pilot Bill Readdy will serve as the intravehicular (IV) crew member inside Discovery, supervising the coordination of spacewalk activities in the Shuttle's cargo bay.

In addition to performing tasks that investigate a spacewalker's mobility in general, Walz and Newman will evaluate several tools that may be used during the servicing of the Hubble Space Telescope (HST) later this year on mission STS-61, including a power socket wrench, a torque wrench, foot restraint, safety tethers and tool holder.

Unlike Shuttle mission STS-57, the astronauts will not use the 50-foot long robot arm during the spacewalk, since it will be important for use several days after the spacewalk to retrieve the ORFEUS-SPAS satellite. Walz and Newman will spend part of their time outside Discovery testing various types of rigid and semi-rigid tethers as well as moving up and down the bay carrying each other, evaluating how well spacewalking astronauts can maneuver in weightlessness with a large object.

Other tests include an evaluation of how well an astronaut must be restrained in weightlessness to apply a large amount of tightening to a bolt using the tools provided. In addition, the spacewalkers will use a large tool onboard Discovery for use in case of a problem with the ACTS/TOS satellite's deployment to evaluate methods of using bulky tools.

As is the rule with the test spacewalks, the STS-51 EVA will be one of the lowest priorities of the flight, subject to cancellation if needed due to a problem with one of the primary payloads. It is planned with a minimum of extra equipment flown on Discovery, making optimum use of materials already aboard for other purposes.

The planned spacewalk will be the third such test spacewalk this year. Previous spacewalk tests were conducted on STS-54 in January and STS-57 in June. NASA plans to continue adding spacewalks to Shuttle flights when they can be performed without interference to the primary activities onboard. The STS-51 spacewalk is the final test EVA planned for 1993. The spacewalks planned for STS-61 in December will be performed to service the HST and not for test purposes.

RADIATION MONITORING EQUIPMENT-III (RME-III)

The Radiation Monitoring Equipment-III (RME-III) measures ionizing radiation exposure to the crew within the orbiter cabin. RME-III measures gamma ray, electron, neutron and proton radiation and calculates in real time exposure in RADS-tissue equivalent. The information is stored in a memory module for post-flight analysis.

The hand-held instrument is stored in a middeck locker during flight except for when the crew activates it and replaces the memory module every two days. RME-III will be activated by the crew as soon as possible after they achieve orbit and it will operate throughout the mission. A crew member will enter the correct mission elapsed time upon activation. ME-III is sponsored by the Department of Defense in cooperation with NASA.

AIR FORCE OPTICAL SITE (AMOS)

This geophysical environmental study will test ground based optical sensors. The experiment will also examine contamination/exhaust plume phenomena using the Space Shuttle as a calibration target.

AURORA PHOTOGRAPHY EXPERIMENT-B (APE-B)

The mission objectives of the Aurora Photography Experiment-B (APE-B) are to photograph the airglow aurora, auroral optical effects, the Shuttle glow phenomenon and thruster emissions in the imaging mode of photography as well as in the Fabry-Perot and spectrometer modes of photography.

COMMERCIAL PROTEIN CRYSTAL GROWTH (CPCG)

The Commercial Protein Crystal Growth (CPCG) payload is designed to conduct experiments which supply information on the scientific methods and commercial potential for growing large high-quality protein crystals in microgravity. The CPCG payload consists of Commercial Refrigerator/Incubator Modules (CR/IM's) and their contents.

There are two possible configurations for this experiment, Block I and Block II. This experiment is configured in Block II configuration for the STS-51 mission, in which the CR/IM contents consist of four cylinder containers of the same diameter but different volumes. The four cylinders are 500 mm, 200 mm, 100 mm and 20 mm. Depending on the specific protein being flown, the temperature is either lowered or raised in up to a five-step process over Flight Day 1 and 2.

One CR/IM occupies the space of one middeck stowage locker. Orbiter 28V dc power is provided to the CPCG CR/IM via single power cables from a standard middeck outlet. The CPCG experiment is installed at the pad within launch minus 24 hours.

HIGH RESOLUTION SHUTTLE GLOW SPECTROSCOPY (HRSGS-A)

The High Resolution Shuttle Glow Spectroscopy-A (HRSGS-A) is an experimental payload designed to obtain high resolution spectra in the visible and near visible wavelength range (4000 angstroms to 8000 angstroms) of the Shuttle surface glow as observed on the orbiter surfaces which face the velocity vector while in low Earth-orbit. The spectral resolution of the spectrograph is 2 angstroms and it is hoped this will help identify the cause of the Shuttle glow. The HRSGS-A will look at the vertical tail, Orbital Maneuvering System Pod or a suitable alternative.

IMAX

The IMAX payload is a 70 mm motion picture camera system for filming general orbiter scenes. The system consists of a camera, lenses, rolls of film, two magazines with film, an emergency speed control, a Sony recorder and associated equipment, two photographic lights, supporting hardware in the form of mounting brackets to accommodate the mode of use, two cables and various supplemental equipment.

The IMAX and supporting equipment are stowed in the middeck for in-cabin use. The IMAX uses two film magazines which can be interchanged as part of the operation. Each magazine runs for approximately 3 minutes. When both magazines are consumed, reloading of the magazines from the stowed supply of film is required. Lenses are interchanged based on scene requirements. The IMAX will be installed in the orbiter middeck approximately 7 days prior to launch.

INVESTIGATION INTO POLYMER MEMBRANES PROCESSING (IPMP)

The research objectives of the IPMP is to flash evaporate mixed solvent systems in the absence of convection to control the porosity of a polymer membrane. Two experimental units will be flown. Each unit will consist of two 304L stainless steel sample cylinders connected to each other by a stainless steel packless valve with an aluminum cap. Before launch, the two larger canisters are evacuated and sealed with threaded stainless steel plugs using a Teflon(tape threading compound.

In the smaller units, a thin film polymer membrane is swollen in a solvent compound. The film is rolled up and inserted into the canisters. The small canisters are sealed at ambient pressure (approximately 14.7 psia). The valves are secured with Teflon(tape.

The locker containing the IPMP payload will be installed in the orbiter during the period from L-6 to L-3 days.

STS-51 CREWMEMBERS

STS051-S-002 -- STS-51 CREW PORTRAIT -- These five NASA astronauts have been assigned to fly aboard the space shuttle Discovery for the STS-51 mission, scheduled for July. Left to right are astronauts Frank L. Culbertson, Jr., mission commander; Daniel W. Bursch and Carl E. Walz, mission specialists; William F. Readdy, pilot; and James H. Newman, mission specialist.

PHOTO CREDIT: NASA or National Aeronautics and Space Administration.

BIOGRAPHICAL DATA

Frank L. Culbertson Jr., 44, Capt., USN, will command STS-51. Selected as an astronaut in 1984, Culbertson will be making his second space flight and considers Holly Hill, SC, his hometown.

Culbertson graduated from Holly Hill High School in 1967 and received a bachelor of science in aerospace engineering from the Naval Academy in 1971.

After serving aboard the USS Fox in the Vietnam War, Culbertson was designated a Naval aviator in 1973 and, from 1974-1976, he served as an F-4 Phantom pilot aboard the USS Midway. Subsequently, he was assigned as an exchange pilot with the Air Force, serving as a weapons and tactics instructor at Luke Air Force Base, Ariz., until 1978. His next assignment was as the catapult and arresting gear officer aboard the USS John F. Kennedy. In 1982, he graduated with distinction from the Naval Test Pilot School and, subsequently, served as a test pilot in the Carrier Systems Branch. He was engaged in fleet replacement training in the F-14A Tomcat in 1984 until his selection by NASA.

Culbertson's first shuttle flight was as pilot of STS-38, a Department of Defense-dedicated mission in November 1990. He has logged more than 117 hours in space, more than 4,500 hours flying time in 40 different types of aircraft and 450 carrier landings.

William F. Readdy, 41, will serve as pilot. Selected as an astronaut in 1987, Readdy will be making his second space flight and considers McLean, Va., his hometown.

Readdy graduated from McLean High School in 1970 and received a bachelor of science in aeronautical engineering from the U. S. Naval Academy in 1974.

Readdy was designated a Naval aviator in 1975. From 1976- 1980, he served as an A-6 pilot aboard the USS Forrestal. He graduated from the Naval Test Pilot School in 1981. His Navy assignments included the Strike Aircraft Test Directorate, instructor duty at the Naval Test Pilot School and strike operations officer aboard the USS Coral Sea.

In 1986, Readdy accepted a reserve commission from the Navy to join NASA as a research pilot and aerospace engineer at JSC. Prior to his selection as an astronaut, he served as program manager for the Shuttle Carrier Aircraft.

Readdy's first flight was on STS-42, the first flight of the International Microgravity Lab (IML), in January 1992. Readdy has logged more than 193 hours in space and more than 5,500 hours flying time in 50 types of aircraft, including more than 550 carrier landings.

James H. Newman, 36, will be Mission Specialist 1 (MS1). Selected as an astronaut in 1990, Newman will be making his first space flight and considers San Diego, Calif., his hometown.

Newman graduated from La Jolla High School, San Diego, in 1974; received a bachelor of arts in physics from Dartmouth College in 1978; and received a master's and doctorate in physics from Rice University in 1982 and 1984, respectively.

Newman performed post-doctoral work at Rice in atomic and molecular physics and was appointed an adjunct assistant professor in the Department of Space Physics in 1985. He later joined NASA, serving as a simulation supervisor for astronaut training at the time of his selection

BIOGRAPHICAL DATA

Daniel W. Bursch, Commander, USN, will be Mission Specialist 2 (MS2). Selected as an astronaut in January 1990, Bursch will be making his first space flight and considers Vestal, NY, his hometown.

Bursch graduated from Vestal Senior High School in 1975; received a bachelor of science in physics from the Naval Academy in 1979; and received a master's in engineering science from the Naval Postgraduate School in 1991.

Bursch was designated a Naval flight officer in 1979 and was assigned to Attack Squadron 34 as a bombardier/navigator in the A-6E Intruder. He graduated from the Naval Test Pilot School in 1984 and later returned to the school as a flight instructor. Later, he was assigned as strike operations officer for Commander, Cruiser Destroyer Group One. He had just completed work at the Naval Postgraduate School at the time of his selection by NASA.

He has logged more than 1,800 flying hours in 35 types of aircraft.

Carl E. Walz, 37, Major, USAF, will be Mission Specialist 3 (MS3). Selected as an astronaut in January 1990, Walz will be making his first space flight and was born in Cleveland.

Walz graduated from Charles F. Bush High School, Lyndhurst, Ohio., in 1973; received a bachelor of science in physics from Kent State University in 1977; and received a master's in solid state physics from John Carroll University in 1979.

Commissioned in the Air Force, from 1979-1982, Walz was assigned as radiochemical project officer with the 1155th Technical Operations Squadron at McClellan Air Force Base, Calif. He graduated as a flight test engineer from the Air Force Test Pilot School in 1983. From 1983-1987, Walz was assigned to the F-16 Combined Test Force, and in 1987 he was assigned as a flight test program manager at Det. 3, Air Force Flight Test Center, where he served at the time of his selection by NASA.

STS-51 MISSION MANAGEMENT

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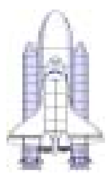
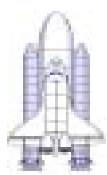
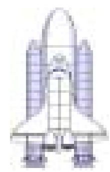
Klaus Steinberg	ORFEUS-SPAS Project Manager
Rolf Densing	ASTRO-SPAS System Scientist
Wolfgang Frings	ASTRO-SPAS Representative at NASA-JSC
Franz-Peter Spaunhorst	Head of Public Affairs Office
Rudolf Teuwsen	ASTRO-SPAS Public Affairs Manager

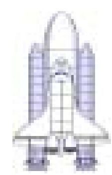
SHUTTLE FLIGHTS AS OF JULY 1993

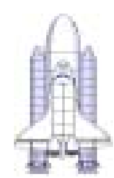
56 TOTAL FLIGHTS OF THE SHUTTLE SYSTEM -- 31 SINCE RETURN TO FLIGHT











		STS-56 04/08/83 - 04/17/93		
		STS-53 12/02/92 - 12/09/92		
STS-55 04/26/93 - 05/06/93		STS-42 01/22/92 - 01/30/92		
STS-52 10/22/92 - 11/01/92		STS-48 09/12/91 - 09/18/91		
STS-50 06/25/92 - 07/09/92		STS-39 04/28/91 - 05/06/91	STS-46 07/31/92 - 08/08/92	
STS-40 06/05/91 - 06/14/91		STS-41 10/06/90 - 10/10/90	STS-45 03/24/92 - 04/02/92	
STS-35 12/02/90 - 12/10/90	STS-51L 01/28/86	STS-31 04/24/90 - 04/29/90	STS-44 11/24/91 - 12/01/91	
STS-32 01/09/90 - 01/20/90	STS-61A 10/30/85 - 11/06/85	STS-33 11/22/89 - 11/27/89	STS-43 08/02/91 - 08/11/91	
STS-28 08/08/89 - 08/13/89	STS-51F 07/29/85 - 08/06/85	STS-29 03/13/89 - 03/18/89	STS-37 04/05/91 - 04/11/91	
STS-61C 01/12/86 - 01/18/86	STS-51B 04/29/85 - 05/06/85	STS-26 09/29/88 - 10/03/88	STS-38 11/15/90 - 11/20/90	
STS-9 11/28/83 - 12/08/83	STS-41G 10/05/84 - 10/13/84	STS-51-I 08/27/85 - 09/03/85	STS-36 02/28/90 - 03/04/90	
STS-5 11/11/82 - 11/16/82	STS-41C 04/06/84 - 04/13/84	STS-51G 06/17/85 - 06/24/85	STS-34 10/18/89 - 10/23/89	
STS-4 06/27/82 - 07/04/82	STS-41B 02/03/84 - 02/11/84	STS-51D 04/12/85 - 04/19/85	STS-30 05/04/89 - 05/08/89	STS-57 06/21/93 - 07/01/93
STS-3 03/22/82 - 03/30/82	STS-8 08/30/83 - 09/05/83	STS-51C 01/24/85 - 01/27/85	STS-27 12/02/88 - 12/06/88	STS-54 01/13/93 - 01/19/93
STS-2 11/12/81 - 11/14/81	STS-7 06/18/83 - 06/24/83	STS-51A 11/08/84 - 11/16/84	STS-61B 11/26/85 - 12/03/85	STS-47 09/12/92 - 09/20/92
STS-1 04/12/81 - 04/14/81	STS-6 04/04/83 - 04/09/83	STS-41D 08/30/84 - 09/05/84	STS-51J 10/03/85 - 10/07/85	STS-49 05/07/92 - 05/16/92
OV-102 Columbia (14 flights)	**OV-099 Challenger (10 flights)**	**OV-103 Discovery (16 flights)**	**OV-104 Atlantis (12 flights)**	**OV-105 Endeavour (4 flights)**