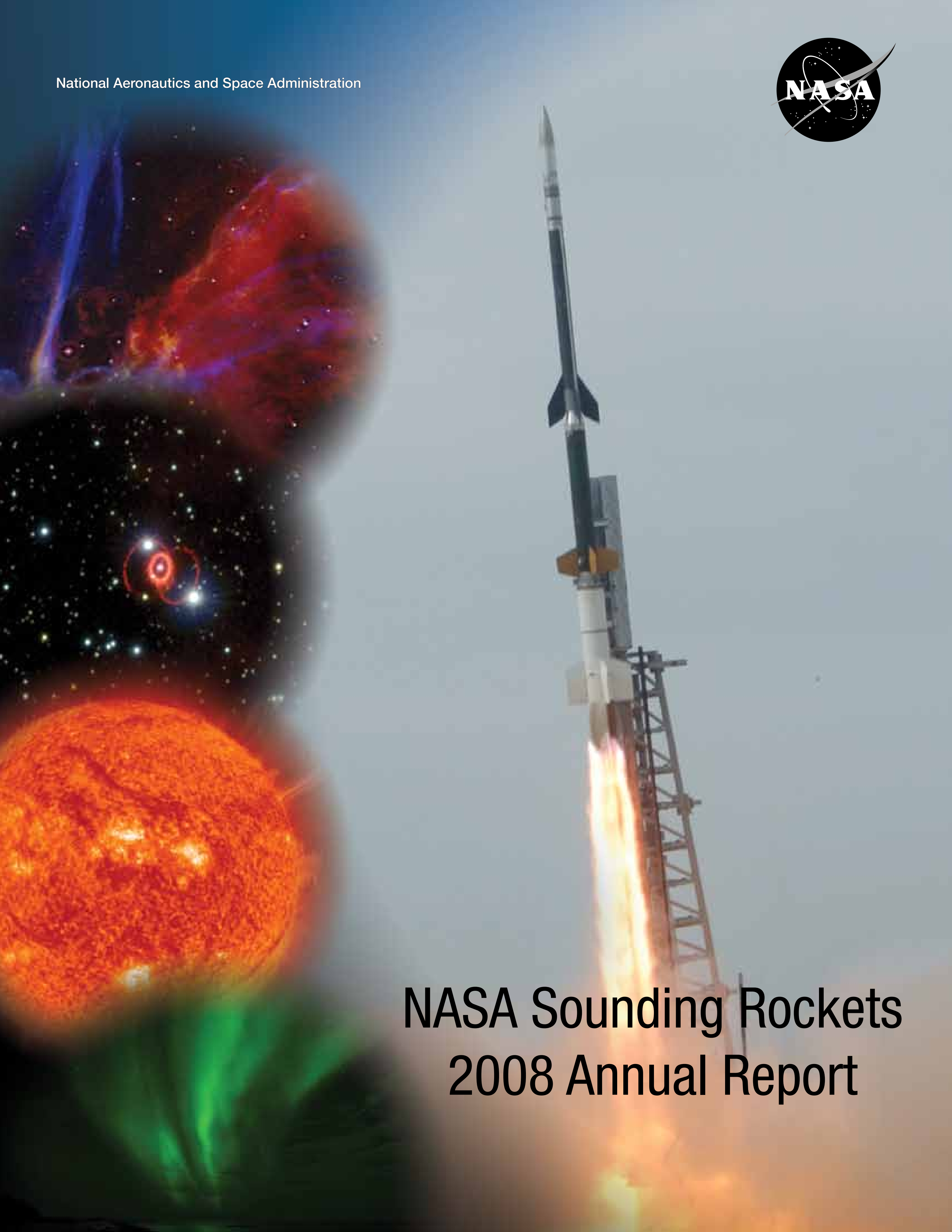
National Aeronautics and Space Administration



NASA Sounding Rockets 2008 Annual Report

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 2008 mis–sions 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 second annual report offers some brief in–sights into the scientific missions, development efforts, and the educational and workforce development projects supported by the NASA Sounding Rockets Program, as well as a fore–cast of challenges "on the horizon."

Phil Eberspeaker

Chief, Sounding Rockets Program Office

Black Brant XI, 39.008 LeClair lift–off from Wallops Island.

Sounding Rockets Program – Annual Report 2008

Introduction

The Sounding Rockets Program supports the NASA 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.

Kletzing, 40.018 & 40.022 ready to launch (top). 40.022 launch (bottom).

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.

Telescopes and spectrometers to study Solar and Astrophysics are flown on sounding rockets to collect unique science data and to test prototype instruments for future satellite missions. The program's rapid response capability enabled scientists to study the Supernova 1987A before it faded from view. Currently, new detectors, expected to revolutionize X-ray astronomy, are under development and have been successfully tested on sounding rocket flights. An important aspect of most satellite missions is calibration of the space based sensors. Sounding rockets offer calibration and validation flights for many space missions, particularly solar observatories such as the Thermosphere-Ionosphere-Mesosphere-Energetics-Dynamics (TIMED) satellite, the Solar Heliospheric Observer and the future Solar Dynamics Observatory (SDO).

Executive Summary

Science with Sounding Rockets

Since their first use for space and atmospheric research in the 1950's, sounding rockets have continued to provide valuable data for scientists in several fields of study. Astrophysics, Heliophysics, and Geospace Sciences all use sounding rockets for relevant research.

Missions 2008

Eight NASA science missions, designed to explore the near Earth space environment by studying magnetic re-connection, measure the Sun's radiative energy in several wavelengths, look deep into space to determine the far-UV scattering and extinction properties of the dust within the Orion Nebula and to obtain high resolution spectra of the diffuse X-ray background of our Galaxy. Additionally, two technology development missions, one university-level educational mission and two vehicle development test flights of the Mesospheric Dart were completed.

Mission Support

In preparation of upcoming missions, 17 payloads were integrated and tested including eight payloads to be launched during the winter campaign in Poker Flat, Alaska, January - March 2009.

Technology Development

Development of the new Mesospheric Dart vehicle reached the testflight stage in 2008. A Terrier-Improved Malemute sounding rocket is under development as well.

Education and Workforce Development

The Sounding Rockets Program enhanced its educational offering by conducting the first Rock-On! student flight in 2008. A total of 60 students and faculty members participated in 2008. Additionally, the Program's highly successful internship program, is in its 10th year.

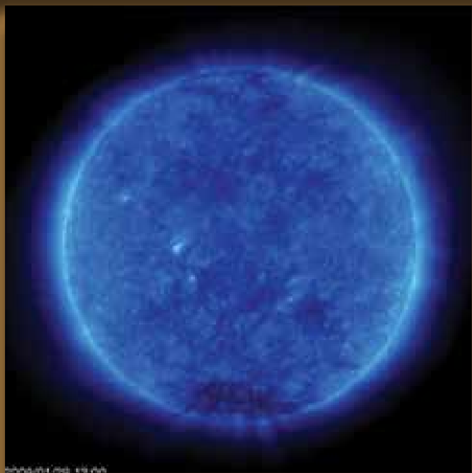
On the Horizon

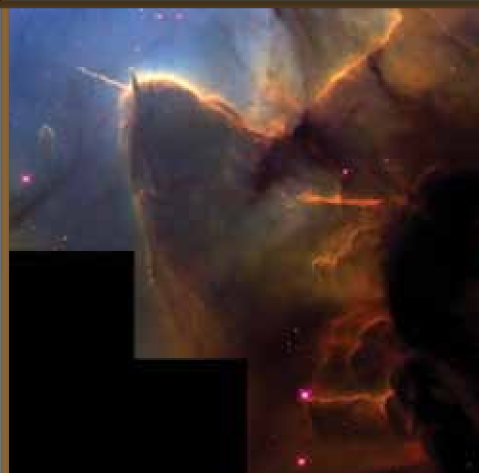
The new Mesospheric Dart vehicle will enable new earth science measurement capabilities; these are being vigorously pursued in cooperation with the NASA science organization. Future flight opportunities will include Kwajalein as a launch site to accommodate low latitude measurements. The potential for longer duration solar and astrophysics flights from Wallops Island is also being evaluated

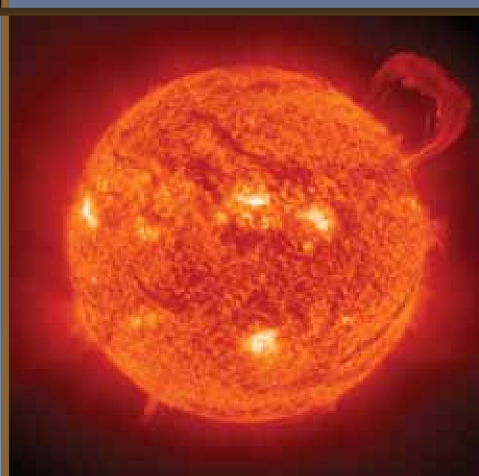
Program Statistics

Charts, graphs and metric analyses quantify the progress and success of the Sounding Rockets Program. These include launch history, launch sites, and vehicle and mission success statistics.

science







Science with Sounding Rockets

In 1957 scientists participating in the International Geophysical Year (IGY) had available to them rockets as research tools for the first time in history. They took full advantage of these new assets, and launched a total of 210 rockets from 7 different sites as part of the United States contribution to the IGY. The research ranged from atmospheric sciences to astronomy. Ionospheric soundings included direct electron density measurements and detailed mapping of the E and F regions.

IGY 1957 firmly established sounding rockets as viable tools for science and proved their utility for in-situ measurements, quick response, and temporal and geographic mobility. The utilization of sounding rockets for science has continued with undiminished importance.

> *...to observe geophysical phenomena and to secure data from all parts of the world, to conduct this effort on a coordinated basis by fields, and in space and time so that results could be collated in a meaningful manner.*
>
> Excerpt from the National Academy of Sciences International Geophysical Year report for 1957.

Heliophysics, Astrophysics, Geospace science and Aeronautics benefit from sounding rockets. Advantages such as the quick response to scientific events, low cost, and mobile operations provide researchers with opportunities to conduct world class science.

Some of the highest resolution spectral data of the Sun are recorded with telescope payloads flying on sounding rockets. Payload recovery yields significant cost savings by ensuring that sensors, one-of-a-kind telescopes, cameras and recorders are available for reflight on future missions.

As research tools, sounding rockets are key to the study of the near Earth space environment; in fact, they are the only means of collecting in-situ data in the ionosphere. Several launch sites in the arctic region enable studies of phenomena such as magnetic re-connection, ion outflows and the effects of Joule heating. Understanding the fundamental processes that govern the Sun-Earth space environment will enhance our ability to more accurately predict the solar storms that can disrupt power grids and satellite-based information systems on Earth.

In the high energy and the ultraviolet and visible parts of the spectrum, Astrophysics uses sounding rockets to test new instruments on unique scientific missions. Sub-systems, developed by NASA, provide unprecedented pointing accuracy for stellar targeting, yielding high resolution spectra and potentially leading to new ground breaking discoveries about our own galaxy.

Science Highlight

X-ray Spectroscopy of the Background and Highly Extended Sources

Principal Investigator: Dr. Webster Cash
University of Colorado

Summary Statement

This is the final report for the sounding rocket program entitled "X-ray Spectroscopy of the Background and Highly Extended Sources." The program was a success in all three of the main areas that the sounding rocket program is designed to support. It was successful in developing and flight demonstrating new technology relevant to NASA's program. It was successful in educating young scientists. It performed cutting edge Astrophysics. A continuation of the program with upgraded performance has now been accepted by NASA.

Fabrication of Payload

The payload featured a novel arrangement of optics. Instead of a telescope it used a collimator with successively finer grid spacings to create an analog of a converging beam. This new kind of collimator proved relatively straightforward to build and align. Two were built and calibrated.

CyXESS payload during integration at White Sands, NM.

Behind the collimators were placed arrays of plane gratings in the off-plane mount at grazing incidence. The gratings were replicated onto 125μ thick nickel sheets and fanned to allow diffracted light from a large angular diameter source. The gratings were mounted on a flexure under tension. This proved a practical way to create a large grating area of the needed quality. GEM (Gas Electron Multiplier) detectors were used as conventional imaging proportional counters.

Technology Development for NASA

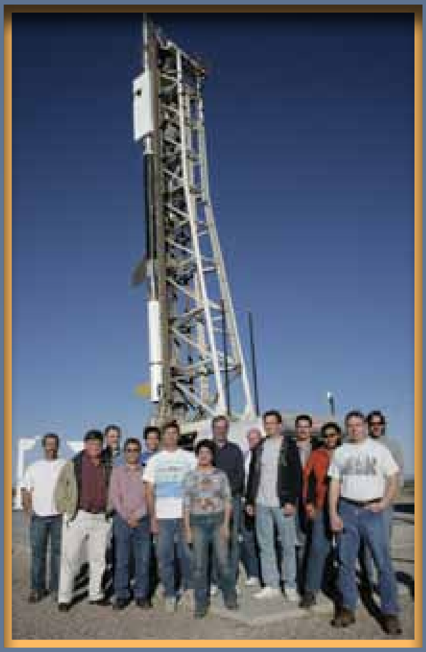
We have spent the duration of the grant developing and testing several new technologies of relevance to NASA's High Energy Astronomy Program.

- The GEM detectors can also be used in a polarization sensitive mode. As such, they have been chosen for use on the GEMS SMEX mission which is currently under study. Our program provided the first flight demonstration of the technology, although in a different operational mode.
- The collimators can be used in any converging beam of x-rays and thus provide a mechanism for observing diffuse x-ray sources at high resolution in the future. They may at some point be proposed for flight on a smex or midex class mission.
- The main area of development was for the gratings. The International X-ray Observatory (IXO, formerly Constellation-X) has a requirement for high efficiency, high resolution x-ray gratings for study of the Warm Hot Intergalactic Medium. The flight demonstration of gratings with our rocket is the highest advancement of the technology in the direction needed for this flagship class mission.

Overall, we have raised the Technical Readinesl Level (TRL) for two major missions as well as providing a technical path for other missions.

Science

The payload was successfully launched aboard a Black Brant rocket in November 2006. We were able to capture a spectrum of the long wavelength end of the spectrum of the Cygnus Loop as a whole, as opposed to the individual bright knots that have been studied in the past. Analysis of the spectrum showed direct evidence for thermal non-equilibrium in the hot, emitting gas. This result was published in the Astrophysical Journal in 2008.



Payload team with the BBIX launch vehicle

Education

In keeping with University of Colorado tradition, this effort was led by a graduate student, Randy McEntaffer who was responsible for the whole program, beginning to end. Randy designed and built the payload, then analyzed and published the results. He filed his dissertation in November 2007. Four months later he was offered a position as Assistant Professor of Physics at the University of Iowa where he will be starting a new program in High Energy Astrophysics. This is how its supposed to work! Randy will undoubtedly be a leader in the field and a NASA Principal Investiator in the very near future. Phil Oakley, another graduate student, assisted Randy in the first flight of the payload and will take the lead in upgrading it for reflight in 2009. Many of the undergraduate students who were involved in the program are pursuing graduate education.

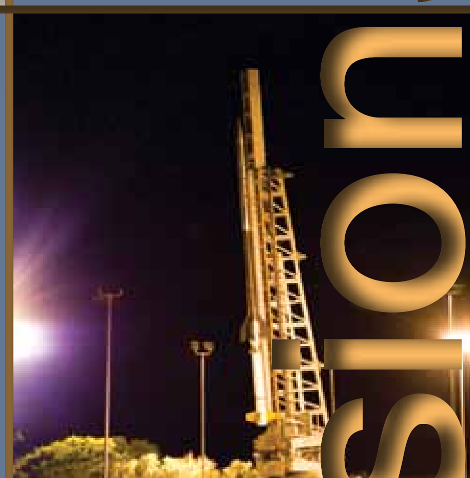
Continuation of Program

In 2008, we proposed and NASA granted a four year continuation of the University of Colorado's Sounding Rocket Program to upgrade program capabilities and to fly at a rate of once per year. We are currently fixing the aspects of the payload we found wanting on the first flight. We expect this will remain a productive program scientifically, technically, and educationally.

Publications

A list of the publications supported in part or in full by this grant can be found in Appendix A of this report.

Those of us involved in the sounding rockets program at the University of Colorado wish to give special recognition to the men and women of NASA Wallops and those working on the NASA Sounding Rocket Operations Contract (NSROC,) whose exceptional capability and dedication have made the success of this program possible.



missions 2008

36.218 UE - STORMS

Mission:	**36.218 UE**
PI:	**Dr. Greg Earle**
Institution:	**University of Texas/ Dallas**
Vehicle:	**Black Brant IX**
Launch Site:	**Wallops Island, VA**
Launch Date:	**October 30, 2007**
PI Website:	

http://www.utdallas.edu/~earle/

In late October of 2007 an instrumented sounding rocket was launched into a mid-latitude spread F (MSF) condition over Wallops Island. The MSF event occurred several hours after an abrupt increase in the Kp magnetic activity index. The rocket experiment measured the plasma density, electric field, and horizontal neutral wind as it traversed a region of the ionosphere that simultaneously produced spread-F signatures on the Wallops Island digisonde system. Prior to and during the rocket flight, the ionospheric medium was continually under observation by a second vertical incidence radar system, a Traveling Ionospheric Disturbances (TID) detection radar, scintillation receivers, and the east coast GPS receiver network. Several competing theories of mid-latitude spread F development will be quantitatively compared to the rocket measurements to determine which are consistent with the observations.

36.241 GS - EUNIS

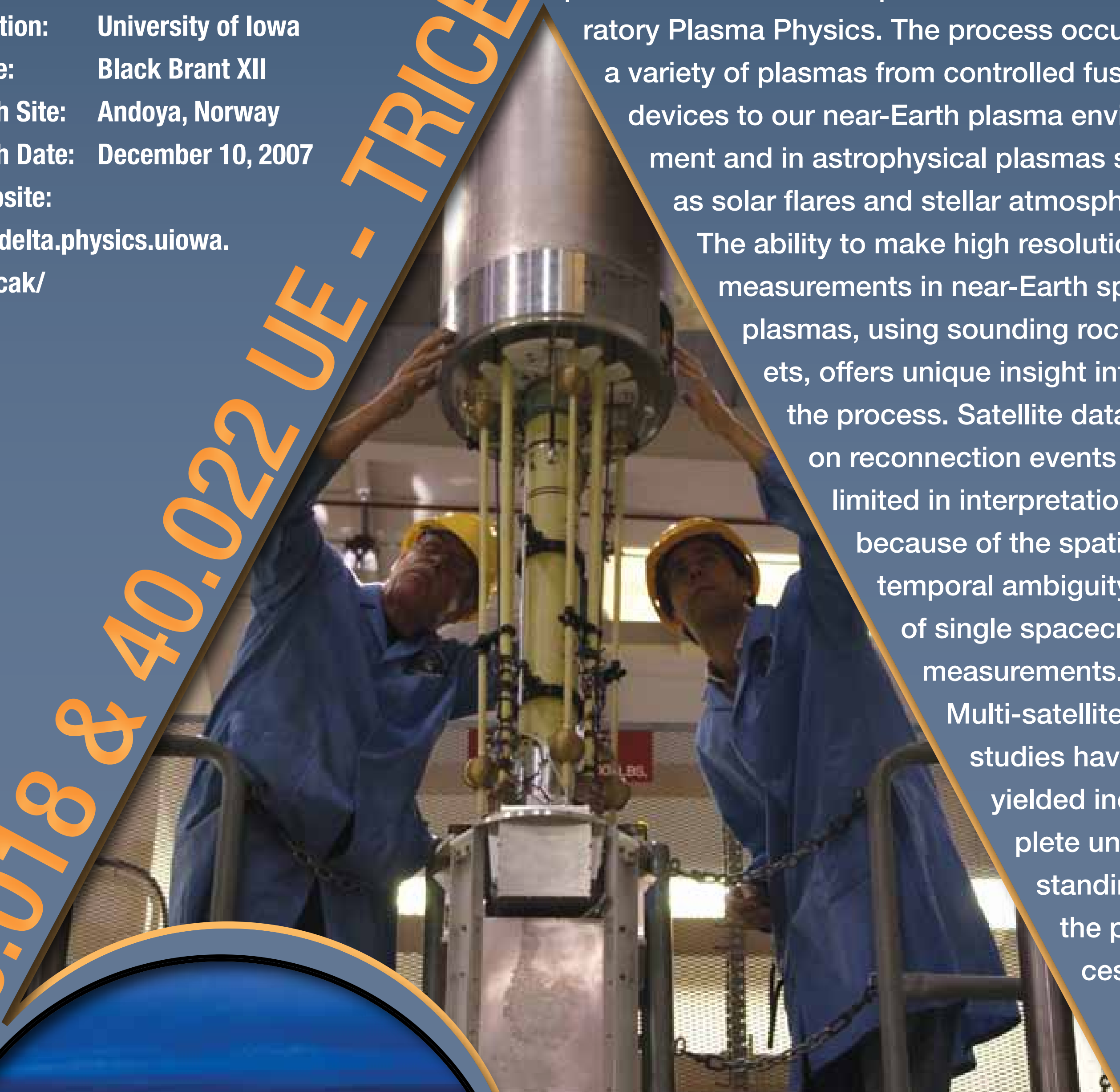
Mission: 36.241 GS
PI: Dr. Douglas Rabin
Institution: NASA Goddard Space Flight Center
Vehicle: Black Brant IX
Launch Site: White Sands, NM
Launch Date: November 6, 2007
PI Website: http://lssp.gsfc.nasa.gov/spl/index.html

The Extreme Ultraviolet Normal-Incidence Spectrograph (EUNIS) sounding rocket instrument is a two-channel imaging spectrograph that observes the solar corona with high spectral resolution and a rapid cadence made possible by unprecedented sensitivity. The rapid cadence of EUNIS is the key to its power to explore the time variable and spatially inhomogeneous heating mechanisms that define the frontier of coronal energetics.

EUNIS-07 obtained 276 science exposures during a period of 371 seconds in each of two wave length channels on three I K x I K active pixel sensors in each channel, this totaled over 1,600 1 Kx 1 K images. After calibration and co-registration, the EUNIS-07 data will provide the first in-orbit radiometric calibration of Hinode's Extreme Ultraviolet Imaging Spectrometer (EIS) and the Solar Terrestrial Relations Observatory's (STEREO) Sun Earth Connection Coronal and Heliospheric investigation, Extreme Ultraviolet Imager (SECCHI/EUVI) instruments. Future flights of EUNIS will focus on coronal heating mechanisms in active regions and bright points as well as chromospheric evaporation in transient features.

40.018 & 40.022 UE - TRICE

Missions: 40.018 & 40.022 UE
PI: Dr. Craig Kletzing
Institution: University of Iowa
Vehicle: Black Brant XII
Launch Site: Andoya, Norway
Launch Date: December 10, 2007
PI Website:
http://delta.physics.uiowa.edu/~cak/



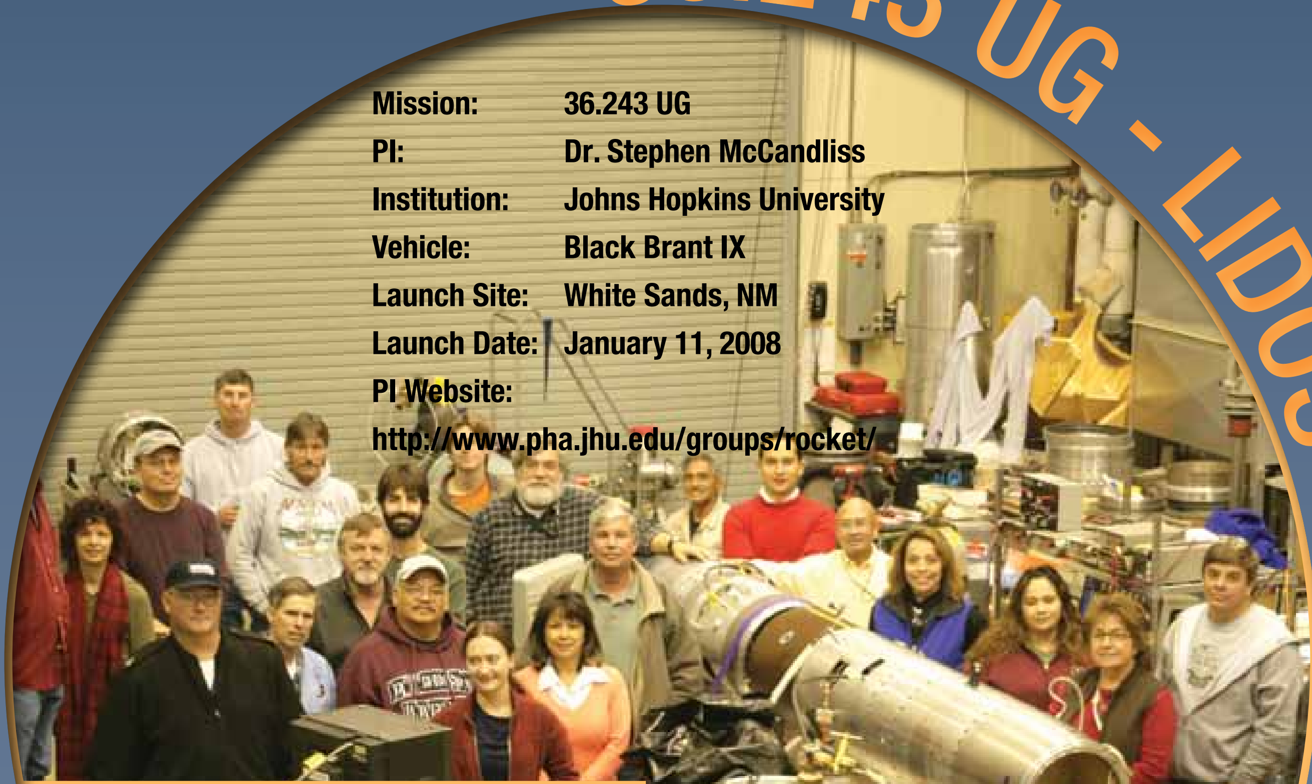
Magnetic reconnection has emerged as a major topic of interest for both space-based and laboratory Plasma Physics. The process occurs in a variety of plasmas from controlled fusion devices to our near-Earth plasma environment and in astrophysical plasmas such as solar flares and stellar atmospheres. The ability to make high resolution measurements in near-Earth space plasmas, using sounding rockets, offers unique insight into the process. Satellite data on reconnection events are limited in interpretation because of the spatial-temporal ambiguity of single spacecraft measurements. Multi-satellite studies have yielded incomplete understanding of the process.

The Twin Rockets to Investigate Cusp Electrodynamics (TRICE) sounding rocket missions allowed selection of the geometry of the experiment with respect to the ionosphere signatures of reconnection in order to better understand the temporal/spatial nature of reconnection. Two four stage Black Brant XII vehicles, were launched along trajectories to allow the payloads to intersect the same magnetic field line at varying times with a large altitude separation.

36.243 UG - LIDOS

Mission:	**36.243 UG**
PI:	**Dr. Stephen McCandliss**
Institution:	**Johns Hopkins University**
Vehicle:	**Black Brant IX**
Launch Site:	**White Sands, NM**
Launch Date:	**January 11, 2008**
PI Website:	

http://www.pha.jhu.edu/groups/rocket/



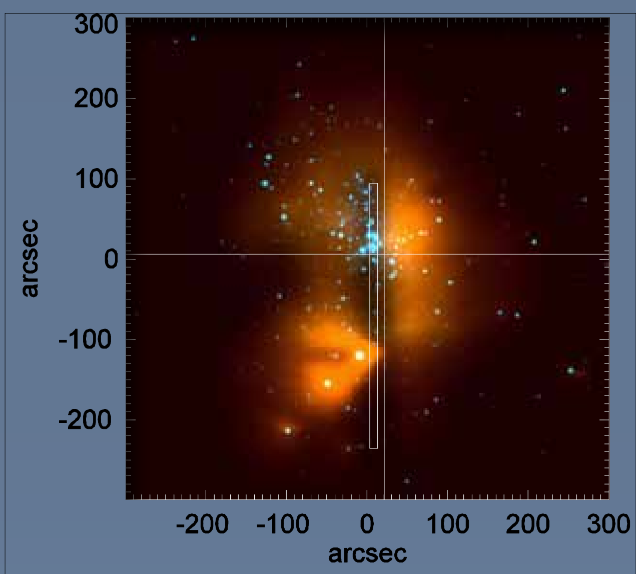
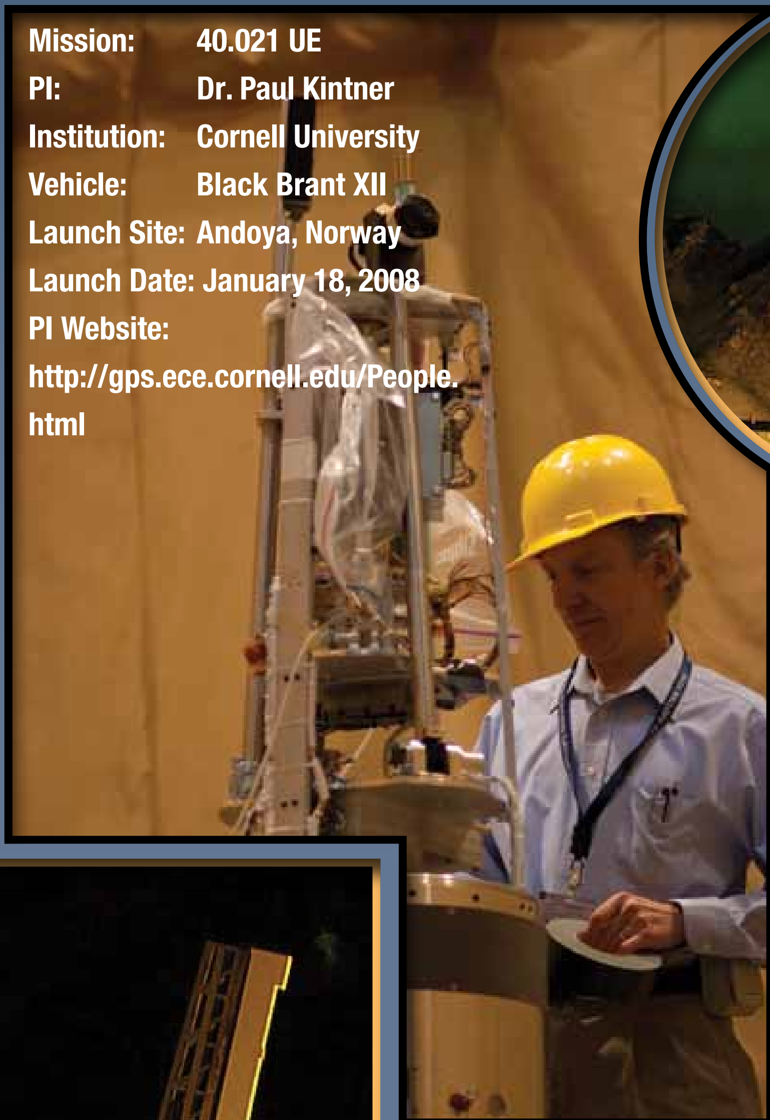


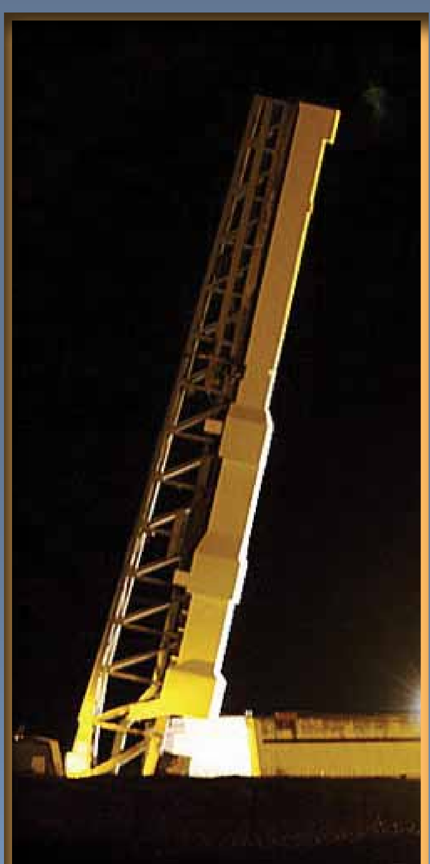
Image of the Orion Trapezium region from the on–board Xybion camera (red) overlaid on a 2MASS H–band image of the same field (blue). The ACS pointing is indicated by the crosshairs.

The 36.243 mission was the third flight of the Long-Slit Imaging Dual Order Spectrograph (LIDOS), an instrument which covers a large dynamic range in the far-ultraviolet bandpass (900 – 1650 Å). LIDOS was launched at 22:23 MST on January 10th, 2008, from White Sands, NM with a Black Brant IX Sounding Rocket. This flight observed the Orion Nebula (M 42), and successfully recorded the spectra of its exciting stars and the scattered light from the surrounding nebular material. The instrument collected data using real-time and pre-programmed pointing maneuvers, relying on the sub-arc-second pointing capability of the new Celestial Attitude Control System (CACS).

40.021 UE - SCIFER-2

Mission: 40.021 UE
PI: Dr. Paul Kintner
Institution: Cornell University
Vehicle: Black Brant XII
Launch Site: Andoya, Norway
Launch Date: January 18, 2008
PI Website:
http://gps.ece.cornell.edu/People.html





The SCIFER-2 (Sounding of the Cusp Ion Fountain Energization Region-2) sounding rocket measured ion drifts and distribution functions, electron temperature and density, electron and ion precipitation, convection electric fields, magnetic fields from which Field Aligned Currents (FAC) can be inferred, and plasma waves from which electron density (Ne) is inferred. Understanding the mass contribution of the ionosphere to the magnetosphere is a critical component of understanding ionosphere-magnetosphere coupling.

During the flight on January 18, 2008, all instruments functioned as planned and showed active and exciting data over the course of the flight. The ground observations were also excellent with many aurorae observed overhead and the EISCAT radar showing the ion upflows critical for the science objectives. The initial trajectory showed the payload passing very, very near to overhead which is serendipitous. In addition the Japanese scientific satellite RE-IMEI appeared to pass directly under SCIFER 2 at apogee and the European Space Agency (ESA) satellite CHAllenging Minisatellite Payload (CHAMP) passed overhead about 20 minutes later.

36.240 UE TIMED SEE

Mission: 36.240 UE
PI: Dr. Tom Woods
Institution: Univ. of Colorado LASP
Vehicle: Black Brant IX
Launch Site: White Sands, NM
Launch Date: April 14, 2008
PI Website: http://lasp.colorado.edu/rocket/

The solar extreme ultraviolet (EUV: 0-120 nm) irradiance is of crucial importance to several topics in the physics of the mesosphere, thermosphere, and ionosphere. This broad range of radiation is mostly deposited in the upper atmosphere providing the energy to form and maintain the ionosphere and to control the dynamics (winds) and photochemistry of the thermosphere. The Solar EUV Experiment (SEE) aboard the NASA Thermosphere-Ionosphere-Mesosphere-Energetics-Dynamics (TIMED) satellite is providing the first daily measurement of the solar EUV irradiance since the AE-E measurements in the late 1970s. In order to establish the solar irradiance variation over the long-term, prototype SEE instruments are flown about once a year on a sounding rocket payload to provide underflight calibrations for TIMED SEE. The launch in April 2008 also provided a unique opportunity to be involved with the international Whole Heliosphere Interval (WHI) campaign to study the Sun during solar cycle minimum conditions. The rocket results with the EUV Variability Experiment (EVE) channels provide significant improvements over TIMED SEE by providing higher spectral resolution of 0.1 nm and over a wider EUV range from 6 nm to 106 nm. The combination of the rocket measurement with satellite observations from TIMED and Solar Radiation and Climate Experiment (SORCE) has provided, for the first time, solar irradiance reference spectra over the full spectral range from 0.1 nm to 2400 nm during solar cycle minimum conditions. These results were critically important in characterizing the irradiance during solar cycle minimum conditions for the international Whole Heliosphere Interval (WHI) campaign held in March – April 2008.

12.065 & 12.066 MESQUITO

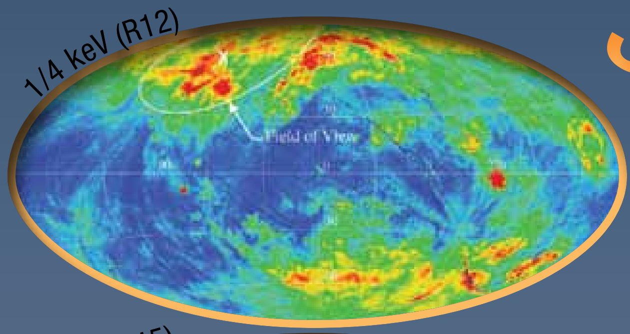
Missions: 12.065 & 12.066
Pi: John Hickman
Institution: NASA/WFF
Vehicle: Mesquito
Launch Site: Wallops Island, VA
Launch Date: May 6 & 7 , 2008
PI Website:
http://sites.wff.nasa.gov/code810

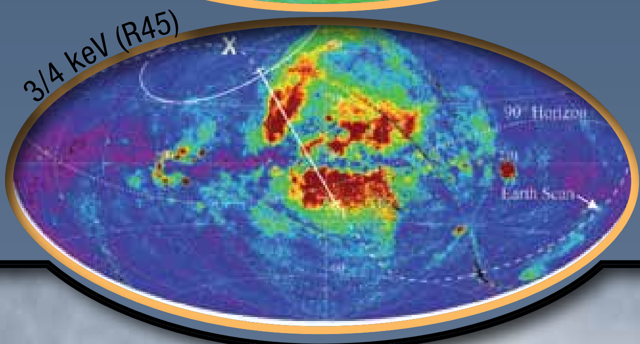
Two test flights of the new Mesospheric Dart were conducted on May 6th and 7th, 2008 respectively. The purpose of the test flights was to evaluate vehicle performance and Dart separation. Based on analysis of the test flight, engineering models were updated and changes will be incorporated into the next flight test vehicles. Several test flights are scheduled for 2009 to further refine and optimize the vehicle system

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

The Mesquito Dart system will enhance in-situ sampling capabilities in the upper atmosphere, and potentially fulfill the need for multiple launches in a given experiment, either in a relatively rapid sequence or as simultaneous launches along different azimuths.

36.223 UH-XQC





Mission: 36.223 UH
PI: Dr. Dan McCammon
Institution: University of Wisconsin
Vehicle: Black Brant IX
Launch Site: White Sands, NM
Launch Date: May 1, 2008
PI Website:
http://wisp11.physics.wisc.edu/xray/

The purpose of this mission was to obtain high resolution spectra of the diffuse X-ray background between 0.1 and 1.5 keV. Observations in this energy range have shown that the interstellar medium (ISM) in our Galaxy contains large amounts of previously unsuspected hot gas in the 1 million to 3 million degree temperature range. This gas can have profound effects on the structure and evolution of galaxies, and plays a key role in the distribution and life cycle of the elements produced deep in the interiors of stars. Despite its importance, this hot component of the ISM is still poorly understood. Well-accepted models of the Galaxy put the fraction of the volume occupied by the hot gas at anywhere from 15% to 90%, and it is not known how cooler material is distributed within or around it. These differences profoundly affect our view of how the Galaxy evolves.

A new type of detector that does classical thermal calorimetry on single photons is being developed as part of the X-ray Quantum Calorimeter (XQC) program. These detectors are expected to revolutionize X-ray astronomy and are baselined for almost every future NASA, ESA, or the Japan Aerospace Exploration Agency (JAXA) major X-ray mission. However, to date they have been employed successfully in flight only on the XQC sounding rocket instrument.

39.008 DR - NGSP

This mission, a sensor development and test project, utlized three small sensors to view free flying objects ejected from the payload under exoatmospheric conditions. In addition to the three sensors the experiment section housed the ejection mechanism for the objects and a camera. The camera is used in conjunction with an Attitude Control System (ACS) uplink command system to adjust pointing of the sensors at the objects after ejection.

The ACS maneuvered the payload to view the Black Brant sustainer rocket motor after viewing the objects. Additionally, the payload demonstrated the use of a Ku-band transmitter to provide high data rate telemetry.

Mission:	**39.008 DR**
PI:	**Dr. Stephen LeClair**
Institution:	**External Customer**
Vehicle:	**Black Brant XI**
Launch Site:	**Wallops Island, VA**
Launch Date:	**June 26 , 2008**

30.074 NO RockOn!

Mission: 30.074 UH
PI: Phil Eberspeaker
Institution: NASA/WFF
Vehicle: Orion
Launch Site: Wallops Island, VA
Launch Date: June 27, 2008
PI Website:
http://sites.wff.nasa.gov/code810/:

University faculty and students from across the country attended the RockOn! Workshop June 22 - 27, 2008 at NASA's Wallops Flight Facility. During RockOn!, they learned the basics of building experiments for flight on suborbital rockets. The RockOn! teams built the experiments from kits developed by students from the Colorado Space Grant Consortium and learned about the steps and procedures for creating payloads for flight. Each experiment package included a Geiger counter and sensors for measuring temperature, acceleration and pressure. The experiments were then integrated into payload cans for launch.

The week culminated with the launching of the experiments early on the morning June 27th aboard a NASA Orion sounding rocket. The 20-foot tall, single-stage rocket flew to an altitude of 67 km. After launch and payload recovery, participants conducted preliminary data analysis and discussed their results. Almost 60 students and faculty from universities in 22 states and Puerto Rico are participating in RockOn!. Eighty-percent of the participants are faculty members.

NASA's Space Grant program sponsors university-based consortia that focus on developing our nation's future scientists and engineers while improving science, engineering and technology education.

41.075 NP

Sub-TEC II

Mission: 41.075 NP

PI: Greg Smith

Institution: NASA/WFF

Vehicle: Terrier–Orion

Launch Site: Wallops Island, VA

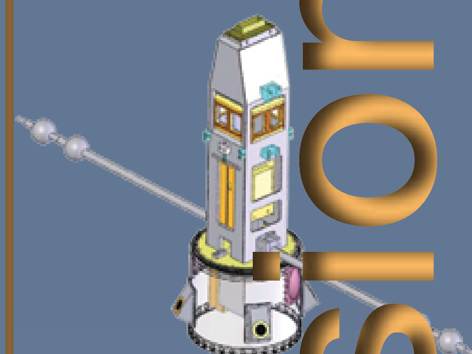
Launch Date: July 14, 2008

PI Website:

http://sites.wff.nasa.gov/code810

The primary objective of the this mission was to test several space system technology experiments in a realistic flight environment. This was the second flight of the Suborbital Technology Experiment Carrier (Sub-TEC) payload. This payload system is specifically designed to be a reusable carrier platform for maturing space system technologies.

The primary experiment was the Beamformer, a new antenna system designed to electronically steer a high gain antenna during flight such that the main antenna beam would remain pointed at a geostationary Tracking and Data Relay Satelite System (TDRSS) satellite. Secondary experiments included a real time attitude determination system consisting of several new and proven sensors, a miniature PCM encoder planned for the Mesquito vehicle, a miniature pyrotechnic control system, next generation GPS, and several other electrical sub-systems. A ground-based real time attitude display system developed by the Wallops Mission Planning Lab (MPL) was also tested on this mission. This system utilized actual data from onboard systems combined with graphical models of the vehicle and payload to display the real time flight attitude and vehicle/payload configuration.



mission support

End-to-End Mission Support

The NASA Sounding Rocket Program provides comprehensive mission support and management services from concept through post flight data distribution. This end-to-end support capability enables the PI to focus on the research aspect of the mission.

The NASA Sounding Rockets Program (NSRP) provides low–cost, suborbital access to space in support of space and earth sciences research and technol–ogy development sponsored by NASA and other users by providing payload develop–ment, launch vehicles, and mission support services.

Extensive experience, over 2,500 missions flown, has lead to streamlined processes and efficient design, manufacturing and assembly techniques. Management and technical support is provided for all facets of a mission and includes engineering design, manufacturing, integration, and testing and evaluation. Periodic reviews are conducted to ensure mission requirements are being met on time and on budget.

Launch Vehicles

The Sounding Rocket Program offers multiple proven launch vehicles to meet the needs of most researchers. New vehicles are brought online periodically to meet customer requirements and enhance capability. Currently, 10 vehicles are provided “off-the-shelf” and range in performance from a single stage Orion to a four stage Black Brant XII. See charts on page 46 for vehicle performance information.

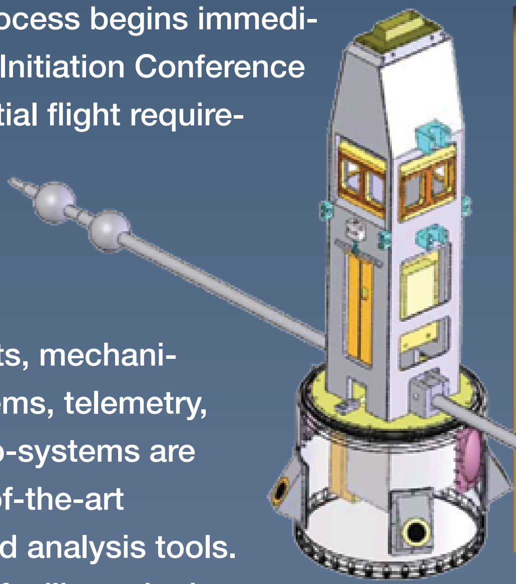
Single stage Orion lift–off

Terrier–Orion on Wallops Island

Black Brant XII lift–off

Payload Design

The payload design process begins immediately after the Mission Initiation Conference (MIC) is completed. Initial flight requirements and schedules are discussed at the MIC.



All payload components, mechanical and electrical systems, telemetry, recovery and other sub-systems are designed using state-of-the-art software, modelling and analysis tools. 3-D visualization tools facilitate the iterative design process by allowing flexibility in design updates and changes. The integrated multi-disciplinary design methods are effective in meeting the needs of the PI.

Mechanical Engineer Shane Thompson working on solid works model of the Robertson payload.

Manufacturing

Extensive in-house manufacturing capability is vital in a program with many customization requirements. The machine shop includes a vast assortment of machinery such as Computer Numerical Controlled (CNC) milling machines, lathes, welders, sheet metal breaks/shears/rollers and additional tools/processes to support the mechanical needs of the program. A recently added waterjet cutting machine enables fast manu facturing of small parts in large quantities.

From the top: Lee Miles, Greg Bridges and Charlie Cathell machining parts. Greg Bridges is using the waterjet.

Assembly

Payload electrical and mechanical assembly begins with decks, longerons and electrical wiring and ends with the integration of all sub-systems and science instruments. Electrical and mechanical technicians are assigned to a mission at the MIC and, to the extent possible, stay with the assigment through flight, contributing greatly to a responsive and customer focused program.

Ronnie Ridley, Herbie Haugh and Pat Fries working on wir–ing and mechanical assembly.

Sub-systems

The Sounding Rocket Program provides standard sub-systems such as recovery, ACS, and the S-19 boost guidance system as required by the mission profile. Custom systems such as telemetry, based on heritage components, are also available.

The boost guidance system controls the path of the rocket during the initial 10 to 15 seconds of flight where air density is adequate to permit course correction by means of movable fins. The vehicle pitch and yaw angles are detected by a gyro platform which produces corresponding output signals; the signals are processed in an autopilot and, after roll resolution, are used as servo command signals.

S– 19 Guidance System Module.

Charlie Kupelian testing the Celestial Attitude Control System.

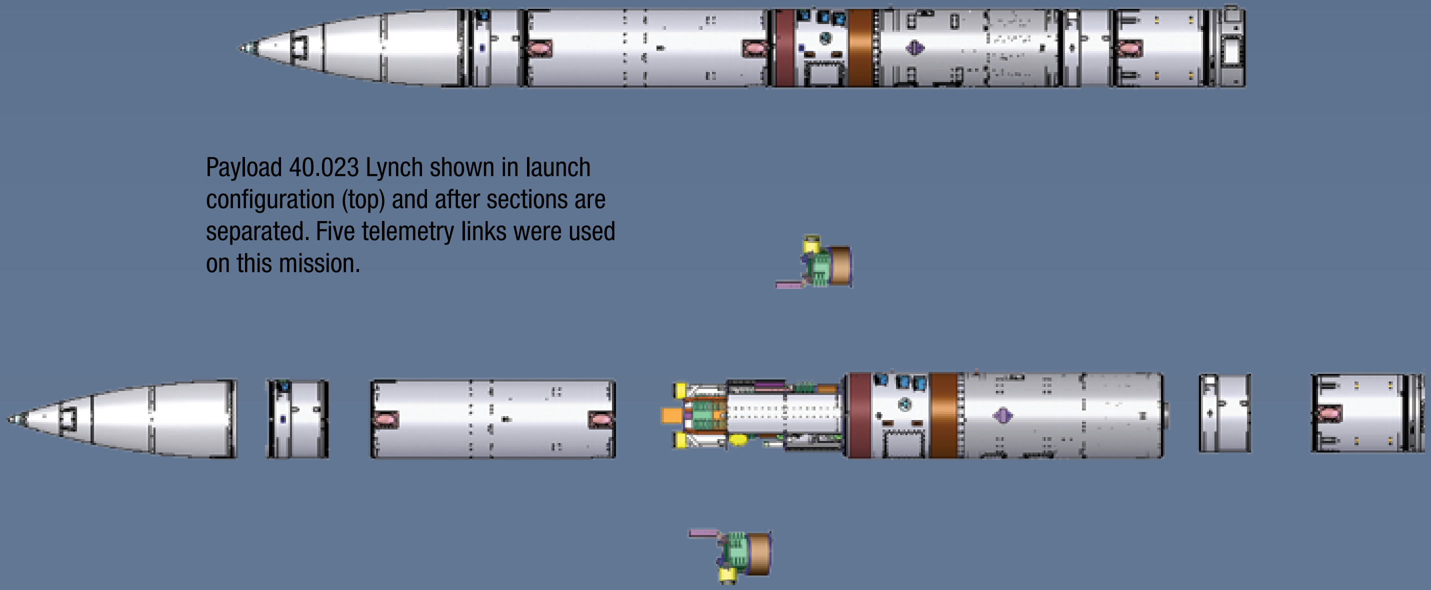
Several types of sensors are used, singly or in combination to provide payload attitude information. They include Magnetometers, Gyroscopes, Solar/Lunar Sensors, Horizon Sensors, Television Cameras, and Film Cameras. The Attitude Control System positions the payload as required using compressed gas that is released through small nozzles located on the payload skin.

Electrically operated vacuum doors are available for most telescope payloads.

Deployment mechanisms actuated by pyrotechnic, electric or mechanical means are available for doors, booms, shutters, etc.

Dr. Michael Zemcov with the shutter door for 36.226 Bock.

In instances where missions require measurements from multiple widely spaced platforms a special payload is created to permit



Payload 40.023 Lynch shown in launch configuration (top) and after sections are separated. Five telemetry links were used on this mission.

separation into several sub-payloads. Each sub-payload has it’s own Telemetry link to transmit all science and housekeeping data for that section.

Telemetry systems are designed to support the requirements of a mission and the configuration is determined by the complexity of the experiment, the configuration of the detectors, and the size of the rocket. Systems vary in complexity from a single link with no command or trajectory equipment to systems containing as many as eight downlinks, and complex command and trajectory hardware.

When payload recovery is required, flight performance engineers predict the radius within which the payload will land; the re-entry path is tracked by radar and the recovery achieved by parachuting the payload to a land or water landing. Recovery is accomplished by boat, helicopter or land vehicle. Additionally, payloads may be designed with gas or liquid tight bulkheads fitted with sealed passages for electrical wiring or piping.

Testing and Evaluation

The launch and flight phases of a sounding rocket mission are violent and stressful events for the scientific payload. The sum of the destructive elements to which such a payload is exposed is called the "payload environment." A rigorous environmental test plan helps to ensure that a payload will survive this hostile environment and continue working through hte successful completion of its mission.

The ultimate purpose of environmental testing and evaluation is to determine if a particular payload can survive the environment specific to the vehicle configuration designated for that mission. A comprehensive preflight qualification process involves subjecting the complete payload, in its flight configuration, to a series of environmental elements such as vibration, bending, heating, spin, de-spin, and vacuum exposure.

Vibration Testing

The test specifications used for a particular payload are determined by the ignition and burn parameters of the rocket motors used for that launch. Vibration tests are performed in three payload axes - thrust and two orthogonal laterals. There are two types of vibration inputs – sine and random – for each axis. Shock pulses can also simulate motor ignition or payload separation events. A payload's response to an input vibration depends on the size, weight distribution, and harmonic frequencies of the assembly. A test is considered successful when the payload continues to perform all functions as designed after each round of vibration.

Payload on vibration table (above) and Glenn Maxfield preparing a prototype light weight mirror for vibration (left).

Bend Testing

The pressure effects of high velocity atmospheric flight create bending moments along the length of a payload, with the maximum moment occurring at the base where the payload attaches to the motor. The severity of this moment and the resultant payload bending are predicted during a detailed performance analysis prior to testing. Commonly, deflection is measured at the tip to determine the sum of all joint deflections under the anticipated bending moment. A test is considered successful if the total tip deflection is equal to or less than that predicted in the performance analysis, and if the deflection at an individual joint is within acceptable limits.

Payload bend testing.

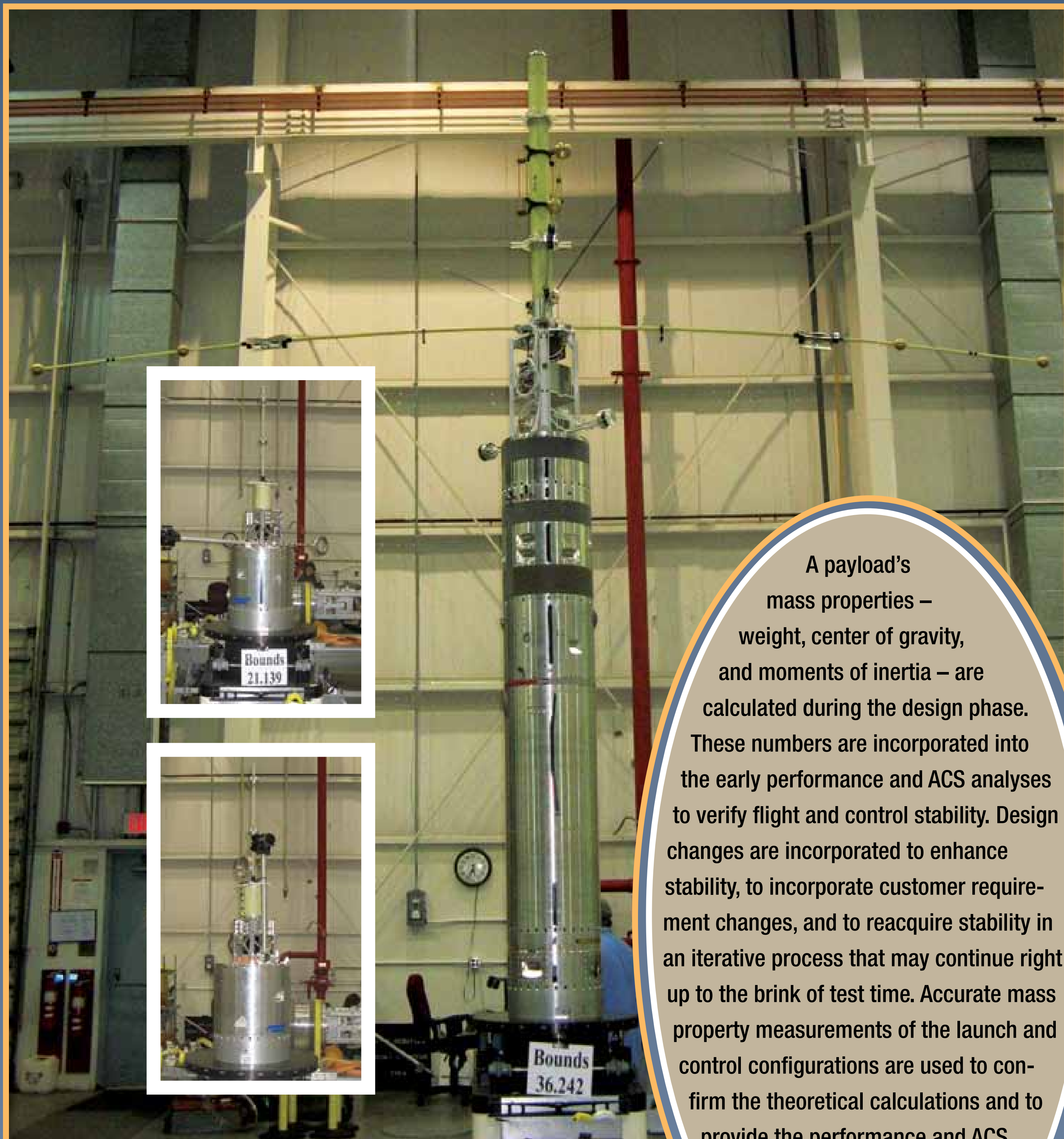
Spin Testing - Operational and Deployment

Sounding rockets are spin stabilized. Motor vehicle fin cants ensure that the assembly begins to spin-up as soon as it leaves the launch rail. The amount of spin at any given time in the flight sequence is referred to as the roll rate. Payloads often use the resultant centrifugal force to deploy doors, sensors, and other devices. Some deployments increase the spin inertia and thereby decrease the roll rate. Some payloads are designed to operate at zero roll rate and de-spin weights can be deployed to achieve that effect. Roll rate gradients occur during the intervals of rate change. Maximum spin rates, maximum rate gradients, and even the entire flight sequence spin rate profile can be reproduced in the spin test bay.

Most spin deployments are performed in the same facility and photo or video data are collected. Using this optical data, in conjunction with telemetry signal data monitored during the tests, the payload team can verify that payload instruments are functioning properly throughout these events, and that the deployments can be performed successfully in flight, and/or they can identify problems which need to be addressed.

Payload boom deployment testing. Above booms folded, left booms deployed.

Mass Properties Measurements



Payload on mass properties measurement table. Inserts show payload sections on mass properties table.

A payload's mass properties – weight, center of gravity, and moments of inertia – are calculated during the design phase. These numbers are incorporated into the early performance and ACS analyses to verify flight and control stability. Design changes are incorporated to enhance stability, to incorporate customer requirement changes, and to reacquire stability in an iterative process that may continue right up to the brink of test time. Accurate mass property measurements of the launch and control configurations are used to confirm the theoretical calculations and to provide the performance and ACS analysts with data to be used in the final pre-flight performance predictions.

New capabilities at the Testing and Evaluation Lab include the upgrades to the Mass Properties measurement table (see page 32).

Static And Dynamic Balancing

Dynamic imbalances in the launch configuration could cause an unstable flight profile such as coning, which would decrease apogee altitude and experiment data collection time. Static or dynamic imbalances in the control configuration could degrade the attitude control system's ability to align property and acquire the mission target(s). The balance facility uses technology similar to that used for automobile tires but it is more accurate. Imbalances are first detected, and adjusted using lead or brass correction weights, then re-measured to verify that the problem has been resolved. Each payload has its own imbalance limits, determined by the launch, control, and mass property parameters specific to that payload.

Payload being prepared for spin–balancing.

Thermal Testing

Thermal testing verifies the ability of a payload or component to withstand elevated temperatures, caused by friction or onboard heat souces such as a transmitter. Several thermal testing chambers are available to accommodate components and systems of various sizes.

Vacuum Testing

Vacuum testing is conducted to verify that component shields and conductive heat sinks are designed such that the components will survive space conditions and function properly throughout all phases of exo-atmospheric flight. Out-gassing is a release of molecules from a material caused by exposure to vacuum and/or heat. Scientific detectors are often very sensitive to contamination and must be isolated from materials that out-gas excessively. Materials that cannot be isolated from the detectors must be thoroughly cleaned and then forced to out-gas completely by high temperature baking and other methods. Subsequent thermal vacuum testing can verify that these materials have been rendered inert.

Launch operations support

Both established and temporary launch sites world wide are available to accommodate the needs of the PI. Established launch ranges exist in Alaska, New Mexico, Virginia, Norway, Sweden and Australia. Coupled with temporary sites in Greenland, Marshall Islands, Puerto Rico and Brazil provide extensive access to phenomena of interest to the science community.

The Sounding Rockets Program, in cooperation with the Wallops Range, provide all necessary personnel and equipment to conduct successful missions anywhere in the world.

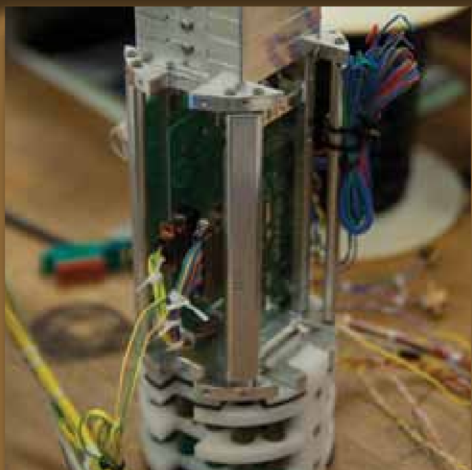
Additionally, ground and flight safety analyses are provided by the NASA Safety group at Goddard Space Flight Center's Wallops Flight Facility, home of the Sounding Rockets Program.

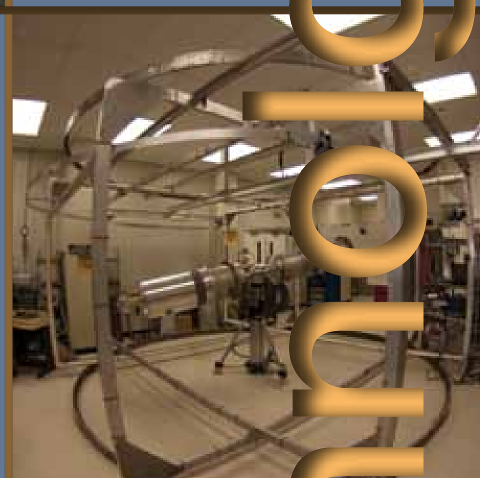
Testing & Evaluation Lab Upgrades

Two significant upgrades, a new vibration controller and enhancements to the mass properties table, are underway in the Testing and Evaluation Lab.

The new vibration controller features an upgraded CPU capable of faster processing at higher data rates, which enables faster response to events. A full complement of 15 sensors, placed on the fixture and at critical locations on the test item, can be used for a complex vibration control strategy involving vibration profiles where limiting is effectively employed on all channels. Time Domain Recording, a new feature, enables enhanced post-flight analysis by allowing test data to be compared to flight data. This function records all channels continuously in the time domain. Other features include data overlays of several tests for easy comparison and efficient data archiving. Future upgrades will incorporate force sensor interfacing for delicate instruments.

Ongoing upgrades to the mass properties test equipment added capability to balancing payloads with booms deployed.

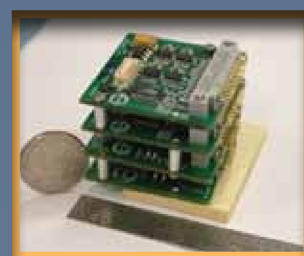




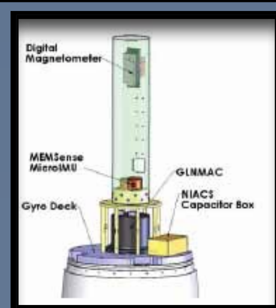
technolgoy

Real Time Attitude Solutions (RTAS)

RTAS is a new system that provides Real Time Attitude Solutions via a converging software routine that melds data from a group of onboard sensor suites. RTAS uses a Gumstix microcomputer running the extended-Kalman filter to calculate three-axis attitude solutions onboard in real time from solar and magnetic fields and a MEMSense three-axis rate integrating gyroscope with integrated digital magnetometer and accelerometers.



New software combined with the Gumstix micro-computer provide body-fixed, independent angular measurements with regard to the solar vector and magnetic fields and to combine data collected from those fields with simple coordinate transformations to provide inertial orientation angles within 5 degrees. Compared to ACS Systems like the Gimbal-mounted LN-200 with Sandia Miniature Airborne Computer (GLN-MAC), which measures internal payload activity with a high rate of accuracy and equally high cost, RTAS offers a new alternative to NASA scientists and investigators seeking low-cost flights.



Student intern Mark Peretich and Dave Jennings installing RTAS in the Sub–TECH II payload (top). RTAS boards (above) and system layout drawing (left)

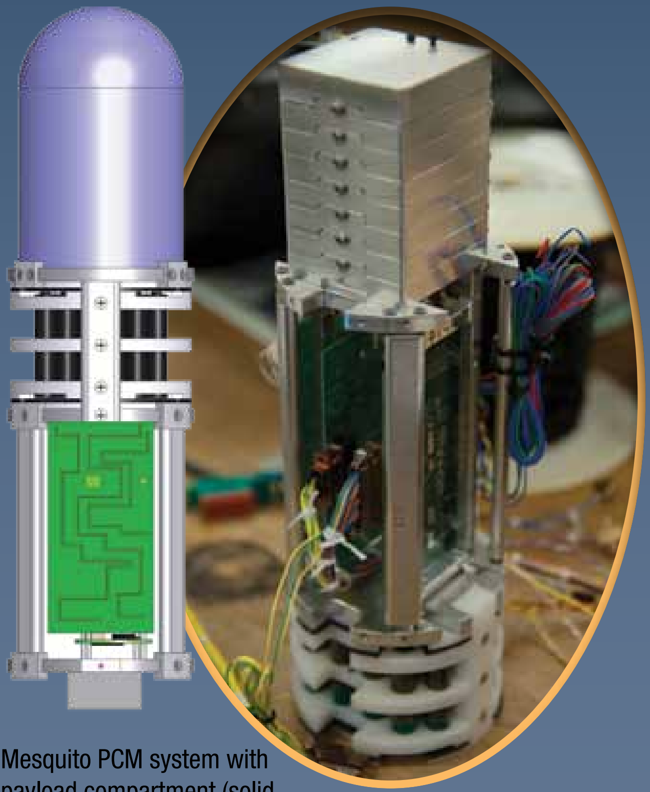
Mesospheric Dart - Mesquito

The Mesospheric Dart is a cost effective solution to many science disciplines requiring in-situ measurements at altitudes up to 95 km.

Two Mesquito test flights were conducted in 2008 and enabled a thorough review of the system. Several additional test flights are scheduled for 2009 and will include the payload avionics suite.

The payload avionics are packaged in a 4” diameter tube and required a completely new design approach to provide data monitoring and downlinking capability. Nearly all of the avionics use

surface mount technology to incorporate the necessary features into very small space.
The Pulse Code Modulation (PCM) system is the heart of the avionics design. The new system currently supports data rates up to 2 Mbps. The Pulse Code Modulation (PCM) system supports synchronous serial, asynchronous serial and analog data inputs and is stackable for additional input capability. The design allows for 16 analog inputs per deck and two synchronous serial or asynchronous serial inputs or a combination of both. The PCM stack is designed to fit within a 2” x 2” frame size with a maximum stackable length of 3.5”.



Mesquito PCM system with payload compartment (solid works drawing left) and the PCM system during buildup (right).

Vehicle flight performance will be monitored by 3-axis sensing accelerometers designed as one of the PCM stackable decks. Maximum thrust axis sensing range will be +/-200 G’s. Payload attitude is determined by a 3-axis magnetometer chip mounted with the accelerometers. Housekeeping signal conditioning will be performed with the new surface mount Conditioning and Power Distribution circuit board.

Instruments deemed feasible for launch with the Mesospheric Dart include:
• Chemical Release payloads
• Electric Field Booms
• Langmuir Probes
• Photometers
• Radiometers
• Robin Spheres
• Meteor Dust Collection
• Aerosol & Gas Sampling

Terrier–Improved Malemute solid works model.

Terrier-Improved Malemute

Development efforts have continued for the new two-stage, Terrier-Improved Malemute sounding rocket vehicle, which is designed to launch payloads between 600 and 1200 pounds to altitudes of 150 to 300 km. The rocket’s first test flight is scheduled for 2009. This vehicle shows promise as an enhancement to the existing fleet with a performance close to the single stage Black Brant V.

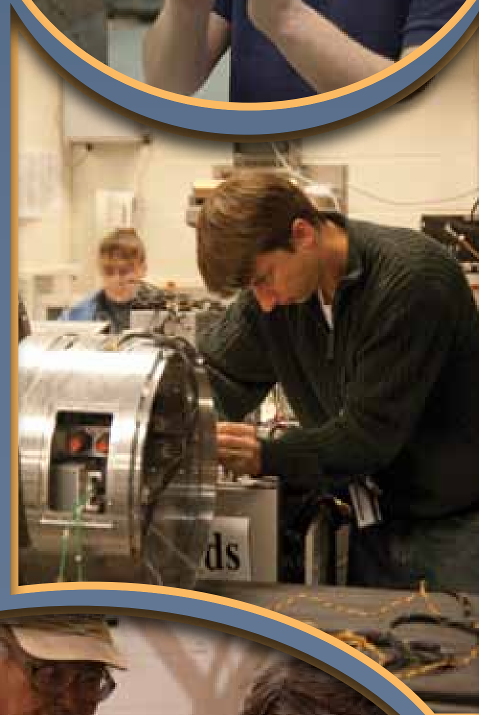
education & workforce development

Internship Program

Over 100 students have participated in the internship program managed for the Sounding Rocket Program Office by the NASA Sounding Rocket Operations Contract. The program, now in its 10th year, provides internships and co-op opportunities for students studying engineering, computer science and electrical or mechanical technology.

Students work side-by-side with experienced engineers and perform significant, valuable engineering tasks, leading to a better understanding of engineering, better grades and solid experience in a workplace environment.

Almost 90 percent of undergraduate students who intern or participate in the co-op program return for additional employment prior to graduation. Participants in the program have gone on to pursue higher education and careers in the engineering and science fields; three participants have doctorate degrees, 18 have or are pursuing master's degrees and 14 are full-time employees in the Sounding Rockets Program.



The student intern program has led to full–time employment for many participants, including (from the top) Josh Yacobucci inspecting the Mesquito Dart, Scott Hesh with the Bounds mission Telemetry system, Nate Wroblewski (left in photo) with Dan Hudson and Tom Russell prepar–ing a sub–payload for balancing, and Andy Owens (left in photo) with Lee Miles inspecting Mesquito hardware.

From Intern to Vehicle Systems Engineer

Meet Catherine Hesh

Cathy with the Improved Malemute motor (top) and with a Terrier motor (left). Cathy is one of nearly 100 students that have participated in the internship program.

Place of origin:

I was born in Fairfax, Virginia but have lived most of my life in Lynchburg, Virginia.

How did you become interested in aerospace?

At the age of 14 I saw the movie Top Gun for the first time and was determined that I wanted to be a fighter pilot. My parents were supportive and arranged a surprise flight lesson for me at my local airport on my 15th birthday. My first flight lesson was in a 2-seater Cessna 152 and from the moment we took off I knew I wanted to pursue a career in aerospace. I took flight lessons as often as I could for a year or two, but was never able to take enough lessons consistently to get my pilot's license. I thought about flying for the airlines as a career choice, but at the time approximately 1,500 flight hours were required and most flight schools only provided 500 flight hours at graduation. A few teachers at my high school encouraged me to consider aerospace engineering since I was interested in airplanes, so when it came time to look for colleges I looked for schools that had an aerospace program.

Where did you go to school?

I went to college at Virginia Tech and majored in Aerospace Engineering.

How did you find out about the NSROC intern & co-op program?

During my sophomore year I was walking through the Aerospace Engineering building on campus and spotted a flyer advertising a meeting of the sounding rocket design team. At the time I didn't know what a sounding rocket was, but the flyer had a picture of a rocket launch that caught my eye. The sounding rocket design team started out as a year-long senior design project where the students were working on designing a sounding rocket payload. Realizing that they wouldn't finish the design and launch the payload that year, the seniors were looking for underclassmen to get involved to keep the project going. I joined the sounding rocket team and started going to the weekly meetings. About halfway through the semester an email came through our listserv saying there were internships available at NSROC. After some persuasion from my professor, I applied for an internship. A few weeks later, I heard from Jan Jackson that NSROC would hire me for a summer internship.

During your internship, what departments did you work in and what where some of the more interesting things you did?

During all 3 of my internships I worked in the Flight Performance department. Mark, Mike, Brent, and Dave taught me how to do pre- and post-flight analyses on a variety of sounding rocket vehicles, and they also taught me how to do wind weighting for WSMR launches. During my 7-month co-op they let me perform the pre-flight analyses for several sounding rocket missions and present at the design reviews and mission readiness reviews. One of my favorite projects that I worked on was an analysis of a Talos–Black Brant vehicle stack to see if it would be a viable vehicle for future sounding rocket use. Mark helped me build all of the vehicle files and GEM deck to perform the analysis. In the end, the performance of the vehicle was great, but the bending moments were too high. It was a great learning experience to start from scratch and analyze the performance and stability of a new vehicle.

My internships in the flight performance department gave me a great foundation for my current job. I learned how each vehicle is analyzed, what inputs go into the trajectory and stability simulations, and what kinds of aerodynamic loads the vehicles are subjected to. I also learned a little bit about the performance of each of the solid rocket motors that we used before I ever started working in the Vehicle Systems Group.

You're now a full-time engineer in the Vehicle Systems section. What do you enjoy the most about your job?

My favorite part about my job is the variety of projects that I get to work on. In the 3 years that I've been in the Vehicle Systems Group I've worked on several sounding rocket missions, static fires, instrumented test flights, fin test flights, motor redesigns, new motors in vehicle stacks, propellant stability testing, cracks in propellant, review of motor x-rays, and recertification of older or damaged rocket motors. I get hands-on experience with rocket motors and hardware as well as analytical experience with post-flight data analysis and new vehicle development. Every day is exciting and challenging and I can't believe how much I have learned in 3 years! NSROC is a unique place where you are given a lot of opportunities as a young engineer.

How has the internship program benefited you?

The internship program gave me a great start to my career. I came to NSROC with essentially no work experience and at the end of my internships I had 12 months of solid work experience. After each summer at Wallops I would go back to college with greater confidence and found that the material I was learning in my classes made much more sense after working in the industry. I could apply what I had learned about rocket aerodynamics from the Flight Performance Department to all of my aero classes. Last, my internship led to my full-time position that I have now, which I absolutely love.

Do you have any recommendations for future interns or co-ops?

My recommendation for future interns or co-ops is to participate in as many internship opportunities as you can during college. The knowledge and experience that you gain is invaluable. Also I found that after each internship my grades at school got better, and I had the encouragement and support from my mentors at NSROC when I was back at school completing my classes.

Project HOPE - On the job training, as only NASA can

Hands-on Project Experience (HOPE) is a new tool for in-house workforce development being evaluated by the NASA Science Mission Directorate and the Office of the Chief Engineer. HOPE will be implemented as a pilot program for the first time in 2009 and uses a sounding rocket mission to train NASA personnel in all aspects of space flight missions, from proposal to flight.

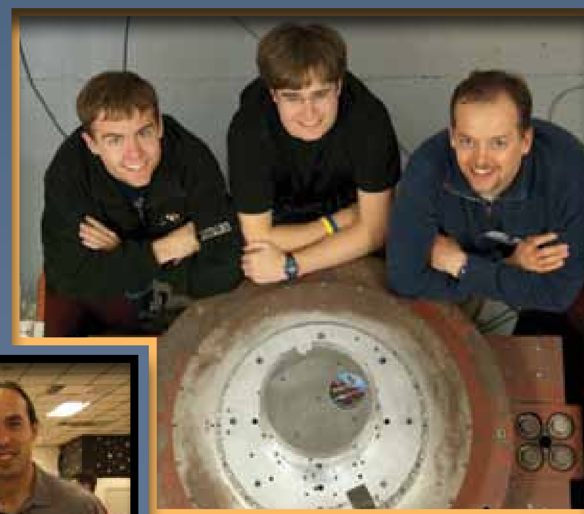
The short mission completion times and many existing sub-systems, such as telemetry, recovery, attitude control, make sounding rockets an optimal carrier vehicle option for the first HOPE payload.

Teams from each NASA Center are invited to submit a proposal to participate in HOPE. One proposal will be selected for development and flight. The objectives of the opportunity are to provide hands-on flight hardware experience to enhance the technical, leadership, and project skills of NASA personnel and to provide a science and/or technology investigation beneficial to the Science Mission Directorate's goals and objectives.

This opportunity will include experience in proposal development, and upon selection, development of a scientific investigation, payload integration and testing, integration of the payload with the launch vehicle, conducting flight operations including data collection and analysis, and project management.

RockOn! Build, Test, Fly - To Space in Six Days!

University faculty and students from across the country attended the first RockOn! Workshop June 22 - 27, 2008 at NASA's Wallops Flight Facility on Wallops Island in Virginia. The workshop is a collaborative effort involving the NASA Space Grant Program, Colorado and Virginia Space Grant Consortia, the NASA Sounding Rockets Program and NASA Education. Almost 60 people from universities in 22 states and Puerto Rico participated in RockOn! 2008. Eighty-percent of the participants were faculty members. Using the lessons learned through RockOn!, participants will work to make flight experiments a part of the educational process at their home institutions. The second RockOn! Workshop is scheduled for June 21-26, 2009.

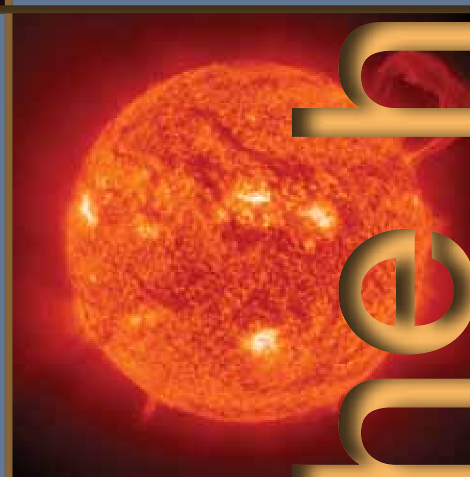


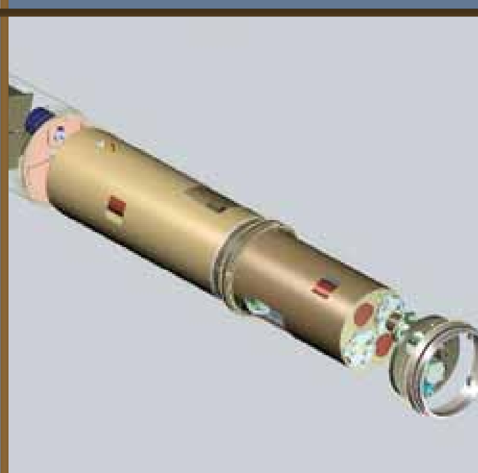
. Students from University of Colorado with a RockOn! can on the vibration table (top). Students reviewing their experiment after the flight (below). Team with RockOn! can and board (left)

During RockOn!, the teams learn the basics of building experiments for flight on sub-orbital rockets. Participants work in teams of three and construct an experiment based on kits developed by students from the Colorado Space Grant Consortium and learn about the steps and procedures for creating payloads for flight. The experiments include a Geiger counter and sensors for measuring temperature, acceleration and pressure and a microprocessor for data handling. Once the participants have completed construction of their experiment boards, written the software, conducted testing on the completed system, and integrate all components into the RockSat cans, the cans are interfaced with the rest of the payload structure and final payload assembly is completed a day or two prior to launch.

NASA's Space Grant Program sponsors university-based consortia that focus on developing our nation's future scientists and engineers, as well as improving science, engineering and technology education.

on the horizon





Kwajelein Campaign

In the recently released Research in Space and Earth Science (ROSES) Announcement of Opportunity (AO), Kwajalein was listed as an acceptable launch site for proposed research missions for Sounding Rockets. This is the first time since the completion of the second Equatorial Ionospheric Study (EQUIS II) Sounding Rocket Campaign in Summer/Fall 2004 that NASA Headquarters Office of Space Sciences has entertained research options that include Kwajalein as a launch site. Over the past few years, budgetary considerations have prohibited the program from offering research opportunities from this launch site. This appears to have been reversed now that the Sounding Rockets Program Office has once again been able to secure a healthy budget.

A Terrier–Malemute (left) and a Nike–Orion (right) ready for launch during the Kwajalein campaign in 2004.

The campaign in 2004 provided significant new information about the processes responsible for initiating irregularity structure in the ionospheric E and F region at the equator, and there has been great interest in the research community in returning to the site for further studies. Kwajalein offers researchers the unique opportunity to conduct experiments in the low-latitude ionosphere near the equator at a location with excellent ground-based support instrumentation, including the high-power and very sensitive ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR). Due to the limited availability of viable equatorial launch sites, especially sites with good ground-based instrumentation, research opportunities for rocket flights in this critical region have only been available once per decade on average, as compared with yearly research opportunities in the polar regions.

High Altitude Solar- and Astrophysics missions

Higher altitude flights for solar- and astrophysics missions, launched from Wallops Island, are being evaluated. Development efforts will focus on a water recovery system for high flying payloads with as much as 1000 lbs of reentry mass. This would enable the use of higher performance vehicles such as the Black Brant X, Black Brant XI, and Black Brant XII. The use of these vehicles would increase observation time by a factor of two, compared to the solar- and astrophysics payloads currently launched on Black Brant IX’s from White Sands Missile Range in New Mexico.

High Data Rate Telemetry

Increased telemetry rates have the potential to enable significant advances in a number of experiment areas, including the detection of multiple component High Frequency plasma waves, high speed auroral imaging, and high resolution spectrometry. Current development efforts will lead to data rates of up to 200 Mbps for missions that have such requirements. Past flights with high-speed telemetry systems include 39.008 LeClair, which used a Ku-Band system achieving 200 Mbps. Future options include new PCM encoders and X-band systems. Both are capable of higher data rates than the most common system in use today at 10 Mbps.

White Sands Facility Upgrades

In response to numerous requests from experimenters to address cleanliness for sensitive instruments and due to the aging facilities, upgrades to the LC-36 Vehicle Assembly Building (VAB) at the White Sands Missile Range are starting to take shape. The first phase will add a new “clean” integration laboratory with a clean tent and standard lab equipment and benches, as well as office space on the second floor to be used by NSROC and transient experiment teams. Phase 1 is set to begin in the fall of 2009 with completion hopefully by the summer of 2010. Should future funding become available, a second phase is being planned that will include a dedicated solar laboratory, pneumatics laboratory, air bearing room and small integration area. After completion of both phases, the program will consolidate all operations into the VAB at LC-36. The facilities at LC-35 are being taken over by the Navy for use on their targets program, which continues to grow. In addition to these two projects, other upgrades are being planned to help with contamination control such as vestibule entranceways and the addition of an HVAC system for the low bay. These upgrades are expected to lead to improved efficiency for integration and launch operations and significant energy, and operation and maintenance cost savings for the program.

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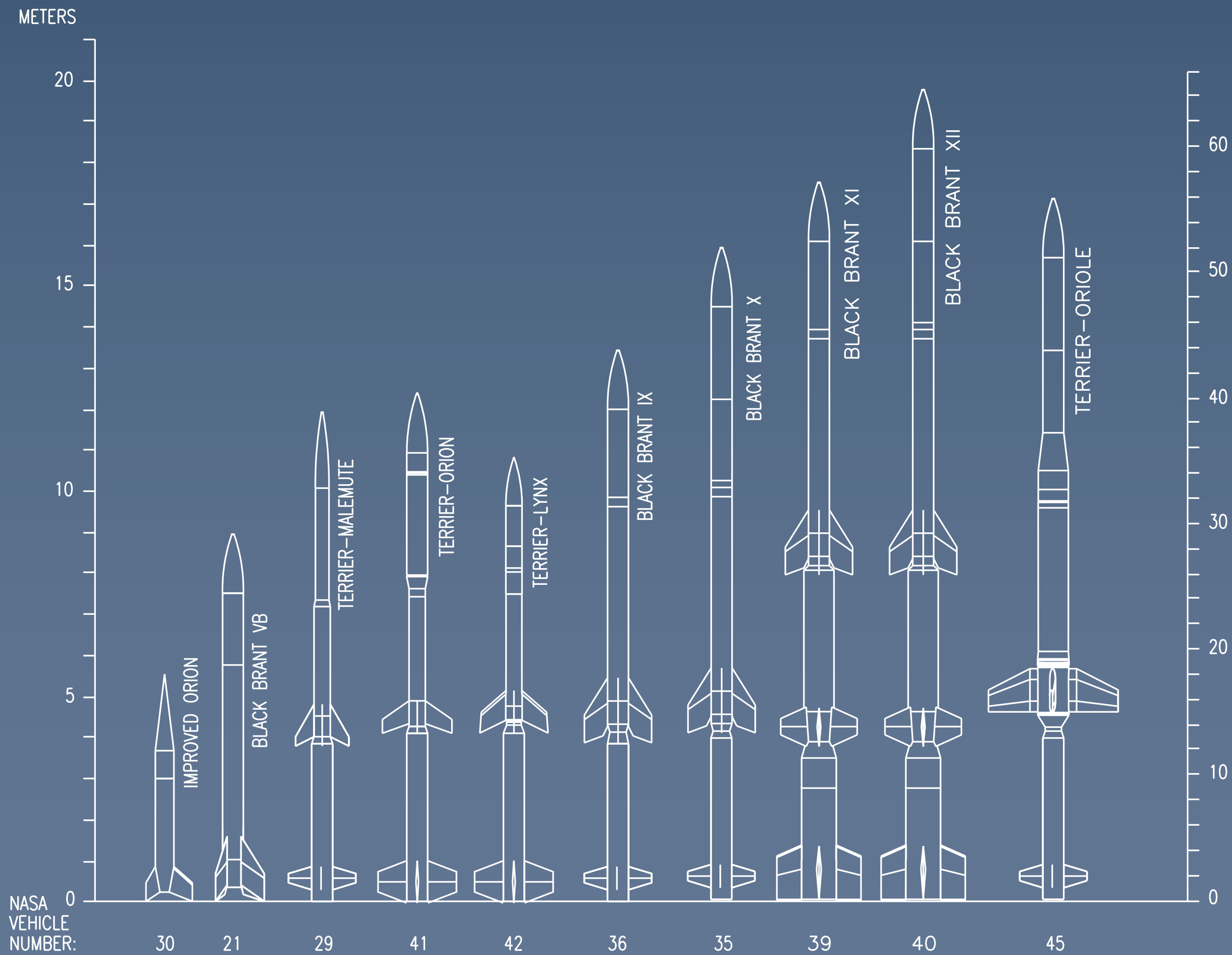
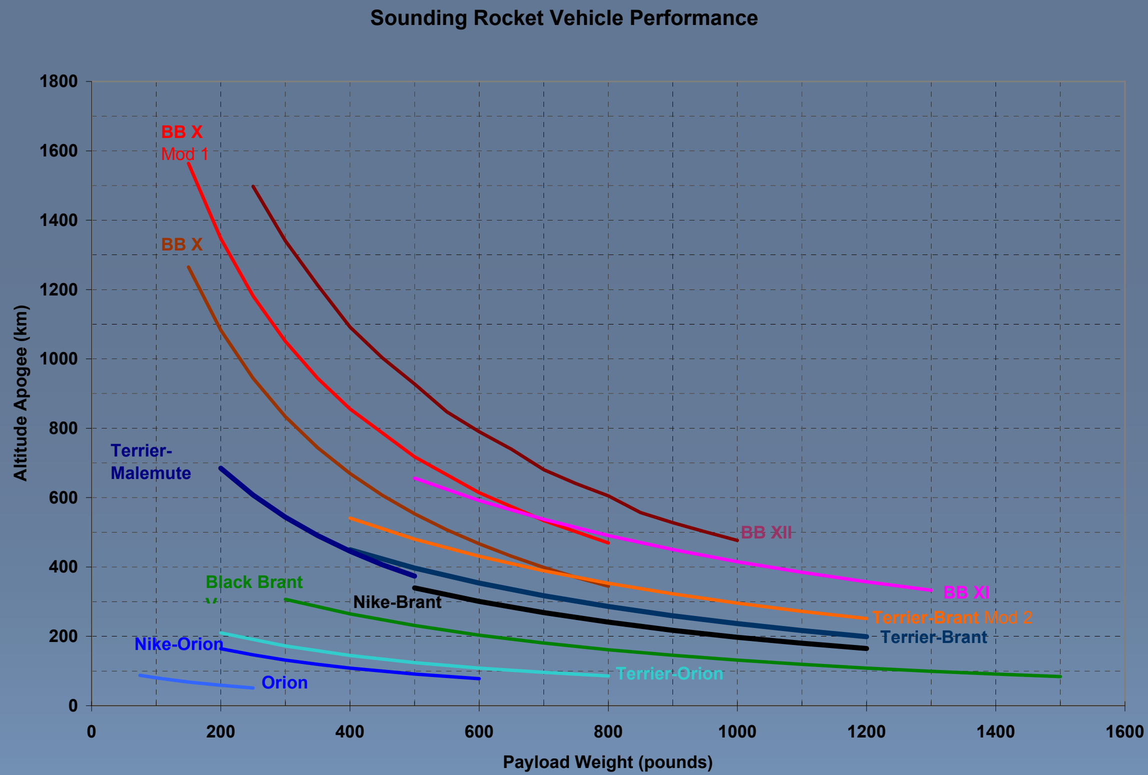
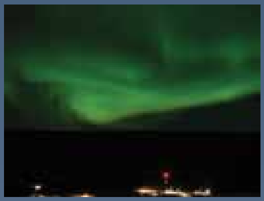
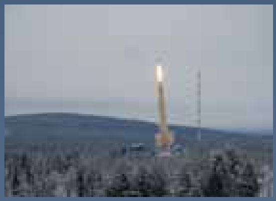


Ten vehicles ranging from a single stage Orion to a four stage Black Brant XII make up the core of the Sounding Rockets Program. New vehicles, the MLRS–Dart and Terrier–Improved Malemute will be added in the near future. Above: relative scale of the currently available vehicles. Below: Vehicle performance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





Poker Flat, Alaska

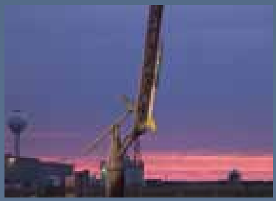


Esrange, Sweden

Kwajalein, Marshall Is.

Andoya, Norway

Woomera, Australia

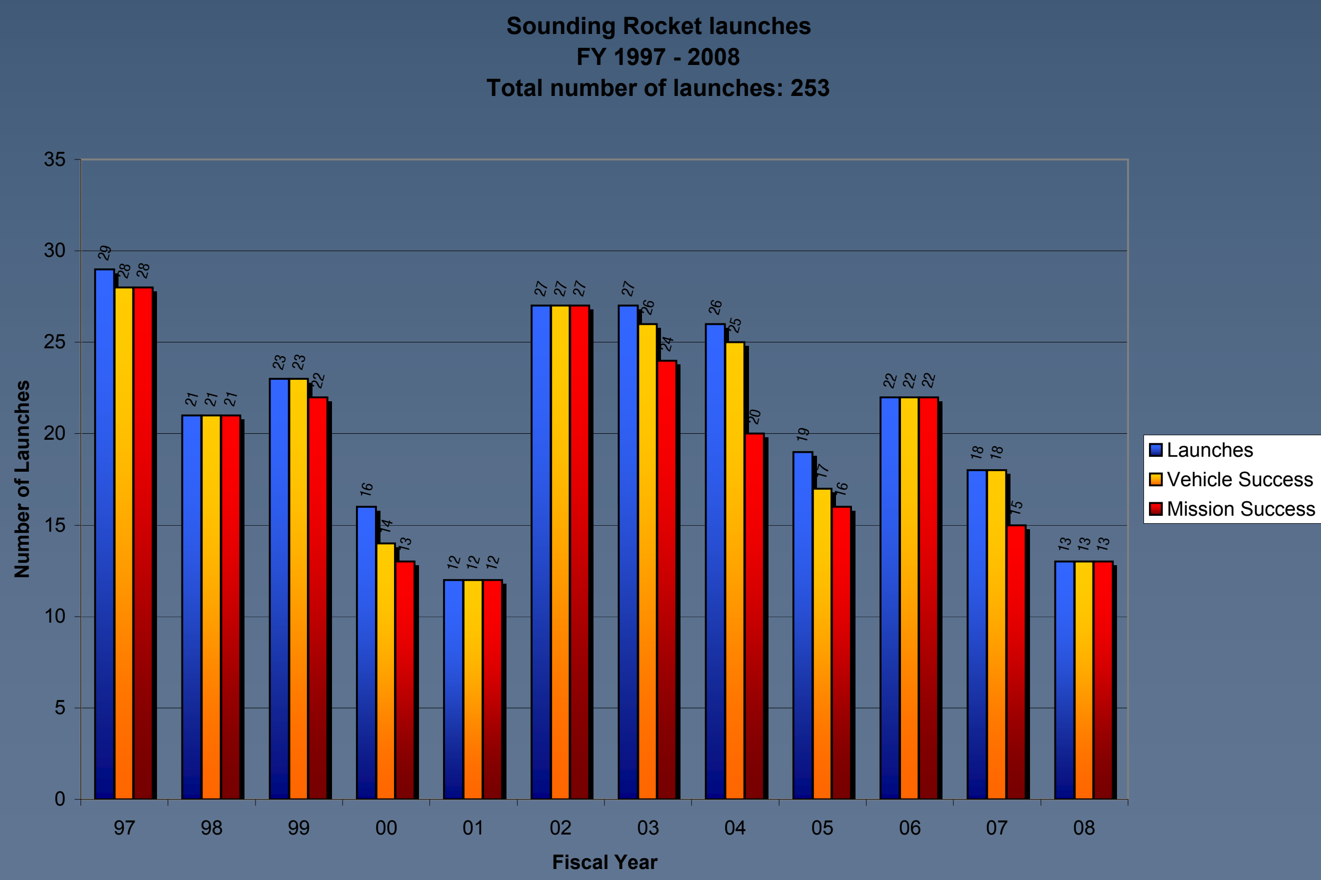


Wallops Island, VA

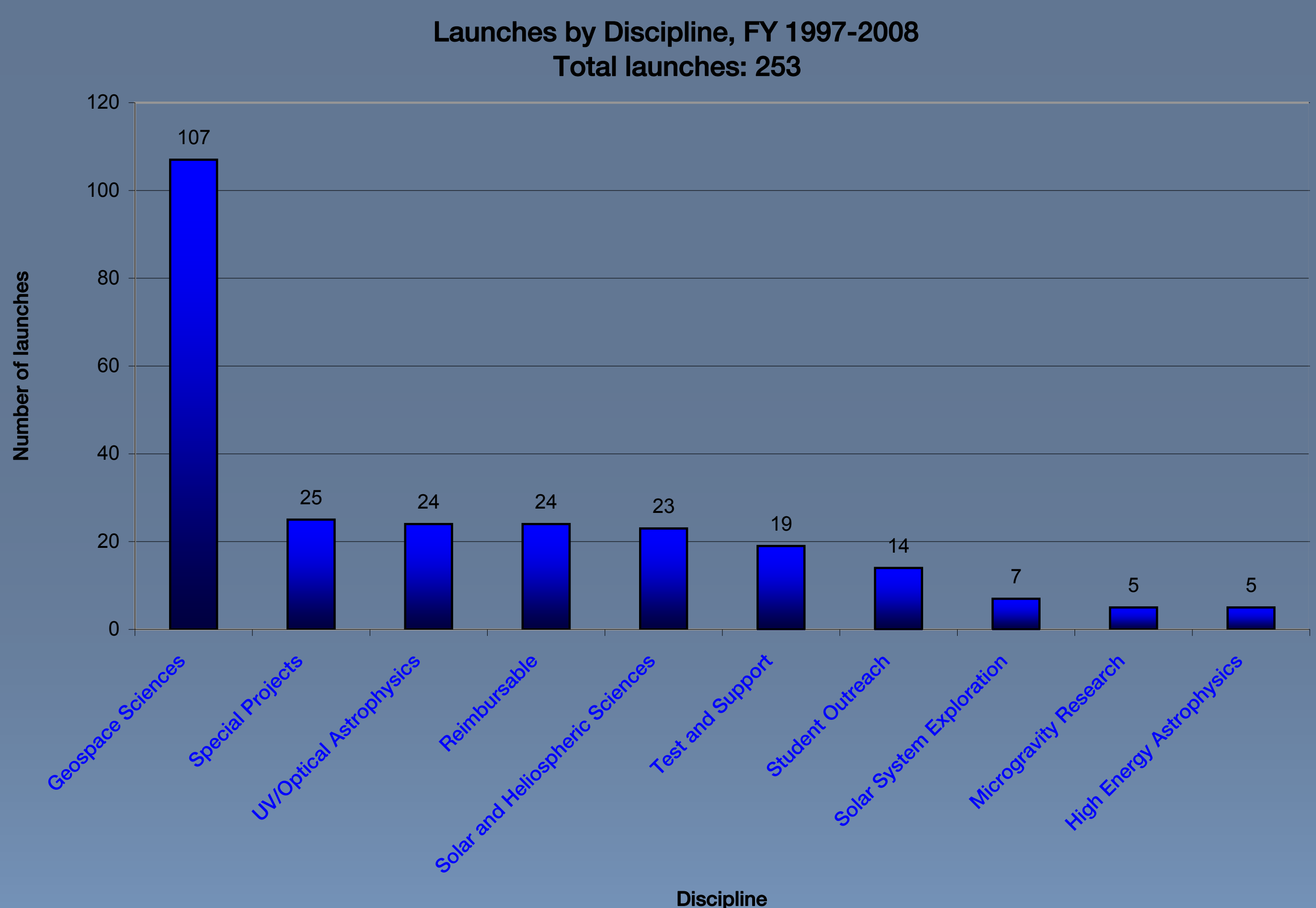
Past and present world wide launch sites used by the Sounding Rockets Program
to conduct scientific research:

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

* Inactive launch sites



Sounding Rocket launches
FY 1997 - 2008
Total number of launches: 253
Number of Launches
Fiscal Year
97
98
99
00
01
02
03
04
05
06
07
08
Launches
Vehicle Success
Mission Success
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
13 13 13



Launches by Discipline, FY 1997-2008
Total launches: 253
Number of launches
Discipline
Geospace Sciences
107
Special Projects
25
UV/Optical Astrophysics
24
Reimbursable
24
Solar and Heliospheric Sciences
23
Test and Support
19
Student Outreach
14
Solar System Exploration
7
Microgravity Research
5
High Energy Astrophysics
5

List of figures 2008 missions

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Images show the Mesquito Dart on the spin-balancing table, vehicle at lift-off and pre-flight preparation. Dave Krause and Andy Owens inspect the Dart on the spin-balancing table, Reginal Justis and Jim Hoffman prepare fins prior to flight.
Photo credit: Berit Bland/launch and testing photo,Andy Owens fin preparation image.

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Images show the area observed by the XQC telescope during the mission and the vehicle ready for launch at White Sands, NM.
Photo Credit: Visual Information Branch, White Sands Missile Range, NM and Dr. McCammon/University of Wisconsin.

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Images show lift-off from Wallops Island, payload in the spin-deployment facility and on-board camera views of the Black Brant motor and the free flying objects.
Photo credit: Berit Bland/launch and testing photo, Dr. LeClair onboard camera images.

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Images show students with one of the experiment post flight, vehicle lift-off on Wallops Island, and a group photo of all participants.
Photo credit: Berit Bland/BBCO/Code 810

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Images show Sub-TEC II during integration and testing and launch. Karl Haugh and Clay Merscham preparing for spin-balancing and Bernita Justis and Nick Cranor conducting electrical checks.
Photo credit: Berit Bland/testing and integration photos, Wallops Imaging Lab/Launch photo

Credits

Page	Photo by
Cover:	Aurora photo: Scott Hesh/NSROC, Supernova 1987A: Hubble Space Telescop, P. Challis (Harvard-Smithsonian Center for Astrophysics), Cynus Loop: Hubble Space Telescope, J.J. Hester (Arizona State University) and NASA, Black Brant XI lift-off: Wallops Imaging Lab, Cover design by Berit Bland/Code 810/BBCO
2	Wallops Imaging Lab
4	Kohlbjorn Dahle, Andoya Rocket Range, Norway
6	Solar images: SOHO, Trifid Nebula: Hubble Space Telescope, Orion Trapezium: Dr. Stephen McCandliss, Aurora over Andoya: Kohlbjorn Dahle, Andoya Rocket Range, Norway, Noctilucent clouds: Ben Fogle, University Corporation for Atmospheric Research
8	Visual Information Branch, White Sands Missile Range, NM
9	Visual Information Branch, White Sands Missile Range, NM
11	Orion launch: Berit Bland/Code810/BBCO, Aurora over Andoya: Kohlbjorn Dahle, Andoya Rocket Range, Norway, Payload image at Wallops: Berit Bland/Code810/BBCO, Trapezium: Dr. Stephen McCandliss, Night photo of vehicle on launch pad: Wallops Imaging Lab, People with payload at White Sands: Visual Information Branch, White Sands Missile Range, NM
24	Wallops Imaging Lab
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26	S-19 photo by SAAB Aerospace, remaining photos by Berit Bland/Code810/BBCO
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42	Kwajalein pad photo by Bruce Scott/NSROC, Kwajalein launch photo by nowhereatoll.com, Trapezium: Dr. Stephen McCandliss, BB XII launch photo by Wallops Imaging Lab, Solar image by SOHO, Telescope model by Dr. Douglas Rabin/NASA GSFC
43	Bruce Scott/NSROC

Graphic design & layout: Berit Bland/BBCO/Code 810

Editor: Jan Jackson/NSROC

References

36.218 UE Design Review Data Package and findings report, Dr. Gregory Earle

36.241 GS Design Review Data Package and findings report, Dr. Douglas Rabin

40.018 & 40.022 UE Design Review Data Package, Dr. Craig Kletzing

36.243 UG Information provided by Dr. Stephen McCandliss

40.021 UE Design Review Data Package and information provided by Dr. Paul Kintner

36.240 UE Information provided by Dr. Tom Woods

36.233 UH Information provided by Dr. Dan McCammon

30.074 NO Design Review Data Package and NASA mission press release

41.075 NP Design Review Data Package

39.008 DR Design Review Data Package

12.065 & 12.066 Design Review Data Package and other NASA sources

NSROC Capabilities Document 2003

Northrop Grumman TS Magazine RTAS article by Jan Jackson

Appendix A

This is a list of the publications supported in part or in full by NASA Grant NNG04WC02G, Principal Investigator: Dr. Webster Cash/University of Colorado. Most are reports in the SPIE, chronicling the development of the payload and the application of its grating technology to the Constellation-X mission. The scientific results are presented in the final two listed.

• Cash, W. and Shipley, A., “Off-plane Grating Mount Tolerances for Constellation-X,” Proc. Soc. Photo-Opt. Instr. Eng., 5488, 335-340, 2004

• Flanagan, K. A., et al, “The Constellation-X RGS Options: Status of the Grating Trade Study,” Proc. Soc. Photo-Opt. Instr. Eng., 5488, 515-529, 2004

• McEntaffer, R., and Cash, W., “High Resolution X-ray Spectroscopy of Supernova Remnants and the Diffuse X-ray Background,” Proc. Soc. Photo-Opt.Instr. Eng., 5488, 136-147, 2004

• Osterman, S., McEntaffer, R., Cash, W., Shipley, A., “Off-plane Grating Performance for Constellation-X,” Proc. Soc. Photo-Opt. Instr. Eng., 5488, 302-311, 2004

• Cash, W., “High Resolution X-ray Spectroscopy: Is It Interesting? Is It Possible?,” Advances in Space Science”, in press 2004.

• Randall L. McEntaffer, Webster Cash, Ann Shipley, “Sounding rocket payload development for x-ray observations of the Cygnus Loop,” Proc. Soc. Photo-Opt.Instr. Eng., 5900, 1B1-1B12, 2005

• Nishanth Rajan, Webster Cash, “Kirkpatrick-Baez optics for the Generation-Xmission,” Proc. Soc. Photo-Opt. Instr. Eng., 5900, 1F1-1F7, 2005

• Shipley, A., Gleeson, B., McEntaffer,R., Cash, W., “Studies in thin diffraction gratings for flight applications,” Proc. Soc. Photo-Opt. Instr. Eng., 6273, 3K, 1-10, 2006

• McEntaffer R., Cash, W., Shipley, A., Schindhelm. E., “A sounding rocket payload for x-ray observations of the Cygnus Loop,” Proc. Soc. Photo-Opt. Instr.Eng., 6266, 44, 1-12, 2006

• Osterman, O., Cash, W., “Kirkpatrick Baez spectrograph concepts for future space missions,” Proc. Soc. Photo-Opt. Instr. Eng., 6266, 38, 1-8, 2006

• Schindhelm, E., Arav, N., Cash, W., “High-resolution x-ray spectroscopy with the reflection grating spectrometer of Constellation-X,” Proc. Soc. Photo-Opt. Instr.Eng., 6266, OC 1-11, 2006

• Lillie, C. F., Cash, W. C., “High Resolution Soft X-ray Spectroscopy for Constellation-X, Proc. Soc. Photo-Opt. Instr. Eng., 6686, 2007

• McEntaffer, Randall, L., Cash, Webster, and Shipley, Ann, “Off-plane reflection gratings for Constellation-X,” Proc. SPIE, 7011, 701107, 8pp, 2008

McEntaffer, R. L., and Cash, W., “Soft X-ray Spectroscopy of the Cygnus Loop Supernova Remnant,” ApJ, 680, 328-335, 2008

McEntaffer, Randall, “X-ray Spectroscopy of the Cygnus Loop,” Doctoral Dissertation,University of Colorado, 2007

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