National Aeronautics and Space Administration

NASA Sounding Rockets

2007 Annual Report

Sounding Rocket launch Kwajalein Atoll, 2004 to study mesospheric instabilities.

Cover: Black Brant XI, 12.064 Hickman, taking off from Wallops Island. Small images represent types of science conducted with sounding rockets; atmospheric sciences, geophysics, heliophysics and astrophysics.

The NASA Sounding Rockets Program has completed another active and successful year. It supported a wide variety of scientific teams on missions studying plasma, solar and cosmic physics, and deep space objects. The program also supported development efforts that will enable new suborbital, orbital, and planetary missions in the future. The program's unique mobile ability facilitates worldwide launches, anytime, anywhere; and takes full advantage of specialized scientific instruments, developed to capture phenomena which occur at a specific time and place in space. Many of the 2007 missions featured increased payload complexity and expanded flight operations. Future missions being planned and designed for the coming year promise even more exciting challenges and significant rewards for the scientific community. This first annual report–offers some brief insights into the scientific missions, development efforts, and the educational and workforce development projects supported by the NASA Sounding Rockets Program, as well as a forecast of challenges "on the horizon."

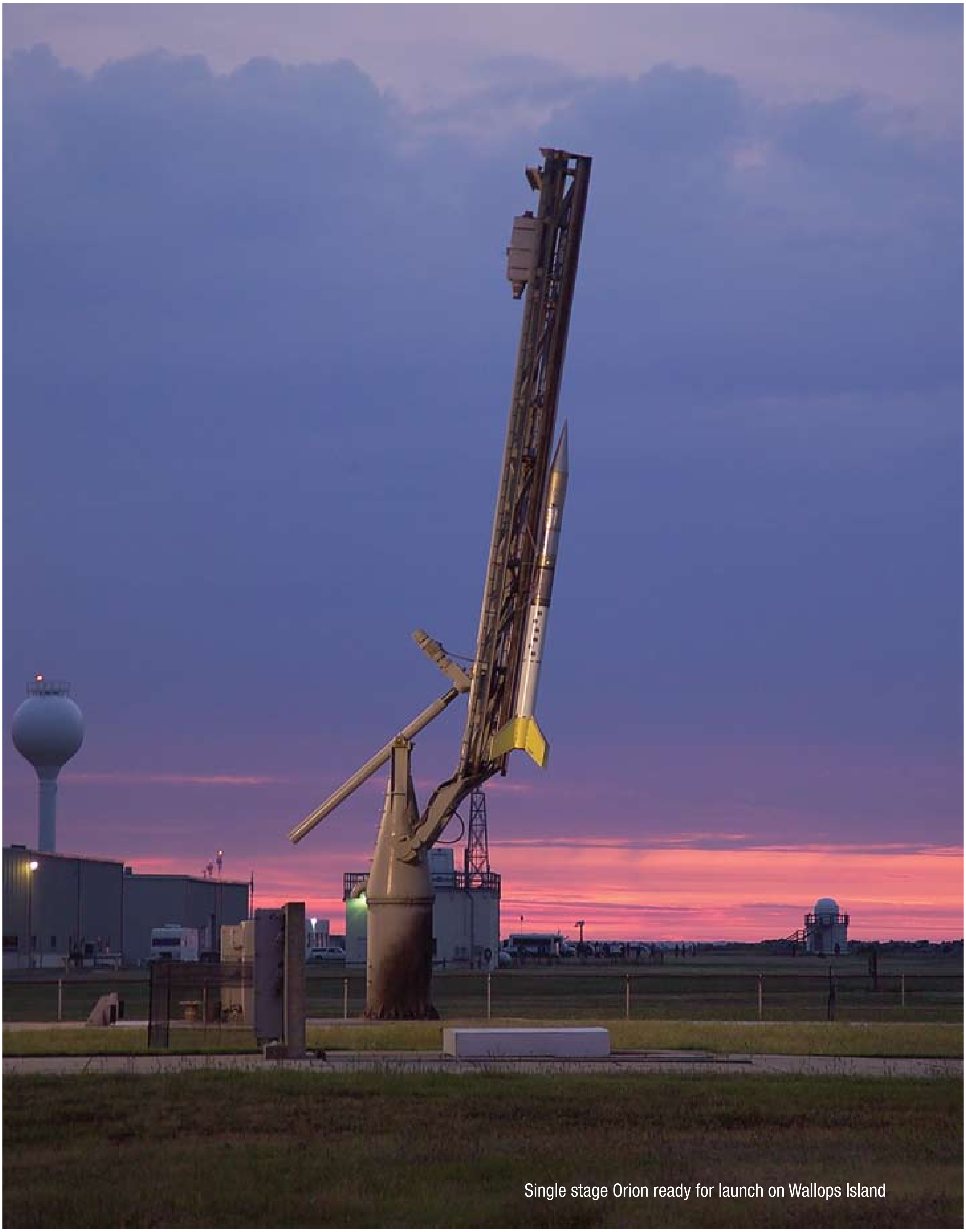
Phil Eberspeaker

Chief Sounding Rockets Program Office

Sounding Rockets Program – Annual Report 2007

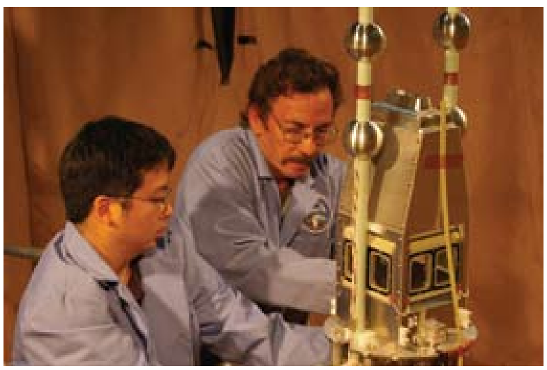
Terrier–Orion launch from Norway

Rockets ready to launch at Poker Flat, Alaska



Single stage Orion ready for launch on Wallops Island

Ultra Light Weight mirror post vibration at Wallops



MASS payload at Wallops

Payload in spin/balancing facility at Wallops

Introduction

The Sounding Rockets Program supports NASA's Science Mission Directorate's strategic vision and goals for Earth Science, Heliophysics and Astrophysics. The 20+ suborbital missions flown annually by the program provide researchers with unparalleled opportunities to build, test, and fly new instrument and sensor design concepts while simultaneously conducting world-class scientific research. Coupled with a hands-on approach to instrument design, integration and flight, the short mission life-cycle helps ensure that the next generation of space scientists receive the training and experience necessary to move on to NASA's larger, more complex space science missions. The cost structure and risk posture under which the program is managed stimulates innovation and technology maturation and enables rapid response to scientific events.

With the capability to fly higher than many low Earth orbiting satellites and the ability to launch on demand, sounding rockets offer, in many instances, the only means to study specific scientific phenomena of interest to many researchers. Unlike instruments onboard most orbital spacecraft or in ground-based observatories, sounding rockets can place instruments directly into regions where and when the science is occurring to enable direct, in-situ measurements. The mobile nature of the program enables researchers to conduct missions from strategic vantage points worldwide.

Executive Summary

Sounding Rockets Support NASA's Strategic Vision and Goals

NASA strategic objectives for Earth Science, Heliophysics, and Astrophysics are supported by core science missions conducted by the Sounding Rockets Program. Sounding rockets are also used to support other strategic objectives of NASA such as Aeronautical research and low-cost test beds for Exploration.

Single stage Orion lift–off from Wallops Island.

2007 Missions and Accomplishments

Ten science investigations involving 17 vehicles were launched in 2007:

- The Poker Flat campaign, January - February 2007, included ten vehicles with four distinct science objectives.
- Several telescope missions were launched from White Sands Missile Range in New Mexico. The new Celestial Attitude Control System (CACS) performed exceptionally well during its first operational flight on the Long-Slit Imaging Dual Order Spectrograph (LIDOS) mission.
- Two payloads were flown from Andoya Rocket Range in Norway for the MASS mission, which measured properties of Noctilucent Clouds (NLCs). These launches were coordinated with the AIM (Aeronomy of Ice in the Mesosphere) satellite and were part of an international collaborative research campaign that included other launches.

New Program Capabilities

Several new capabilities were implemented in 2007. As noted above, CACS was tested and successfully flown on its first operational mission. A tailored trajectory allowing nearly horizontal flight was successfully accomplished for only the second time using a new and improved ACS. Additionally, the S-19 guidance system was upgraded with a new guidance sensor, and the program's launch capability was enhanced with refurbishment of the new Athena Launcher, which was subsequently installed in Norway.

Education & Workforce Development

Sounding rockets provide opportunities for a wide range of students from undergraduates to PhD candidates and Post Docs. Career opportunities range from engineering to scientific research and development with industry, academia, and government. New flight opportunities for undergraduate students are under development.

On The Horizon

New vehicles, several campaigns, new sub-systems, and hypersonic research support are on the horizon for the Sounding Rocket program.

Program Statistics

Program statistics presented graphically depict variables such as, the flight history, vehicle stable and other important quantifiable aspects of the program.

Sounding Rockets Support NASA's Strategic Goals

NASA Strategic Plan Sub-goal 3B: Understanding the Sun and its effect on Earth and the solar system.

NASA's Strategic Plan Sub-goal 3C: Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.

NASA's Strategic Plan Sub-goal 3D: Discover the origin, structure, evolution and destiny of the universe, and search for Earth like planets.

NASA's Strategic Plan Sub-goal 3E: Advance knowledge in the fundamental disciplines of aeronautics, and develop technologies for safer aircraft and higher capacity airspace.

Heliophysics and Earth Sciences

Heliophysics support includes launches to study the fundamental processes connecting the Sun and Earth. The solar corona is studied with Extreme UV and X-ray telescope payloads. In-situ measurements of the ionosphere are conducted with Sounding Rocket instruments flown from launch sites around the world. Arctic launch sites support the study of Noctilucent clouds and Polar Mesospheric Summer Echos (PMSE), as well as studies associated with the Aurora Borealis.

Astrophysics

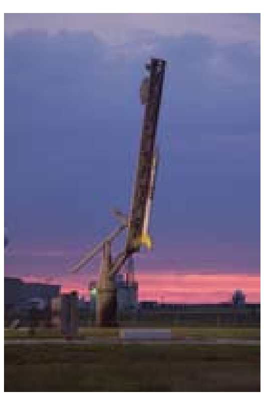
In the high energy and the ultraviolet and visible part of the spectrum, Astrophysics utilizes sounding rockets for testing of new instruments and for unique observational science missions.

Aeronautics

Sounding rockets contribute to NASA's aeronautics program by providing high-speed test beds for fundamental aeronautical research. Sounding rockets provide a realistic hypersonic flight test environment for new materials, shapes and aeronautical concepts.

Planetary Sciences

Studies of planetary and cometary atmospheres have been conducted with sounding rockets.



Sub–SEM ready to launch, June 2006

Sub–SEM launch, June 2005

Terrier–ASAS motor test round, June 2005

Black Brant XI launch, September 2006

science missions – 2007

In 2007 the Sounding Rockets Program Office (SRPO) supported 10 science research missions, with a total of 17 vehicles, in five different disciplines. A winter campaign in Poker Flat, Alaska included ten vehicles to study various aspects of the aurora. The MASS mission launches from Norway were correlated with a pass of the new Aeronomy of Ice in the Mesosphere (AIM) satellite.

Light weight mirror pre–integration testing.

Rocket Observations of Pulsating Aurora (ROPA) launch, Poker Flat, Alaska 2007.

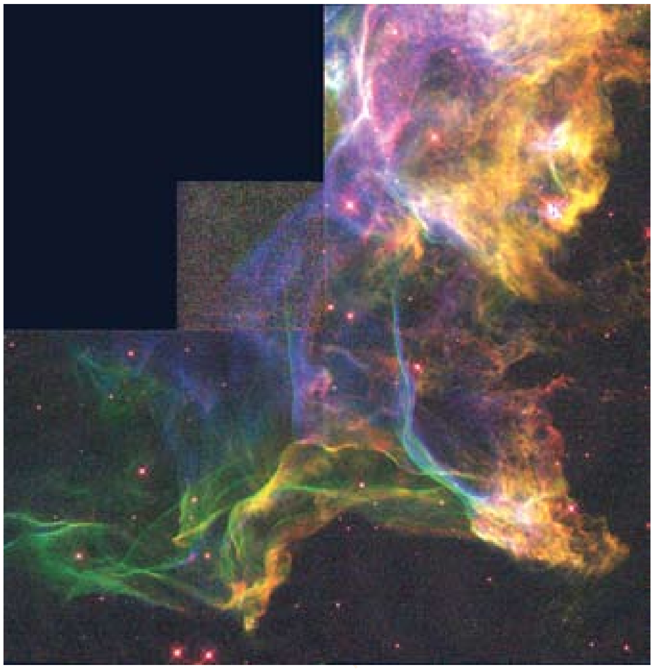
Cygnus X–ray Emission Spectroscopic Study (CyXESS)

Mission: 36.224 UH
Discipline: High Energy Astrophysics
Principal Investigator: Dr. Webster Cash
Institution: University of Colorado/LASP

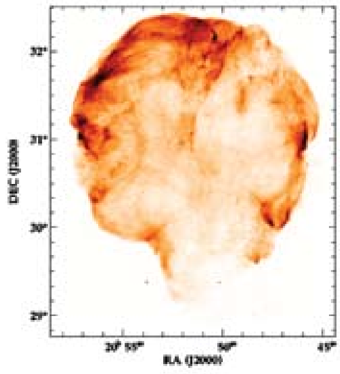
The scientific goal of this sounding rocket was to obtain x-ray spectral diagnostics of a nearby extended supernova remnant, the Cygnus Loop. The Cygnus Loop is the quintessential middle aged, shell structured supernova remnant.

Understanding the relationship that supernovae have with their environments is crucial when considering everything from interfaces between different phases of the ISM to star formation to energy and matter feedback in galaxies and clusters.

The CyXESS instrument addresses the structure and dynamics of supernova remnants and the hot phase of the interstellar medium. The CyXESS can obtain physical diagnostics of the galactic halo and possibly even detect emission from the intergalactic medium.



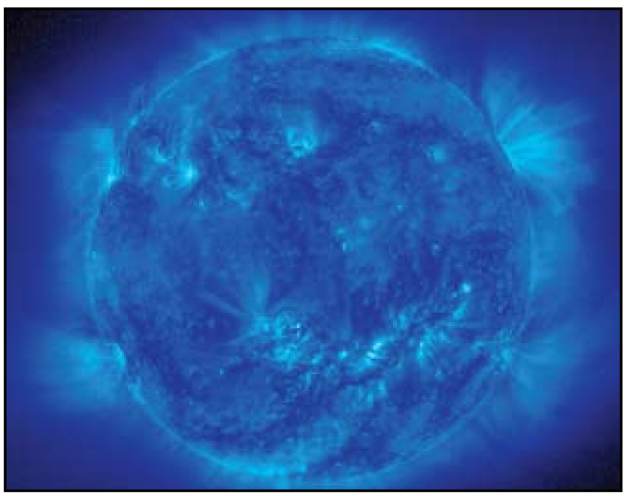
Hubble Space Telescope image of the Cygnus Loop



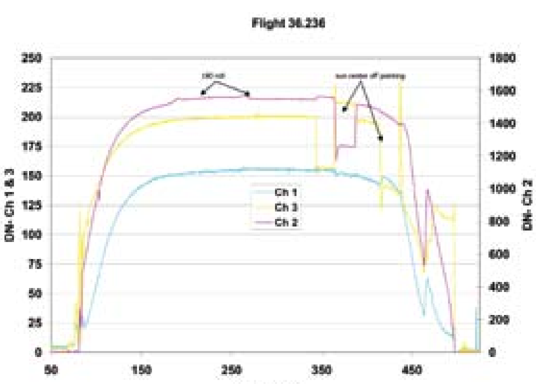
ROSAT X–ray image of the Cygnus Loop

Rocket Underflights for SOHO Cross–Calibration & Solar Atmosphere

Mission: 36.236 US
Discipline: Solar & Heliophysics
Principal Investigator: Dr. Darrell Judge
Institution: University of Southern California



SOHO Eit image of the Sun



Data from 36.236 US

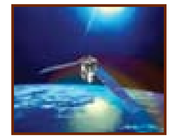
Rocket underflights for SOHO cross-calibration and solar atmosphere investigations constitute a multi-year program to provide the absolute solar flux in the extreme ultraviolet (EUV) wavelength region. The data obtained will provide calibration data for the Solar Heliospheric Observer (SOHO) Solar EUV Monitor (SEM).

This flight presented a unique opportunity to provide cross-calibration of three EUV instruments and a continuous calibration record between SOHO-SEM, TIMED-SEE, and the upcoming SDO-EVE instruments.

The payload was a re-flight of 36.227 US that was successfully launched and recovered on August 3, 2005, from White Sands Missile Range, NM.

The science objectives for this mission included:

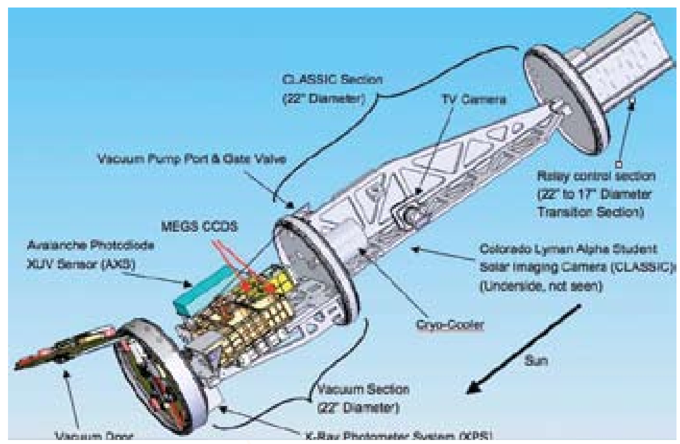
- Measurement, distribution and publication of accurate absolute solar EUV Irradiance data in support of the SOHO mission.
- Analysis and interpretation of the solar EUV data for the purpose of improving global solar atmospheric models and to enhance our understanding of solar variability.
- Measurement of the Solar EUV input to Earth's atmosphere resulting in increased understanding of the consequences of the changing flux on atmospheric density and ionization.



TIMED SEE Calibration Experiment

Mission: 36.233 UE
Discipline: Geospace Sciences
Principal Investigator: Dr. Tom Woods
Institution: University of Colorado/LASP

The primary objective for this mission was to provide an underflight calibration for the Solar EUV Experiment (SEE) aboard the NASA Thermosphere-Ionosphere-Mesosphere-Energetics-Dynamics (TIMED) satellite. The TIMED satellite was launched in December 2001. The Sounding Rocket payload 36.192 was launched in February 2002 as the first SEE calibration measurement. Two additional underflight calibrations of the TIMED satellite were completed in 2003 and 2004 with the launch of 36.205 and 36.217, respectively



Sounding Rocket payload 36.233

Solar extreme ultraviolet (EUV: 0-120 nm) irradiance impacts the physics of the mesosphere, thermosphere and ionosphere; because this broad range of radiation is mostly deposited in the upper atmosphere, it provides the energy to form and maintain the ionosphere, and to control the dynamics (winds) and photochemistry of the thermosphere. The TIMED SEE investigation has been providing the first daily measurements of the solar EUV irradiance since the late 1970s. In order to establish the solar irradiance variation over the long-term, prototype SEE instruments were developed to measure underflight calibrations.

Rocket Observations of Pulsating Aurora (ROPA)

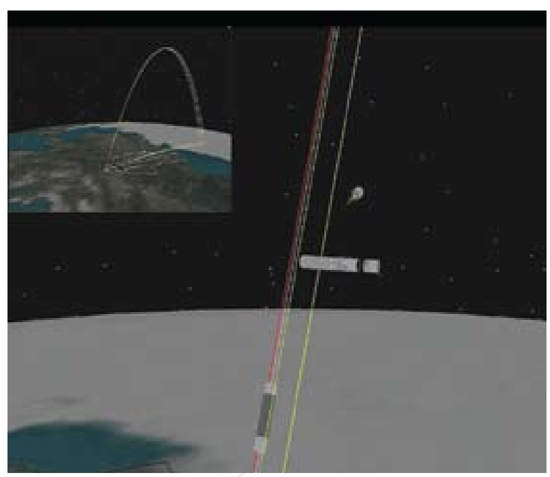
Mission(s): 40.020 UE
Discipline: Geospace Sciences
Principal Investigator: Dr. Marc Lessard
Institution: University of New Hampshire

ROPA Black Brant XII launch

The primary objectives of the ROPA mission were:

- To acquire large-scale, topside images of a pulsating auroral region for comparison to other in-situ data and to optical data from ground observations;
- To investigate current closure associated with pulsating patches.

Two Fly Away Detectors (FADs) were incorporated to obtain information about pulsating aurora over an extended region. Each FAD included a science-grade magnetometer, a GPS receiver, and a HEEPS (tophat) electron detector. The FADs had small rocket motors to achieve separation velocities of a minimum of~15-20 m/s to provide simultaneous, multipoint observations with separations in the order of 7-10 km (a significant fraction of typical patch sizes) at apogee. Surplus Star retro rockets, developed for the Mars Lander program, were used to propel the sub-payloads



40.020 UE Mission Planning Lab simulation

A simulation of the Lessard 40.020 UE mission was conducted at the Mission Planning Lab (MPL) at Wallops Flight Facility. The MPL, developed by the Real Time Software Branch, enables visualization of flight trajectories and payload events such as deployments, Attitude Control System (ACS) operation, and as with the Lessard mission, FAD deployments.

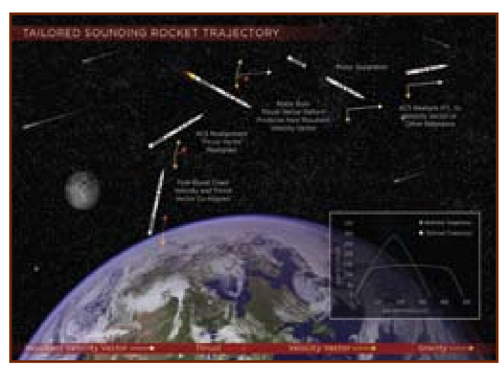
HEX–2

Mission(s): 35.037, 41.061, 41.062 & 41.063 UE
Discipline: Geospace Sciences
Principal Investigator: Dr. John Craven
Institution: University of Alaska

The HEX-2 mission included four rockets to measure all terms in the atmospheric mass continuity equation for the first time. All four payloads were launched in 15-minute launch window. The HEX-2 mission objectives were driven by results obtained from its precursor, HEX-1, launched in 2003, and by the need to examine the relative importance of various terms in the continuity equation. Using a combination of rockets and various ground-based diagnostics facilities, these investigations may provide answers to the physical processes at work in driving compositional mixing within the lower thermosphere.

The first rocket, a Black Brant X, delivered a two-part payload into a nearly horizontal trajectory with a nominal apogee of 158-km. This type of Tailored trajectory is a relatively new capability provided by the SRPO that enables unique scientific research. The following three rockets placed identical two-part payloads into conventional steep trajectories suitable for releasing six near-vertical chemical trails between 80- and 180-km altitudes to make near simultaneous measurements of the neutral winds over a wide area of the arctic region over central Alaska.

HEX–2 Lift–off from Poker Flat, Alaska



Tailored Trajectory illustration

Joule–2

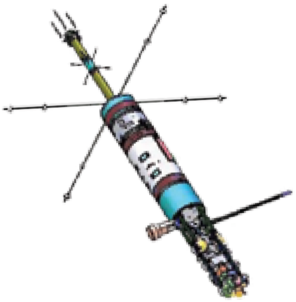
Mission(s): 21.138, 36.224, 41.064 & 41.065 UE
Discipline: Geospace Sciences
Principal Investigator: Dr. Miguel Larsen
Institution: Clemson University

Four rockets (one Black Brant, one Terrier-Black Brant and two Terrier Orions) were launched to study Joule heating in the ionosphere during an active aurora above Fairbanks, Alaska in January.

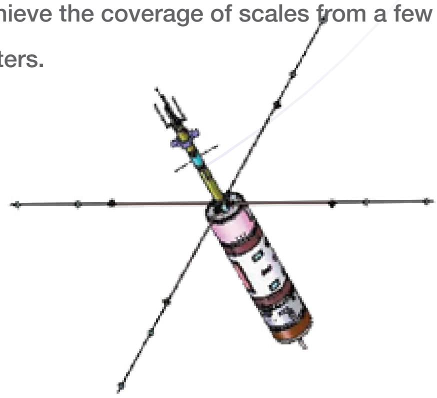
Four rockets ready to launch at Poker Flat, Alaska

Joule heating is critical to the dynamics, electrodynamics, and chemistry of the high-latitude region. Each instrumented rocket was paired with a chemical release rocket and flown along the same azimuth to map out the gradients in the neutral winds and their effect on the local heating rates as a function of altitude and horizontal distance. The primary measurements from the instrumented rockets were vertical profiles and horizontal variations in the electron densities and the horizontal variations in the electric fields.

By combining the in situ rocket measurements with measurements from a high-resolution coherent scatter radar interferometer, the AMISR incoherent scatter radar, ground-based photometers, magnetometers, and the SuperDARN radars the scientists were able to achieve the coverage of scales from a few meters to several hundred kilometers.



Payload 36.224 Terrier–Black Brant



Payload 21.138 Black Brant

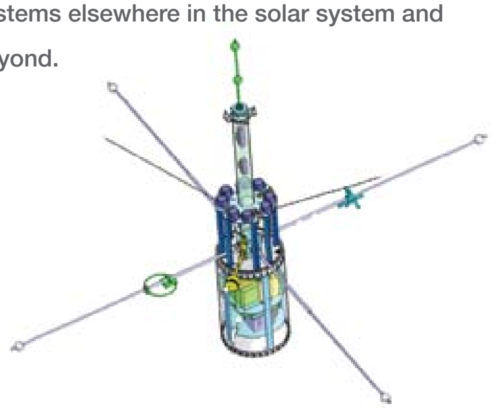
Correlation of High Frequencies and Auroral Roar Measurements (CHARM)

Mission(s): 40.019 UE
Discipline: Geospace Sciences
Principal Investigator: Dr. James Labelle
Institution: Dartmouth College

The CHARM rocket experiment was designed to answer several of the outstanding questions about the physics of high-frequency waves in the Earth's aurora. It was also designed to enhance our understanding of the dynamical role of Langmuir and upper hybrid waves, and the mechanisms and characteristics of resulting electromagnetic radiation.

By including sophisticated measurements of correlations between Langmuir waves and auroral electrons of various energies, this experiment will directly test theoretical predictions of wave growth, electron bunching, and resulting wave evolution. The experiments included in the CHARM payload were designed to significantly advance knowledge of high-frequency emissions in the Earth's aurora and, by extension, in analogous beam-plasma systems elsewhere in the solar system and beyond.

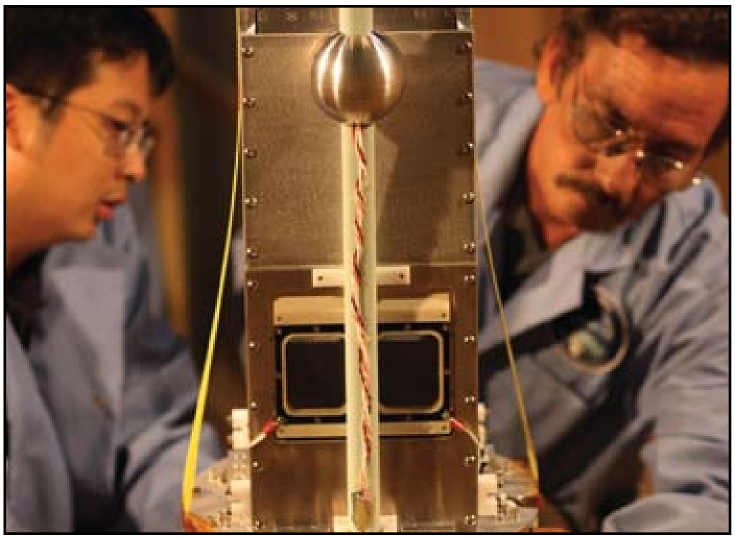
CHARM payload on the spin/balance table.



The CHARM payload engineering drawing.

Mesospheric Aerosol Sampling Spectrometer (MASS)

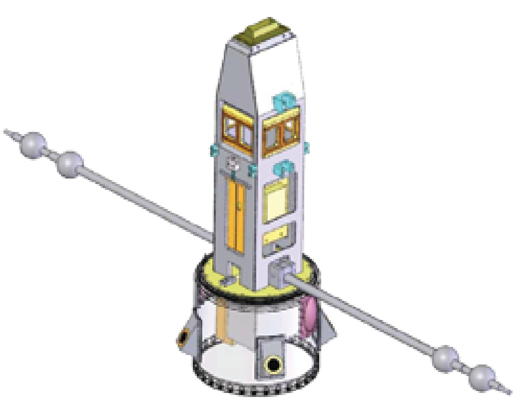
Mission(s): 41.069 & 41.070 UE
Discipline: Geospace Sciences
Principal Investigator: Dr. Scott Robertson
Institution: University of Colorado/CISP



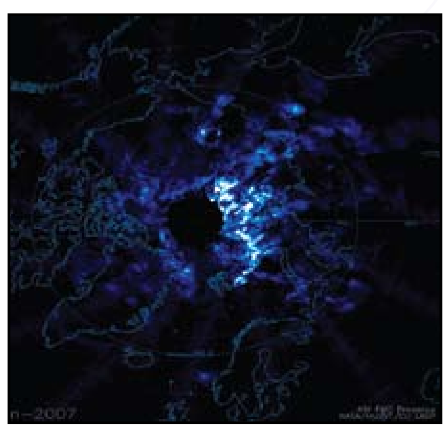
MASS payload prepared for spin/deployment

The frequency, brightness and spatial coverage of noctilucent clouds (NLCs) are of increased interest since they were suggested as a “miner’s canary” for global change. NLC formation involves the presence of water vapor, nucleation sites and cold temperatures. Questions remain about the size distribution of precursor particles, their coupling to electrons and ions, and their relationships to Polar Mesospheric Summer Echoes (PMSEs) and anomalously large electric fields.

Launched in 2007, the AIM (Aeronomy of Ice in the Mesosphere) satellite was designed to observe and measure the formation and variability of noctilucent clouds by remote sensing. To complement its measurements, two rockets were launched from Andoya, Norway, in the summer NLC season of 2007. The rockets were instrumented for in situ observations of charged and neutral aerosol particles and electric fields. The MASS launches were coordinated with the German-Norwegian ECOMA (Existence and Charge State of Meteoric Smoke Particles in the Middle Atmosphere) rockets, which had similar science objectives.



MASS payload rendering

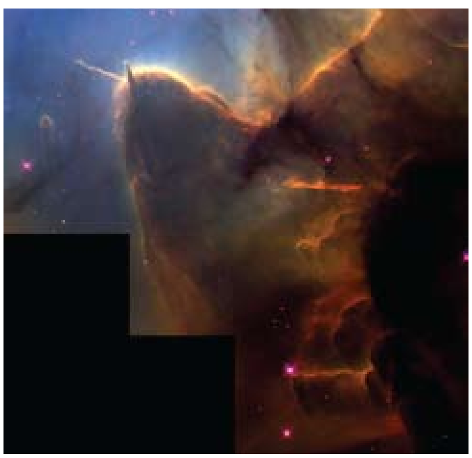


Noctilucent Clouds imaged by the AIM satellite.

Long–Slit Imaging Dual Order Spectrograph (LIDOS)

Mission(s): 36.220 UG
Discipline: UV/Optical Astrophysics
Principal Investigator: Dr. Stephen McCandliss
Institution: Johns Hopkins University

The LIDOS instrument was launched from White Sands, NM with a Black Brant IX Sounding Rocket. LIDOS investigated the relationship between the far-ultraviolet scattering and extinction properties of dust and molecular hydrogen (H2). This flight observed the Trifid Nebula (M 20), to measure the spectra of its exciting stars and the surrounding gas and dust, and to account for the total luminous output of the nebula in the far-ultraviolet.



Hubble Space Telescope image of the Trifid Nebula

The LIDOS mission incorporated the new Celestial Attitude Control System (CACS). CACS provides sub-arc-second pointing capability allowing precise alignment with the object under study. Additionally, observation times are increased and the command uplink, for pitch, yaw and roll control, allows for real-time adjustments of the payload pointing.

CACS airbering test.

Inflatable Reentry Vehicle Experiment (IRVE)

Mission(s): 41.055 NP
Discipline: Special Project
Principal Investigator: Player
Institution: NASA Langley Research Center

IRVE fully inflated

IRVE before inflation

IRVE was the first in a series of flight tests designed to develop and validate an inflatable decelerator ballute concept. The conceptual testing of the inflatable decelerator will be conducted in a stair-step manner with future test building on the previous test.

IRVE is intended to demonstrate inflation and survivability at a realistic dynamic pressure and ballistic coefficient. Follow on flights will demonstrate survivability and performance at relevant heating and relevant vehicle size.

IRVE stowed

The mission objectives for the IRVE series are to:

- Execute flight-tests that demonstrate inflation and survivability at a relevant dynamic pressure.
- Assess the performance of the vehicle from a thermal and structural dynamics perspective.
- Validate the analysis and design techniques used in the development of the Reentry Vehicle.

new capabilities

Launch capability was enhanced with the installation of the Athena launcher in Norway. New and upgraded sub–systems and new capabilities placed in service include: Celestial Attitude Control System (CACS), S19L boost guidance system and an ability to fly more accurate tailored trajectories.

A four stage Black Brant XII lifts off from the newly installed Athena launcher in Norway.

New Program Capabilities

Celestial Attitude Control System (CACS)

The new Celestial Attitude Control System was flight demonstrated to achieve better than 0.2 arcsec, 1 sigma and 0.5 arcsec Full Width at Half Maximum (FWHM) pointing precision for each axis. Key components of this new ACS include a roll stabilized fiber optic gyro; a precision fiber optic gyro; a cold gas linear thrust module; a pitch, yaw and roll uplink command system; and a 3 axis star tracker.

The Celestial Attitude Control System airbearing test.

In addition to providing gyro drift compensation, the star tracker provides celestial reference through its Lost in Space (LIS) solution. The maneuver algorithm employed rotates the pointing axis of the payload along a great circle to science targets. The successful flight test of this system, developed in house, enabled the payload science team to study the Trifid Nebula in the far-Ultra Violet (UV). Time to target was much shorter with this new system and increased science observation time. A re-fly mission is scheduled to study the Orion Nebula also in the far-UV. Additionally, flights to study cosmic background radiation and to test a nulling interferometer designed to detect exo-planets, are planned for the future.

GPS Velocity Vector Attitude Control System

The NSROC Inertial Attitude Control System (NIACS) was modified to accept GPS inputs and perform computations and control solutions to allow the payload to remain aligned with the velocity vector throughout the entire flight. This system also permits attitude corrections during payload events such as sub-payload and main boom deployments, and main payload attitude control after boom deploy.

Raw payload position and velocity are provided by the GPS. The computer uses the GPS information to determine a refined velocity vector for the target. The computer also determines the attitude solution and, based on the mission plan, determines thruster firings to achieve the desired payload attitude. The GPS-based Velocity Vector Input to NIACS has been flown five times to date; this included one development validation flight and four science missions. This system was critical to the MASS missions launched from Norway in August 2007.

Tailored Trajectory

A horizontal trajectory, using the more accurate NIACS, was flown on the Craven 35.037 (Black Brant X) Sounding Rocket mission. This was the first in a series of four launches to measure all components of the atmospheric continuity equation.

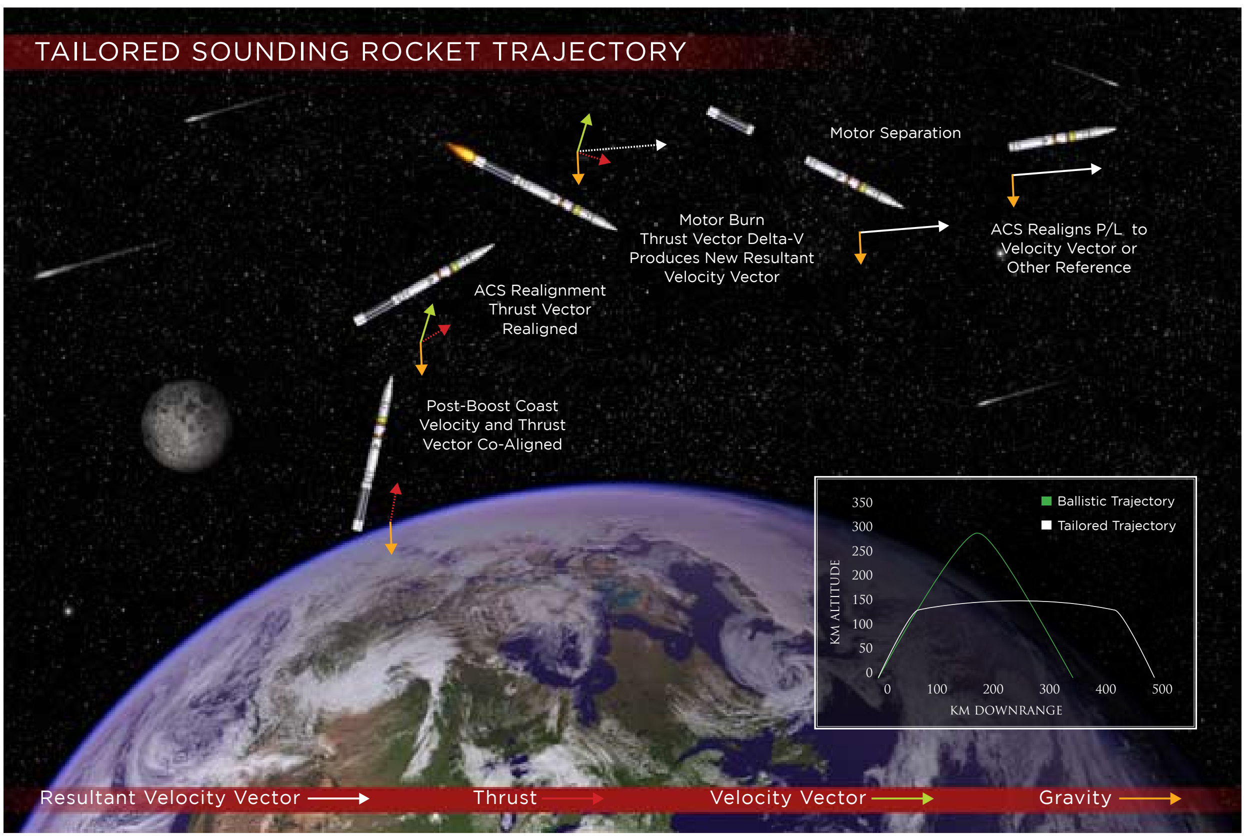


Illustration of tailored trajectory flight.

For the Craven mission the mother-daughter payload and the third stage Nihka were reoriented prior to Nihka ignition. Nihka ignition occurred at around 110-km altitude. This provided additional horizontal velocity needed to achieve the near-horizontal tailored trajectory for the science portion of the flight. At approximately 160-km altitude, a 200-km TMA chemical trail was deployed nearly horizontally across a region of active aurora.

This new and improved, near horizontal trajectory option expands the envelope for science investigations using sounding rockets and allows longer flight times in a specific science region of the atmosphere.

Athena launcher installation in prog–ress at Andoya Rocket Range, Norway (above). Launcher leaving Wallops Island (right).

New Launch Capability in Norway

To enhance launch capability and to support NASA's largest sounding rocket vehicles, the Athena launcher was refurbished at Wallops then shipped, reassembled and installed at Andoya Rocket Range. The launcher was used for the MASS mission in August 2007, and will be crucial in supporting the TRICE missions. The Trice missions will require near simultaneous launch of two Black Brant XII vehicles in December 2007.

Upgraded S-19L Guidance System

The S19 boost guidance system significantly reduces impact dispersion and enables flights from locations with limited impact areas, such as White Sands Missile Range in New Mexico. Over 200 sounding rockets have flown with this system.

The S19L is the fourth generation guidance system and includes significant gyro and processor upgrades. The strapped down LN 200 Fiber Optic Gyros used in the S19L are far more accurate and reliable than their predecessors. The gyros remain active throughout flight, providing additional attitude information for post flight analysis of payload position during mission and re-entry.

Black Brant X launch from White Sands Missile Range, NM with an S19 boost guidance system.

education & workforce

Michael Shimogawa, graduate student at University of Washington preparing one of the MASS payloads for spin/deployment tests at Wallops.

Sounding rockets provide numerous opportunities for students, ranging from new undergraduate flight opportunities to doctorate level research. Scientists with sounding rocket experience are successful competitors for satellite flight opportunities.

Scott Knappmiller, graduate student at University of Colorado, working with Dr. Zoltan Sternovsky on one of the MASS payload.

NSROC engineering intern Nate Empson working on the LeClair payload.

Mike Larson, graduate student University of Iowa and Chris Colpitts graduate student Dartmouth College working on one of the TRICE payloads.

Education & Workforce development

For decades, the Sounding Rockets Program has provided hands-on training opportunities for scientists, graduate and undergraduate students, engineers, and technicians. These early experiences in developing sensors, instruments, and other subsystems for spaceflight are invaluable to gaining an understanding of what it takes to fly instruments in the unforgiving environment of space. The short mission life cycle coupled with the design-build-fly nature of the program ensures exposure to all facets of spaceflight.

Professors, Post Docs, and PhD candidates from within NASA, other government organizations, and academic institutions are all currently working on instruments which will be flown in the near future on a Sounding Rocket mission. The knowledge gained through this direct hands-on experience helps to ensure that a steady pipeline of scientists, researchers and engineers are prepared to take on the next challenges of NASA's scientific research programs. Sounding Rocket Principal Investigators are frequently selected as instrument PIs on satellite programs such as the Radiation Burst Storm Probes (RBSP), currently under development. The two instrument PIs on this project began their research on Sounding Rocket missions.

The NASA Sounding Rocket Operations Contract (NSROC) has developed a successful intern and co-op program. To date, 86 undergraduate and graduate students from ten different universities have participated. Over 10% of the students have been hired by NSROC as full time employees; 18 have obtained or are currently pursuing advanced engineering degrees and several others are working in related industries.

University Student Experiment Ride Share (USERS)

Geared toward undergraduate students, the USERS program is currently in the development stage. A pilot program has been initiated to evaluate the viability of this program as a cost-effective means of increasing exposure to sounding rocket technology across academia. USERS will allow up to four universities to build, test, and fly experiments on a single mission. A university with prior launch experience will be competitively selected through a proposal submission and review process to serve as USERS Integrator. The Integrator will be responsible for coordination, payload design, and initial integration of all payload experiments. One Terrier-Orion flight per year from Wallops Island is planned for this project.

on the horizon

Two campaigns, Norway 2008 and Poker Flat 2009, are in process. New vehicle systems under devel–opment include a Mesospheric Dart and a two–stage Terrier–Improved Malemute. Additionally, hypersonics support, technology payloads, and new upgraded support systems are on the horizon.

On the Horizon

TRICE payload in the magnetic calibration facility at Wallops.

SCIFER–2 in the spin/deployment facility at Wallops.

Campaigns: Norway FY 08

Three Black Brant XII vehicles will be launched from Andoya Rocket Range in Norway during the 2007 - 2008 auroral season. The new Athena launcher will enable the Twin Rockets Investigating the Cusp Electrodynamics (TRICE) mission to launch two Black Brant XII rockets in very close sequence. SCIFER-2 which is also a Black Brant XII will launch after the TRICE mission is completed.

The TRICE mission will be initiated with the launch of a Black Brant XIII (TRICE-HIGH), with a predicted apogee greater than 1150 km. Approximately two minutes later another Black Brant XII (TRICE-LOW), will be launched at lower elevation so that it achieves an apogee of 400 km at approximately the same time TRICE-HIGH reaches apogee. TRICE will study the ionosphere signatures of reconnection in order to better understand the temporal/spatial nature of reconnection. Reconnection research is very active, but the ability to make high resolution in-situ measurements in near-Earth space plasmas, using sounding rockets, offers unique insight into the process. The signatures of magnetic reconnection are often observed in satellite data, but these data are limited in interpretation because of the spatial-temporal ambiguity of single spacecraft measurements. The Principal Investigator for TRICE is Dr. Craig Kletzing, University of Iowa.

Sounding of the Cusp Ion Fountain Energization Region-2 (SCIFER-2) is scheduled for launch from Andoya Rocket Range in Norway following the TRICE launches. The SCIFER-2 mission will study ion outflows between 200 and 1400 km in the polar cusp. In addition to the rocket, two EISCAT radars (Svalbard and Tromsø) will be used to monitor ion flows under the rocket apogee for comparison with the sounding rocket data and to determine the launch conditions. The Principal Investigator for SCIFER-2 is Dr. Paul Kintner, Cornell University.

Beamformer, developed by JEM Engineering, being pre–pared for testing at Wallops.

Campaigns: Poker Flat FY 09

Eight missions have been selected for flight from Poker Flat, Alaska during the auroral season January - March 2009. Participating organizations include University of Iowa, Dartmouth College, Clemson University and University of Alaska. The scientific investigations will study several facets of Auroral electrodynamics. Additionally a student outreach mission will be launched in support of the University of Alaska project.

Sub-TEC II

The Sub-TEC technology demonstration initiative serves to improve technical capabilities of the Sounding Rocket Program and other users by providing a standardized carrier platform to flight demonstrate new technologies. Sub-TEC payloads provide opportunities for multiple experiments and organizations to share the cost of a flight test mission. The Sub-TEC II 2008 flight includes a Phased Array Antenna/Beamformer, developed by JEM Engineering under NASA's Small Business Innovative Research (SBIR) Program. Other Sub-TEC II components and instruments provided by NSROC include a Miniature PCM Encoder and Pyro Control System, Sun Sensors, Horizon Crossing Indicator, micro/miniature real time attitude solution (RTAS) unit, and Next Generation GPS

New Vehicle Systems

A Mesospheric Dart, based on the Multiple Launch Rocket System (MLRS) M26 motor, is under development. The M26 is a military surplus motor and the Dart is designed and manufactured at Wallops Flight Facility.

Predicted flight performance indicates altitudes around 95 km with a 50 lb dart are possible. Several test flights are scheduled to confirm the performance envelope of the system, as well as flight qualify sub-systems and payload electronics.

This new capability is a cost effective solution to many science disciplines requiring in-situ measurements at altitudes up to 95 km. Instruments deemed feasible for launch with the Mesospheric Dart include:

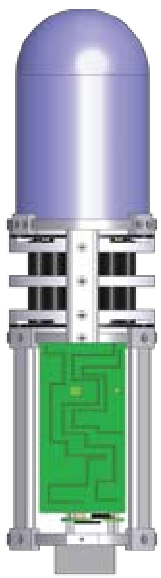
- Chemical Release payloads
- Electric Field Booms,
- Langmuir Probes
- Photometers
- Radiometers

Mesospheric Dart

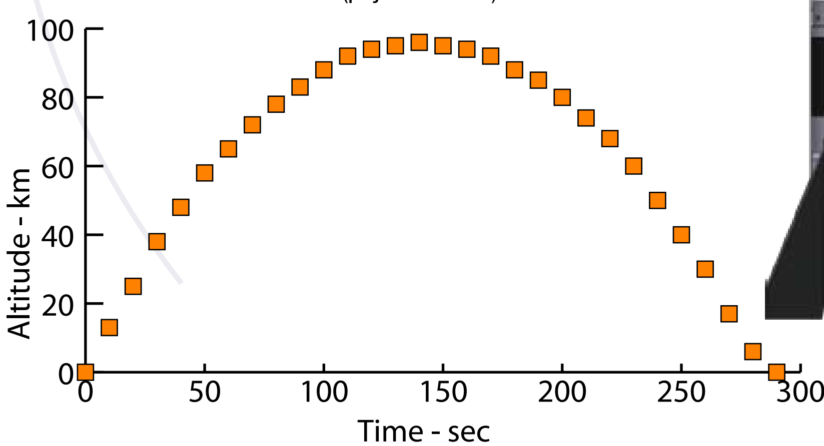
Length: 58 inches
Total weight: 51 lbs
Diameter: 4 inches

Experiment Volume: 34 in^3
Experiment diameter: 3.5 in
Experiment Weight: 7 lbs

Avionics suite:
PCM system
32 channel TM
3–axis Magnetometer
3–axis Accelerometer
14 V , 5 Amp NiMH
battery pack



Estimated preliminary performance
(payload 50 lbs)



Terrier–Malemute in Kwajalein 2004.

HyBolt on the vibration table at Wallops.

SCRAMP – Typical geometry

- Robin Spheres
- Meteor Dust Collection
- Aerosol & Gas Sampling

A Terrier-Improved Malemute motor stack is being evaluated for future use based on the recent availability to the SRPO of a new surplus upper stage motor. This vehicle shows promise as an enhancement to the existing fleet with a performance close to the single stage Black Brant V. Payloads between 600 and 1200 pounds can be launched to altitudes of 150 to 300 km. This vehicle, which features reduced wind sensitivity and smaller impact dispersions, is well suited for hypersonic research, re-entry test flights and other missions with high Mach number requirements.

Flight Termination System

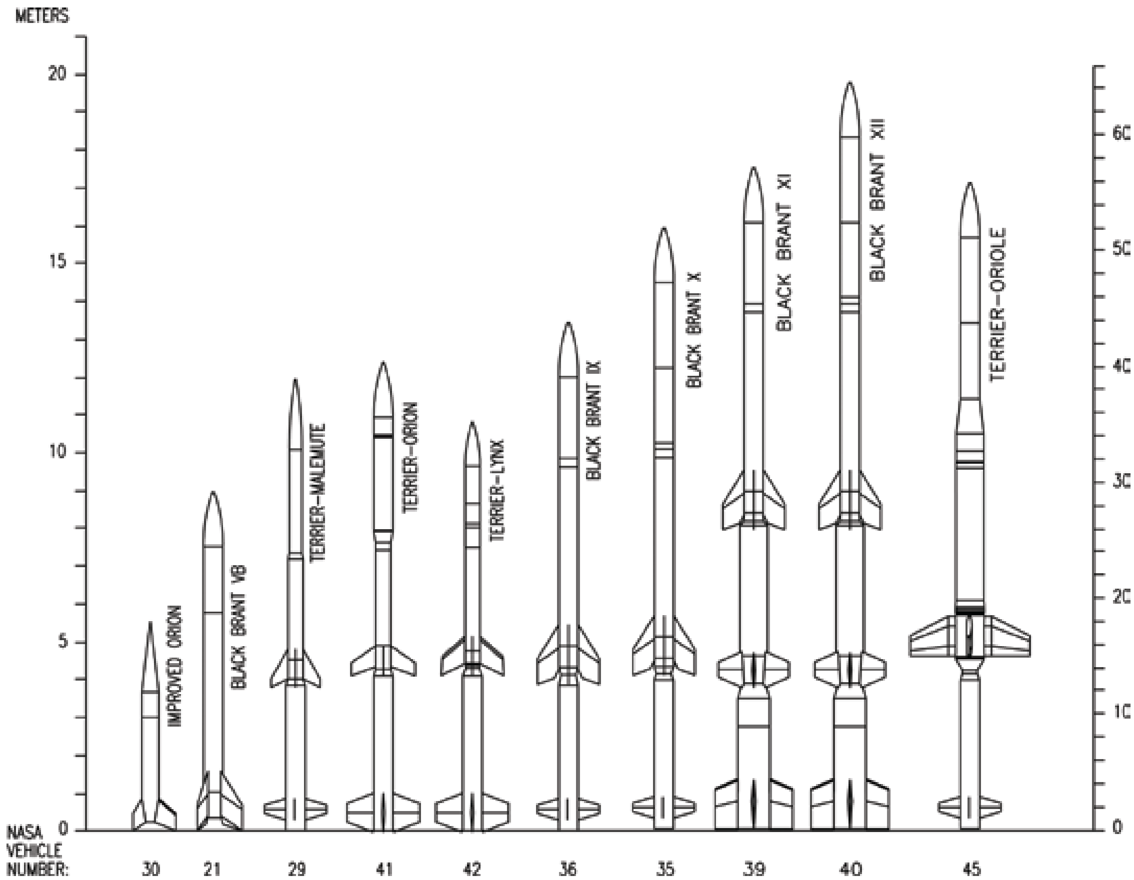
Black Brant IX flights from White Sands Missile Range and shaped mission trajectories require a Flight Termination System (FTS). A new next generation FTS, compliant with the redundancy requirements of the Range Commanders Council, Range Safety Group, is under development. Preliminary component selection has been completed and the components will be evaluated based on environmental data collected for Black Brant MK1 motor.

Hypersonics Support

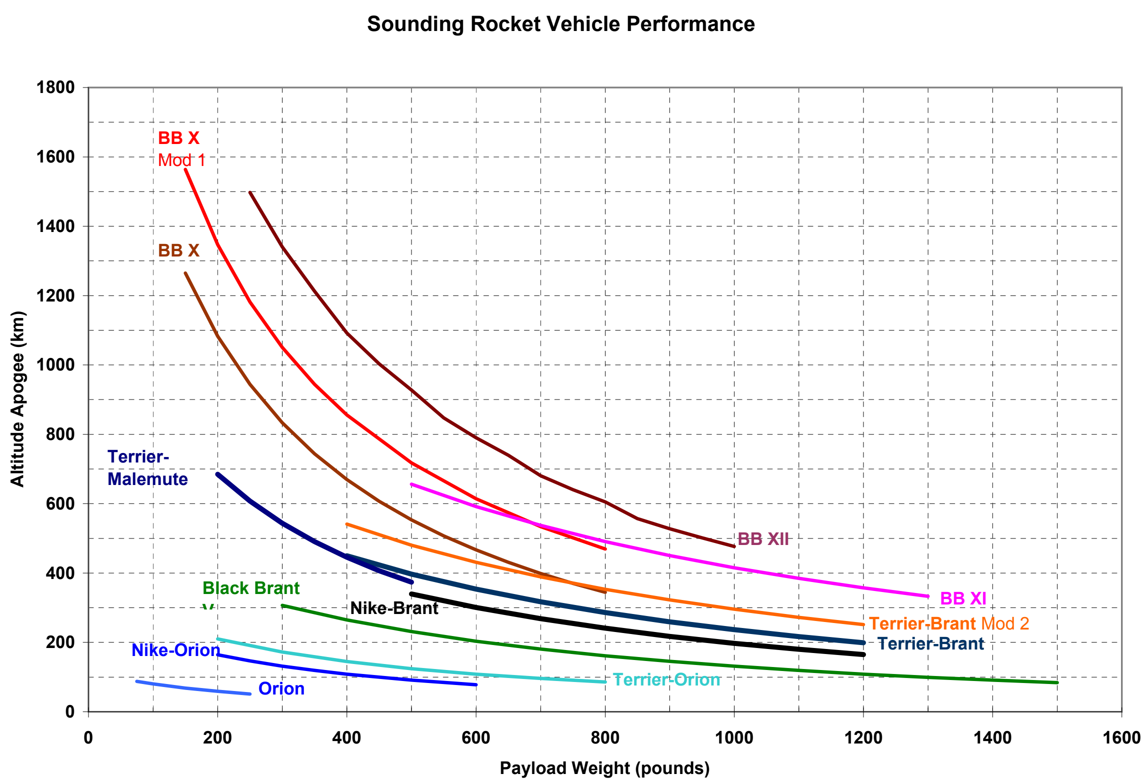
Several hypersonics projects are supported by SRPO and NSROC. Environmental testing and engineering support is being provided for the HyBolt experiment team. HyBolt will be launched onboard the ATK ALV-X1 vehicle. The HyBolt experiment will measure boundary layer transition location, fluctuation intensity, disturbance frequencies, and propagation speed and direction. A roughness experiment will provide confirmation of the relative effectiveness of several representative tip configurations. Included in the first ATK ALV-X1 launch is an experiment from NASA Ames. This non-traditional entry probe configuration is introduced as the SCRAMP, or Slotted Compression RAMP probe.

Another Inflatable Re-entry Vehicle Experiment (IRVE) flight is anticipated in the future. The IRVE ballute experiments provide valuable data for future planetary entry missions requiring high speed re-entry. Sounding rockets provide a functional test bed for these types of experiments.

program statistics



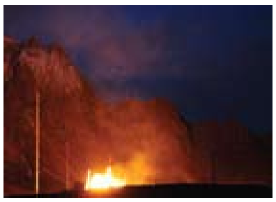
Ten vehicles ranging from a single stage Orion to a four stage Black Brant XII make up the core of the Sounding Rockets Program. New vehicles, the MLRS–Dart and Terrier–Improved Malemute will be added in the near future. Above: relative scale of the currently available vehicles. Below: Vehicle performance altitude vs. payload weight.



Poker Flat, Alaska

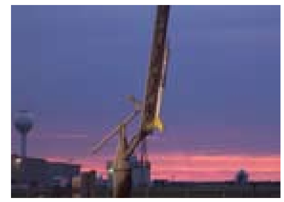
Esrange, Sweden

Kwajalein, Marshall Is.

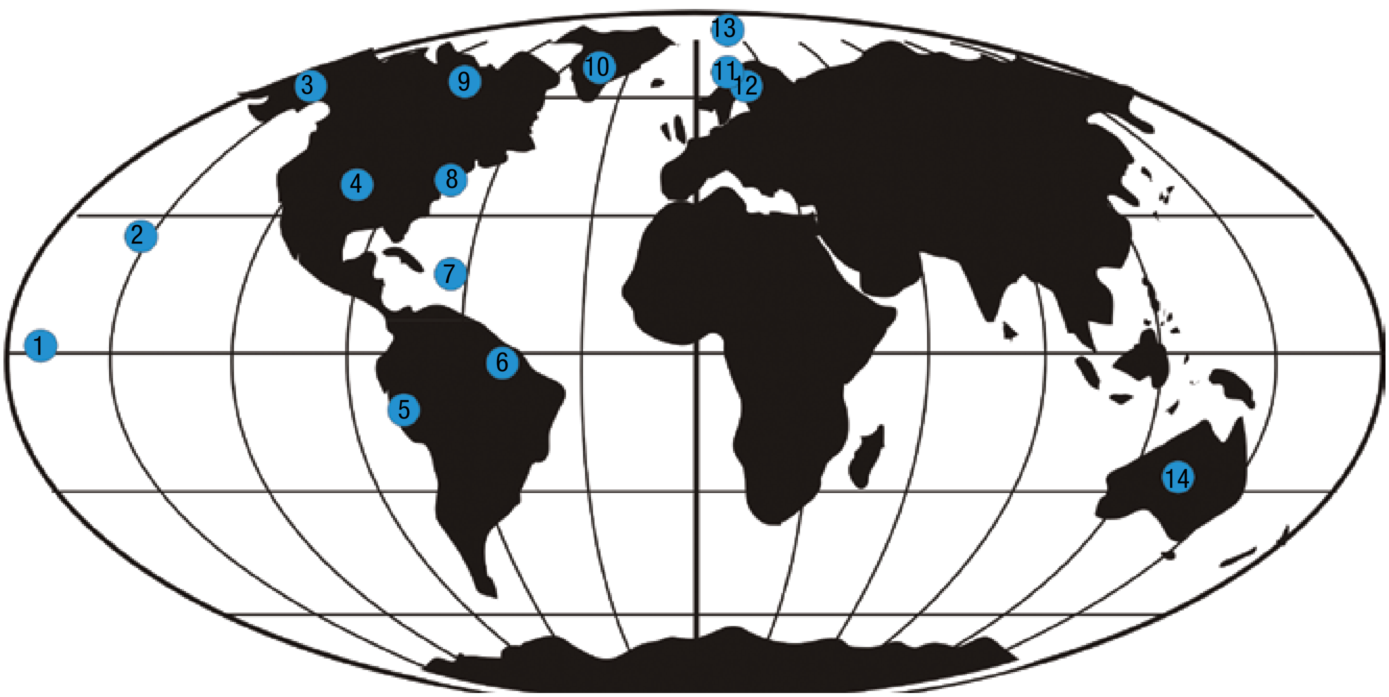


Andoya, Norway

Woomera, Australia



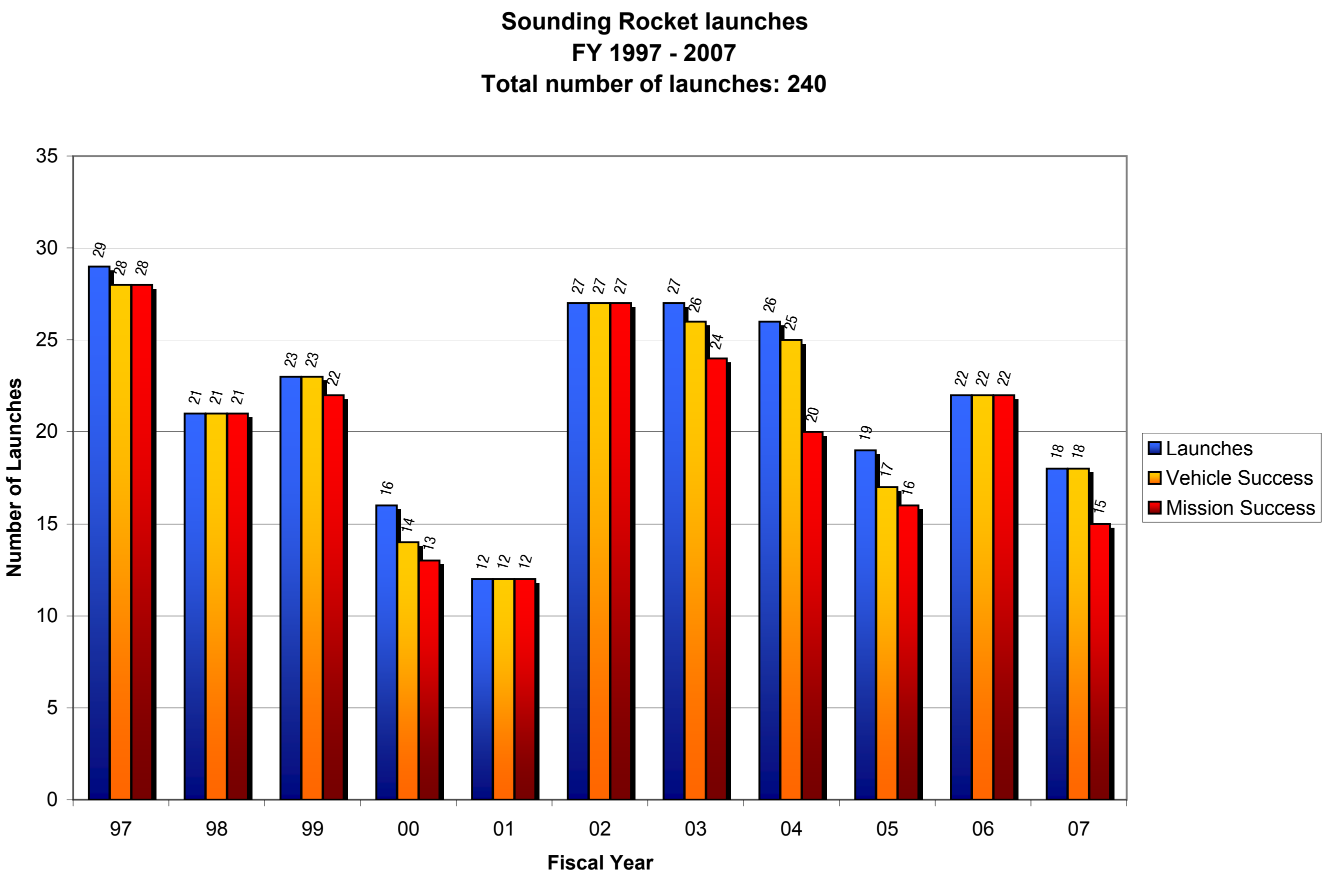
Wallops Island, VA



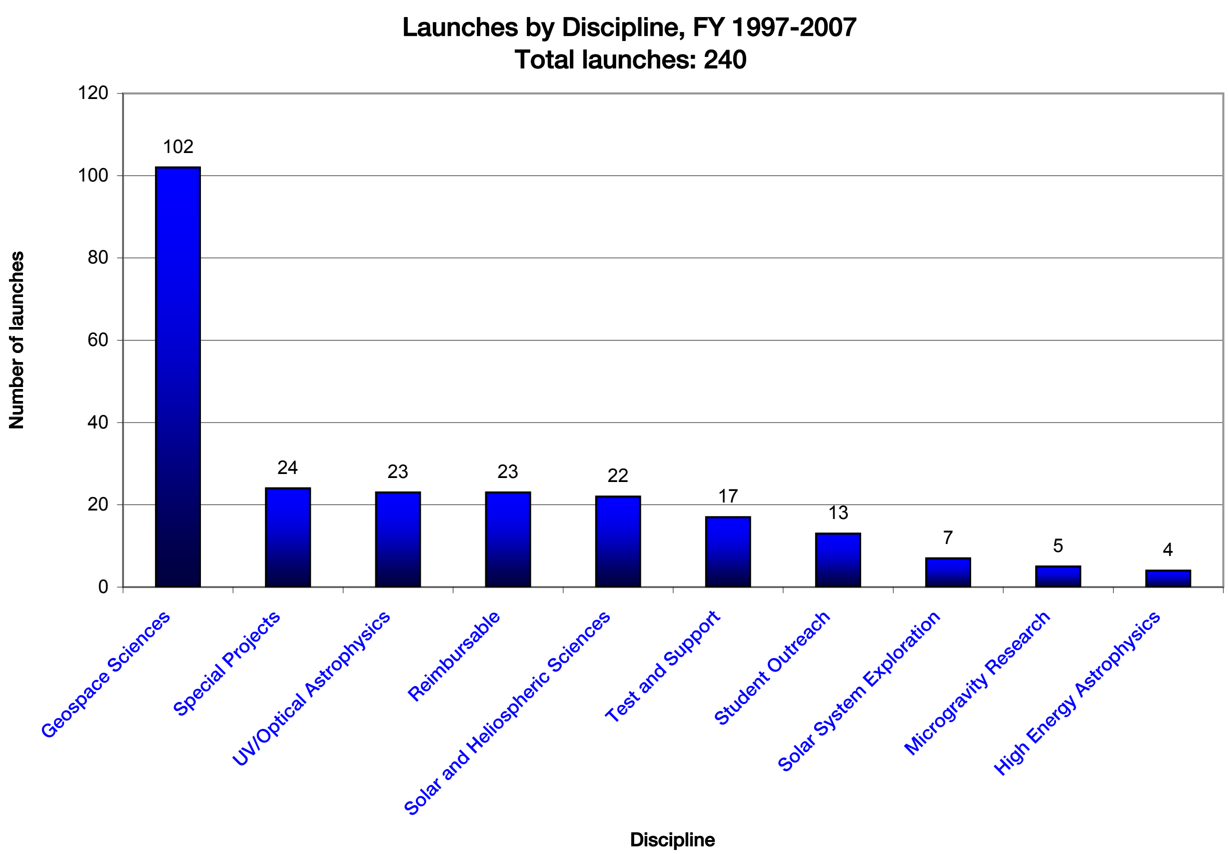
Past and present world wide launch sites used by the Sounding Rockets Program to conduct scientific research:

1. Kwajalein Atoll, Marshall Islands
2. Barking Sands, HI
3. Poker Flat, AK
4. White Sands, NM
5. Punta Lobos, Peru *
6. Alcantara, Brazil *
7. Camp Tortuguero, Puerto Rico *
8. Wallops Island, VA
9. Fort Churchill, Canada *
10. Greenland (Thule & Sondre Stromfjord) *
11. Andoya, Norway
12. Esrange, Sweden
13. Svalbard, Norway
14. Woomera, Australia

* In–active launch sites



Sounding Rocket launches
FY 1997 - 2007
Total number of launches: 240
Number of Launches
Fiscal Year
97
98
99
00
01
02
03
04
05
06
07
29 28 28
21 21 21
23 23 22
16 14 13
12 12 12
27 27 27
27 26 24
26 25 20
19 17 16
22 22 22
18 18 15
Launches
Vehicle Success
Mission Success



Launches by Discipline, FY 1997-2007
Total launches: 240
Number of launches
Discipline
Geospace Sciences 102
Special Projects 24
UV/Optical Astrophysics 23
Reimbursable 23
Solar and Heliospheric Sciences 22
Test and Support 17
Student Outreach 13
Solar System Exploration 7
Microgravity Research 5
High Energy Astrophysics 4

References

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Dr. Judge, Sounding Rocket Design Review Data Package 36.236

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Dr. Larsen, Sounding Rocket Design Review Data Package 21.138, 36.224, 41.064, 41.065

Dr. Craven, Sounding Rocket Design Review Data Package 35.037, 41.061, 41.062, 41.063

Dr. Lessard, Sounding Rocket Design Review Data Package 40.020

Dr. Labelle, Sounding Rocket Design Review Data Package 40.019

Dr. Robertson, Sounding Rocket Design Review Data Package 41.069, 41.070

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Kletzing et al., Sounding Rocket Design Review Data package, May 2007

Credits:

Cover: Rocket liftoff photo by Wallops Photolab. Report cover, layout and design by Berit Bland/810/BBCO.

Page 2: Kwajalein rocket launch, nowhereatoll.com (http://www.nowhereatoll.com)

Page 3: Launch from Norway, Scott Hesh/NSROC, Rockets on the pad in Alaska, Scott Hesh/NSROC

Page 4: Orion on the launch pad, Lee Wingfield/Wallops photolab

Page 5: All photos, Berit Bland/810/BBCO

Page 6: Orion lift–off, Wallops Photolab

Page 8: All photos, Wallops Photolab

Page 9: Photo by Berit Bland/810/BBCO

Page 10: ROPA Launch photo by Todd Valentic

Page 11: Cygnus loop, NASA HST& Jeff Hester/Arizona State University and ROSAT image of Cygnus loop, Levenson et al

Page 12: SOHO image of the Sun, Payload data graph: Dr. Judge, SOHO space craft image, Alex Lutkus

Page 13: Payload drawing, Dr. Woods, TIMED satellite rendering, NASA/Johns Hopkins University Applied Physics Laboratory (JHU/APL)

Page 14: ROPA launch photo, Todd Valentic, MPL screen shot by Code 589 Wallops

Page 15: HEX–2 liftoff, Tailored Trajectory graphic designed by Jessica Ransone

Page 16: Rockets ready to launch in Alaska, Scott Hesh/NSROC, Payload renderings, NSROC Mechanical Section

Page 17: Payload on spin/balance table, Berit Bland/810/BBCO, Payload rendering, Shane Thompson/NSROC

Page 18: Photo pf spin/deploy, Berit Bland/810/BBCO, Noctilucent Cloud by AIM satellite, AIM satellite graphic, Emily Hill Designs/ Hampton University, MASS rocket payload drawing, Shane Thompson/NSROC

Page 19: Trifid Nebula, NASA Hubble & Jeff Hester/Arizona State University, CACS airbering test, Berit Bland/810/BBCO

Page 20: All photos by NASA Langley IRVE team

Page 21: Rocket launch from Andoya, Trond Abrahamsen

Page 22: Airbearing test, Berit Bland/810/BBCO

Page 23: Tailored Trajectory graphic design by Jessica Ransone

Page 24: Andoya launcher installation, NASA, Athena launcher leaving Wallops, Jan Jackson/NSROC, Rocket Launch, Visual Information Branch, White Sands Missile Range, S–19, SAAB

Page 25: Photo by Berit Bland/810/BBCO

Page 26: Photos by Berit Bland/810/BBCO

Page 27 Image Science and Analysis Laboratory NASA Johnson Space Center “The Gateway of Astronaut Photography of Earth”.

Page 28: Photos by Berit Bland/810/BBCO

Page 29: Photos by Berit Bland/810/BBCO

Page 30: Mesquito renderings by Andy Owens and Joshua Yaccobucci, NSROC

Page 31: Terrier–Malemute in Kwaj, Bruce Scott/NSROC, Hy–Bolt, Berit Bland/810/BBCO, SCRAMP, Mark Murbach/NASA Ames

Page 34: Poker Flat, Scott Hesh/NSROC, Kwaj, Bruce Scott/NSROC, Esrange launch, Esrange/SSC, Andoya launch/Scott Hesh

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