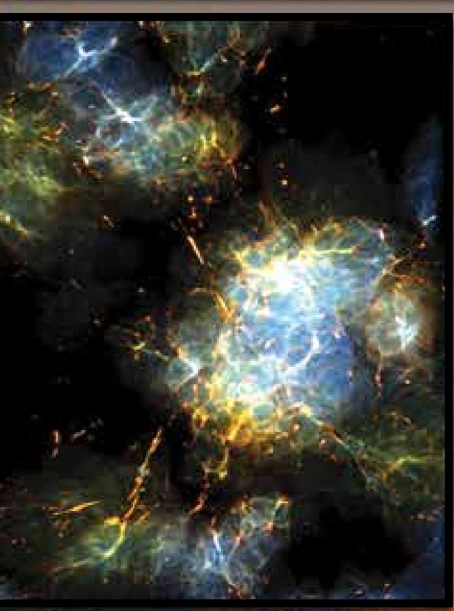
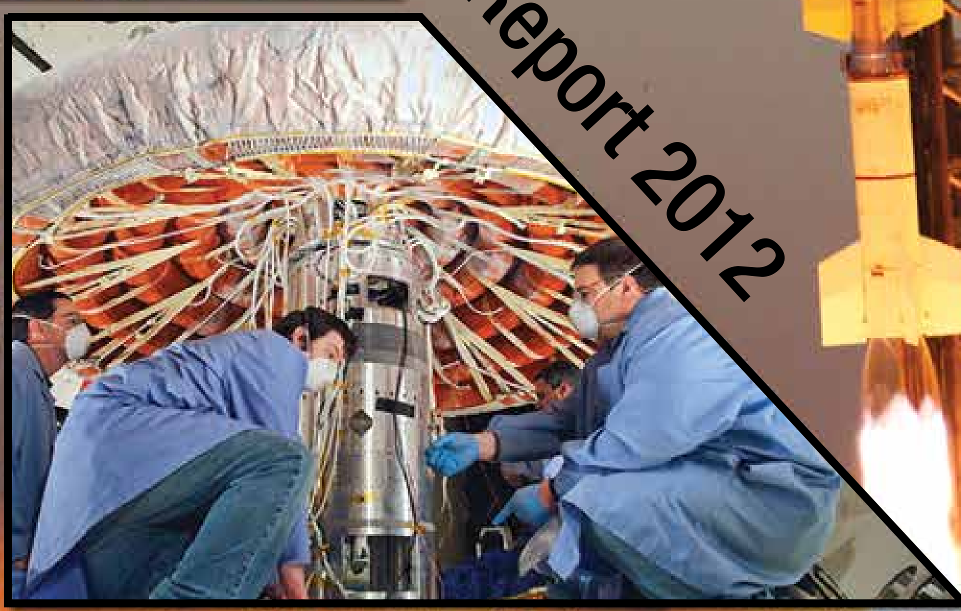
National Aeronautics and Space Administration

NASA Sounding Rockets Annual Report 2012





The Sounding Rockets Program was very busy in 2012, with scientific instruments being launched that made significant contributions to the nation's goal to remain a leader in scientific discovery. The highest resolution images ever recorded of the Sun were captured with the Hi-C sounding rocket telescope flown from White Sands, New Mexico, the high altitude jet stream at 120 km was studied in depth using five rockets launched within a brief seven minute period from Wallops Island, Virginia and the third underflight calibration mission for NASA's Solar Dynamics Observatory was successfully launched in June. Additionally, several astrophysics and technology missions enhanced our understanding of the Universe and furthered technologies for future space missions. Along with supporting scientific missions, the program continued to invest in subsystems development and vehicle technologies to provide researchers with higher data rates, finer instrument pointing, and more options for launch vehicles.

Education has always been a fundamental part of the Sounding Rockets Program; today's graduate students are tomorrow's scientists. The short mission lead times, sometimes less than a year, make sounding rockets optimal training platforms giving students the opportunity to participate in spaceflight missions from concept to launch. Involvement in a sounding rocket flight includes theoretical studies as well as nuts and bolts technology and engineering, giving students a unique, well-rounded, in-depth experience. In 2012, two dedicated university student missions were conducted. Approximately 100 undergraduate students from around the nation were offered opportunities at several levels of complexity, ranging from a standardized experiment to experiments completely designed and constructed by students. The program also continued to build a foundation for inspiring high school students by once again offering the Wallops Rocket Academy for Teachers and Students, where teachers from across the country were given skills and materials needed to enable the incorporation of spaceflight concepts into their classrooms. Our philosophy of "teaching the teachers" is an excellent investment that will have positive impact for years to come.

Sounding rockets offer world class support to scientists engaged in unique research. This world class support is provided by highly dedicated, extraordinarily competent, and innovative men and women working for NASA's Sounding Rockets Program in both civil service and contractor organizations. I, as well as everyone else supporting the program, am proud to play an important role in NASA's quest for scientific knowledge.

Phil Eberspeaker
Chief, Sounding Rockets Program Office

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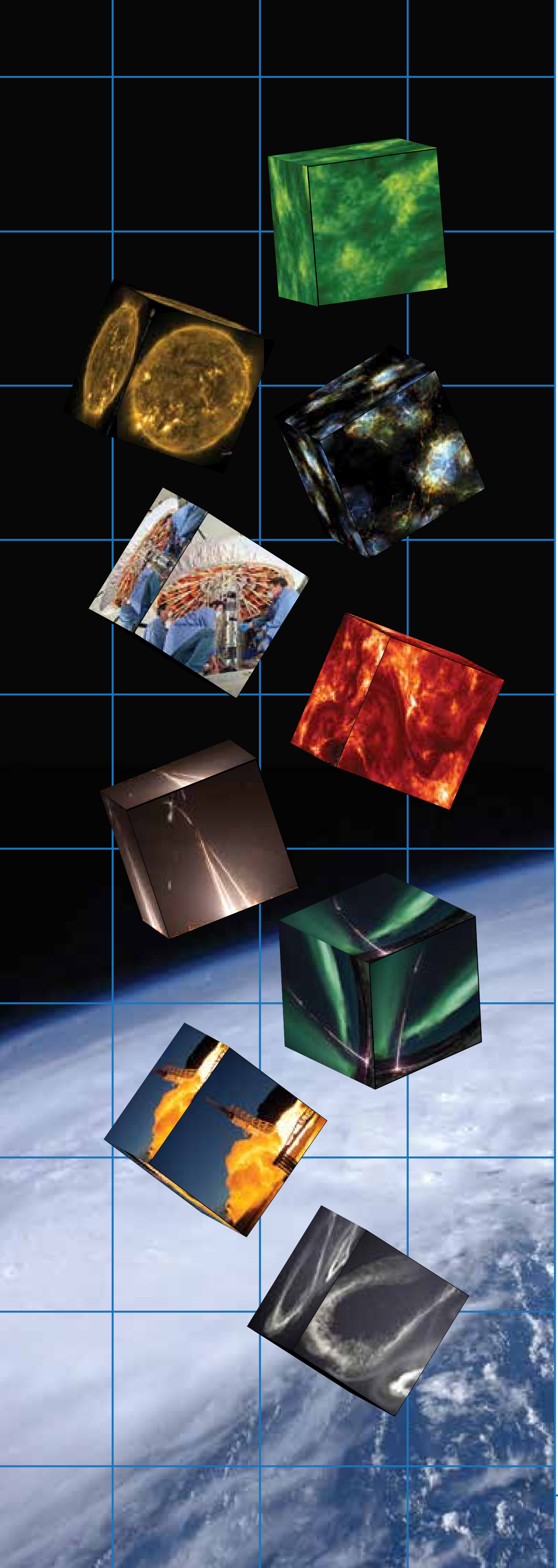


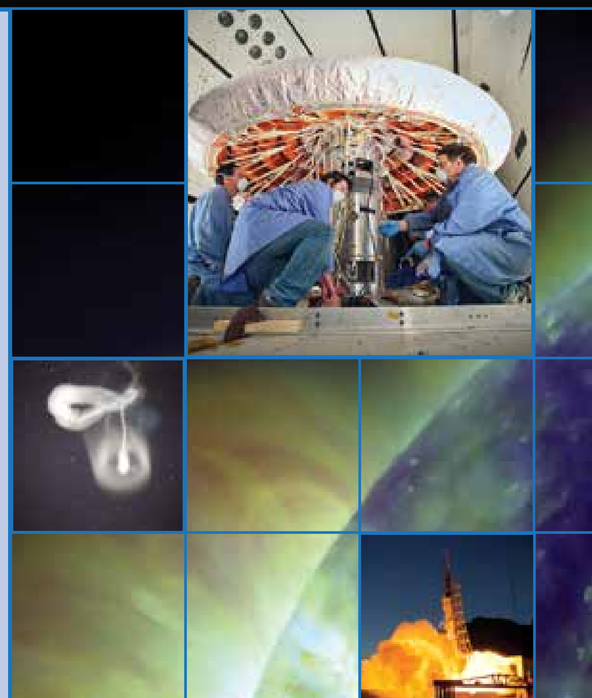
Introduction

The Sounding Rockets Program supports the NASA Science Mission Directorate's strategic vision and goals for Earth Science, Heliophysics and Astrophysics. The approximately 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 worldclass 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 on board 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. 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 NASA's latest probe, the Solar Dynamics Observatory (SDO).

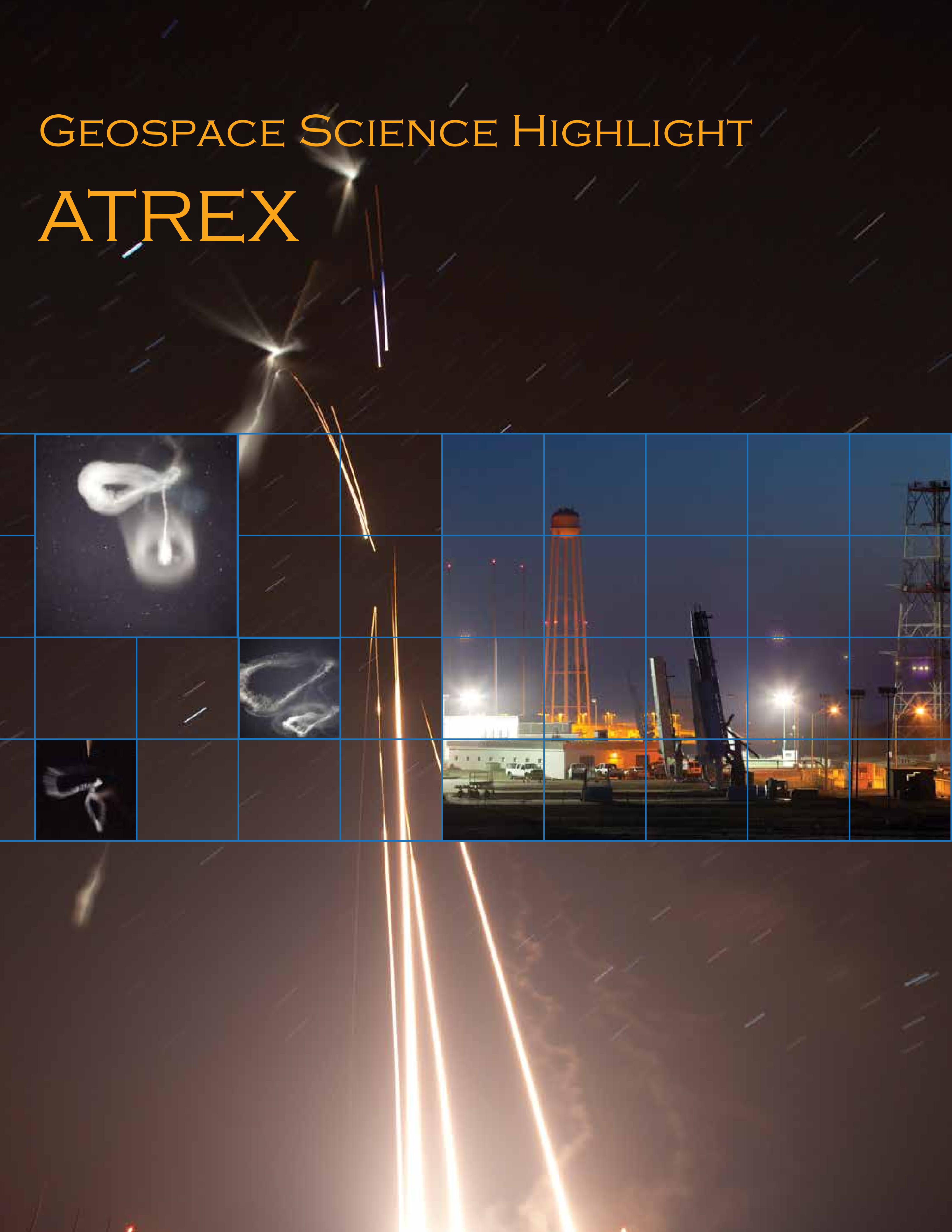
Missions 2012

Sixteen science, technology and education investigations, using a total of 21 vehicles, were flown in 2012. A planetary imaging mission started the Fiscal Year with a launch from White Sands Missile Range, NM. Technology development missions focused on new vehicle configurations with two successful testflights. Two geospace science investigations, one each from Poker Flat, Alaska and Wallops Island, VA focused on ionospheric phenomena such as the Aurora Borealis and measuring high altitude winds. Several missions to study the Sun were flown in 2012, including the Hi-C instrument which resulted in unprecedented images of the solar corona. Two education missions included student experimenters from universities around the country.



Geospace Science Highlight

ATREX



Anomalous TRansport EXperiment

ATREX

Principal Investigator:
Dr. Miguel Larsen
Clemson University

Mission Number:
41.097 UE
41.098 UE
45.004 UE
46.002 UE
46.003 UE

Launch site:
Wallops Island, VA

Launch date:
March 27, 2012

The ATREX Experiment:

Jetstreams in the Earth's Geospace Region

The jetstream is now a well-known feature of our atmosphere's global weather system. Most people are familiar with the band of enhanced winds located near the base of the stratosphere where many commercial aircraft fly. Flights are often helped by strong tail winds or hampered by strong head winds. Maps that show the location of the jetstream are a regular feature of the evening weather forecast on local television stations or the Weather Channel.

Clear evidence of the existence of the jetstream as a regular feature in the atmosphere did not emerge until the second World War when long flights across the Atlantic and Pacific became common. As aircraft performance improved and aircraft routinely started to fly at higher altitudes, it quickly became apparent that strong winds with a general west to east direction were a common characteristic at altitudes near 30,000 feet.

During the last decade, new evidence has shown that another band of strong winds and significantly enhanced transport exists much higher in the atmosphere, in the region that we typically think of as the Earth's near-space environment, or geospace, as it is also known.

The geospace atmosphere is a tenuous gas with a mixture of charged and neutral gas particles. The flow of the neutral portion of the atmosphere is particularly difficult to measure at those heights because the gas densities are low. Some of the first measurements became possible in the late 1950's when new high-power rockets became available that could reach that part of the atmosphere, and at least a few of those early rocket flights involved the use of luminous chemical tracers that were released from the rockets to measure the winds by tracking the releases with cameras on the ground.

Over the next four decades more than 500 such measurements were made of the wind profiles at locations around the world in different seasons and at different times of day. The wind measurements from the large rocket data set were analyzed by Prof. Miguel Larsen from the Department of Physics & Astronomy at Clemson University and described in a journal article published in 2002.

A surprising result was that nearly all the measurements, showed a region with very strong winds between 100 and 110 km altitude (62 to 68 miles). The peak winds were often between 100 and 150 meters per second (225 to 335 m.p.h.). Such large winds at those heights are difficult to explain based on our current understanding of the forces that drive the winds at those altitudes. The analysis provided the first evidence of the high-speed flows at high altitudes based on an extensive set of data.

Additional critical information came to light soon after as a result of the long series of Space Shuttle launches carried out in the last two decades.

The Shuttles were launched from Florida and after the initial ascent would settle into a long, nearly horizontal flight path along the east coast of the United States as they burned the fuel in the main motor and accelerated to get into final orbit. The horizontal portion of the flights occurred in the altitude range between 100 and 110 km, which coincidentally is where the large winds were observed with the sounding rocket tracer releases. The height chosen for the horizontal burn was based on orbital dynamics rather than any particular relation to the atmospheric winds.

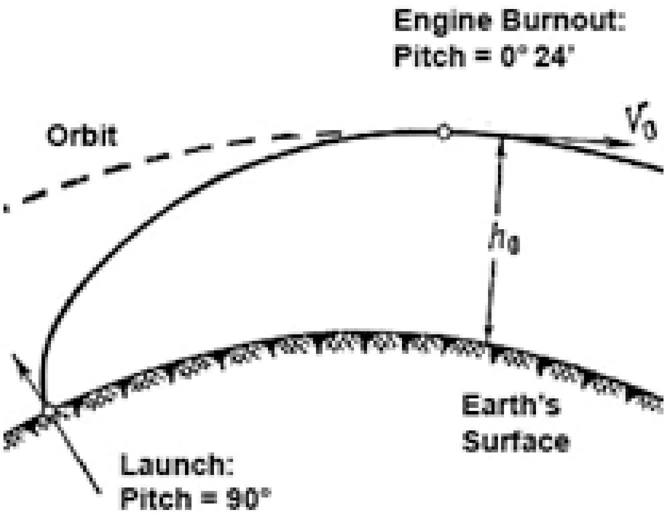


Diagram showing the typical initial flight path of the Space Shuttle, including the long, nearly–horizontal flight path during the main motor fuel burn.

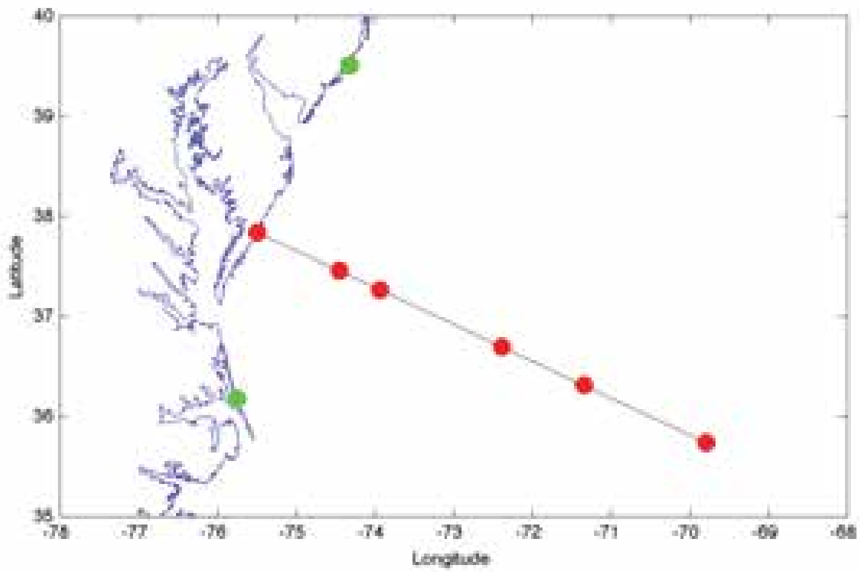
A product of the combustion during the main motor burn was a large quantity of water vapor that was deposited in the high windspeed region. A group led by researchers from the Naval Research

Lab in Washington, DC, decided to try to track the Shuttle exhaust products using special cameras on orbiting satellites that could detect the optical wavelengths associated with the water vapor clouds. The tracking was very successful, which was surprising since locating and following the cloud over a period of several days was expected to be difficult. The results were also surprising because they showed a rapid movement of the cloud from the location at mid latitudes where the launch occurred to the polar regions in a period as short as a day or two.

Based on the long sequence of rocket wind measurements, the fact that the Shuttle exhaust cloud experienced high wind speeds was not surprising, but the fact that the cloud was transported across a large part of the globe so rapidly was unexpected. A less surprising result would have been that the water vapor cloud moved rapidly but chaotically, as might be expected from the effect of wave buffeting. Instead, the observations showed a strong coherent flow, of the type typically associated with an atmospheric jetstream.

Theoretical predictions for the winds at the high-altitude jetstream height show wind systems dominated by atmospheric tides driven by solar heating. Such tides are expected to have maximum wind speeds that are half or less of the peak winds that are observed. The motion for a cloud embedded in a tidal flow is expected to be a slow elliptical motion that returns the cloud to its original position after a fraction of a day. The transport of the Shuttle exhaust cloud is more similar to the high-speed transport and large north-south swings that characterize the lower atmosphere jetstream, although with much larger wind speeds.

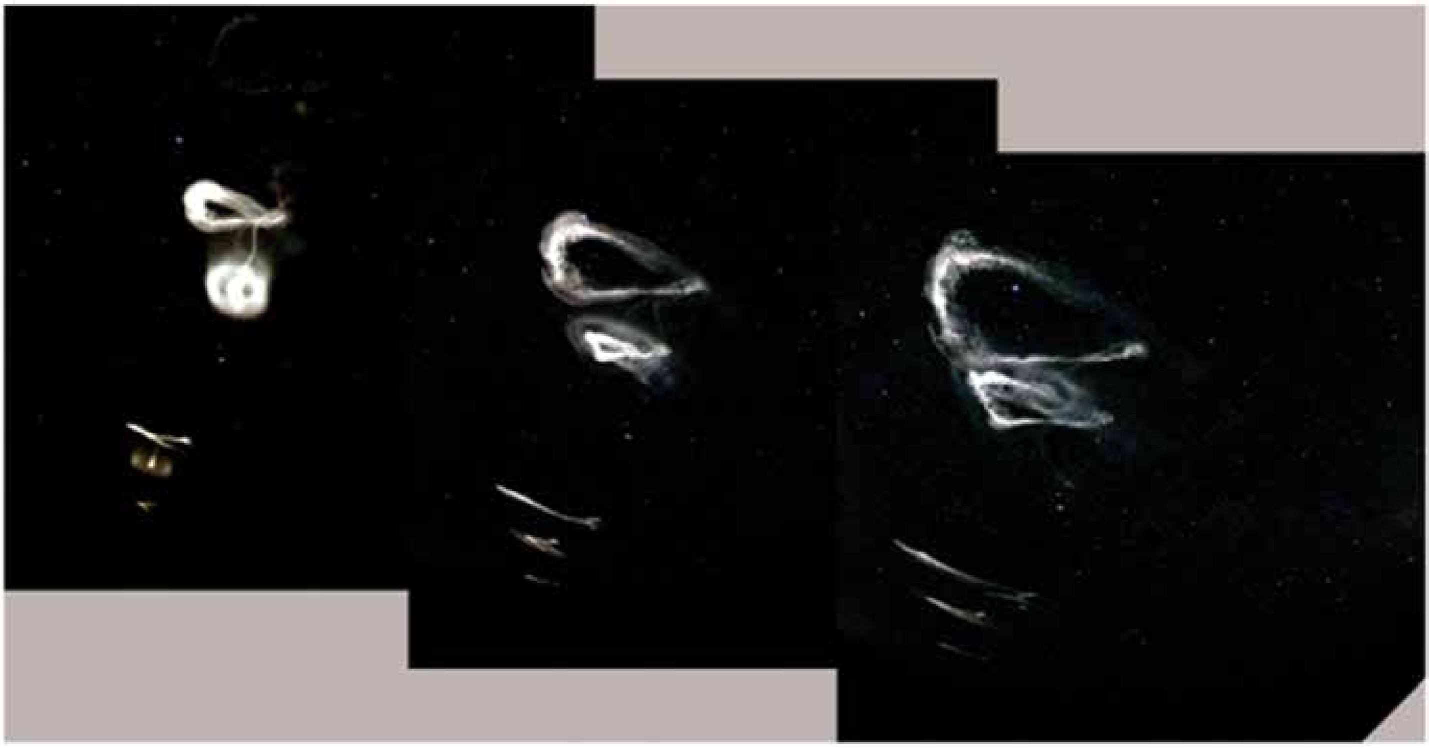
Prof. Miguel Larsen from Clemson University is the Principal Investigator for the Anomalous Transport Rocket Experiment (ATREX). Dr. Gerald Lehmacher from the same institution is the co-investigator responsible for the instruments flown on two of the five rockets. The chemical tracer used in the experiment is trimethyl aluminum, a chemical that reacts with oxygen and produces chemiluminescence when exposed to the atmosphere. The products of the reaction are aluminum oxide, carbon dioxide, and water vapor, which also occur naturally in the atmosphere. The launches were carried out on March 27, 2012, from Wallops. The launch azimuth and approximate distribution of the trail releases is shown in the figure below. Cameras at locations in New Jersey and North Carolina, as well as at the launch site, were used to track the trails as they moved across the night sky. All five rockets were launched within a period of a few minutes, and all the trails were visible at the same time.



Red dots show the location of the tracer releases in the ATREX experiment. Green dots show the camera sites used to support the experiment.

The figure on the next page shows a sequence of three images taken from the Wallops camera site. The photographs cover a total interval of 5 minutes and show the evolution of the five down-range trails. The rapid expansion of the trails in the altitude range near 100 km due to the high-speed winds is evident. Very similar structure is also apparent in the five trails. The trails closest to the launch site show a loop structure due to the rotation of the winds with height. The loops are seen edge-on in the trails that are further away, but the same general rotation of the winds with height is present in those trails. The preliminary results therefore show evidence that the high-speed flows in the lower thermosphere region are large-scale features, consistent with the idea that they are part of a large circulation feature.

The more detailed analysis of the turbulence structure in the trails, which is the primary objective of the experiment is ongoing. The calculations required to obtain the turbulence structure functions, which determine the nature of the turbulent transport and the associated dynamical processes, involve calculations of squared differences for every combination of trail pixels in each image, i.e., all combinations for each individual trail, as well as all combinations between separate trails, a job that requires highly efficient computational algorithms and supercomputing speeds. The computing



A sequence of three photographs taken from a camera site at the NASA/Wallops Flight Facility that shows the five downrange trimethyl aluminum trails. These three photographs were taken 2 1/2 minutes apart. The rapid displacement of the tracers due to the high–speed winds is evident. The loops seen in the two trails closest to the launch site are seen edge–on. It is clear that the same wind structure exists over the entire range covered by the releases, indicating that the high–speed winds are a large–scale feature rather than random local fluctuations in the winds.

algorithms have been developed and are being implemented. First results from the analysis of a single trail suggest that structure expected for quasi-two-dimensional turbulence is present in the trails as they expand to the largest scales that were observed. Determining if there is evidence for this type of turbulence is one of the objectives of the experiment since two-dimensional turbulence is a means for producing large-scale coherent winds.

More comprehensive results are expected by the spring of next year, approximately one year after the launch.

Charge and mass of Meteoritic Smoke Particles

CHAMPS

Principal Investigator:
Dr. Scott Robertson
University of Colorado

Mission Number:
41.093 & 41.094 UE

Launch site:
Andoya Rocket Range, Norway

Launch date:
October 11, 2011
October 13, 2011

The Charge and mass of Meteoritic Smoke Particles (CHAMPS) rockets were launched from Andoya Rocket Range in Norway on October 11 and 13. The scientific objectives of the two rockets were to detect and measure the density and size distribution of meteoritic smoke particles (MSP) in the mesosphere that have long been thought to be the condensation nuclei for noctilucent clouds. The data from the multichannel mass spectrometer showed positively and negatively charged MSPs below about 90 km with a density rising to about 5,000/cc below 70 km, with lower densities of charged particles in the daytime than at night. Few of these particles had radii above 1.2 nanometers. The launches were conducted from the Andoya Rocket Range in Norway in order to benefit from simultaneous meteor radar and lidar observations of winds and temperatures.

CHAMPS launch Andoya Rocket Range, Norway.

CHAMPS instrument deployment test.

Magnetosphere–Ionosphere Coupling in the Alfvén resonator

MICA

Principal Investigator:
Mr. Steven Powell
Cornell University

Mission Number:
36.273 UE

Launch site:
Poker Flat Research Range, AK

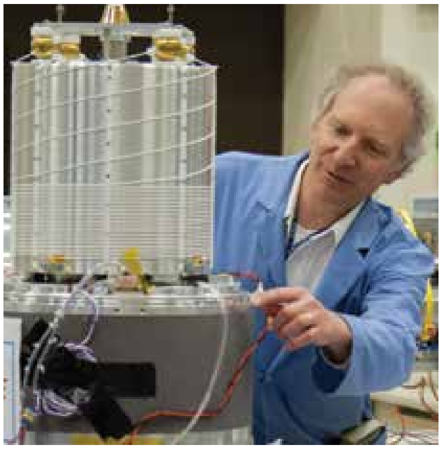
Launch date:
February 19, 2012

Web site: http://gps.ece.cornell.edu/

The MICA (Magnetosphere-Ionosphere Coupling in the Alfvén resonator) sounding rocket investigation, successfully launched on February 19th, 2012, combined science measurements from a sounding rocket along with data from a ground-based radar (the PFISR, Poker Flat Incoherent Scatter Radar) and auroral imagers, in order to provide a more complete scientific investigation of the ionosphere and of the space weather that effects our satellite-based electronic systems, such as GPS. The sounding rocket measured ion temperature and density, electron temperature and density, electron precipitation, ion upflow, convection and ULF electric fields, magnetic fields from which field-aligned current (FAC) can be inferred, and plasma waves. The objectives of the experiment were to investigate the role of active ionospheric feedback in the development of large amplitude and small scale electromagnetic waves and density depletions in the low altitude (<400 km), downward current, auroral ionosphere. Understanding how the ionosphere participates in providing the downward current is a critical component of understanding magnetosphere-ionosphere coupling. The payload consisted of both mature technology with heritage on multiple sounding rocket experiments and new technology developments that are looking forward to conducting experiments in the low altitude ionosphere, including auroral electron detectors with low voltage delta-doped CCD sensors and GPS TEC (Total Electron Content) receivers.

MICA launches from Poker Flat, Alaska.

The MICA payload and team during final assembly at the Poker Flat, Alaska launch site.

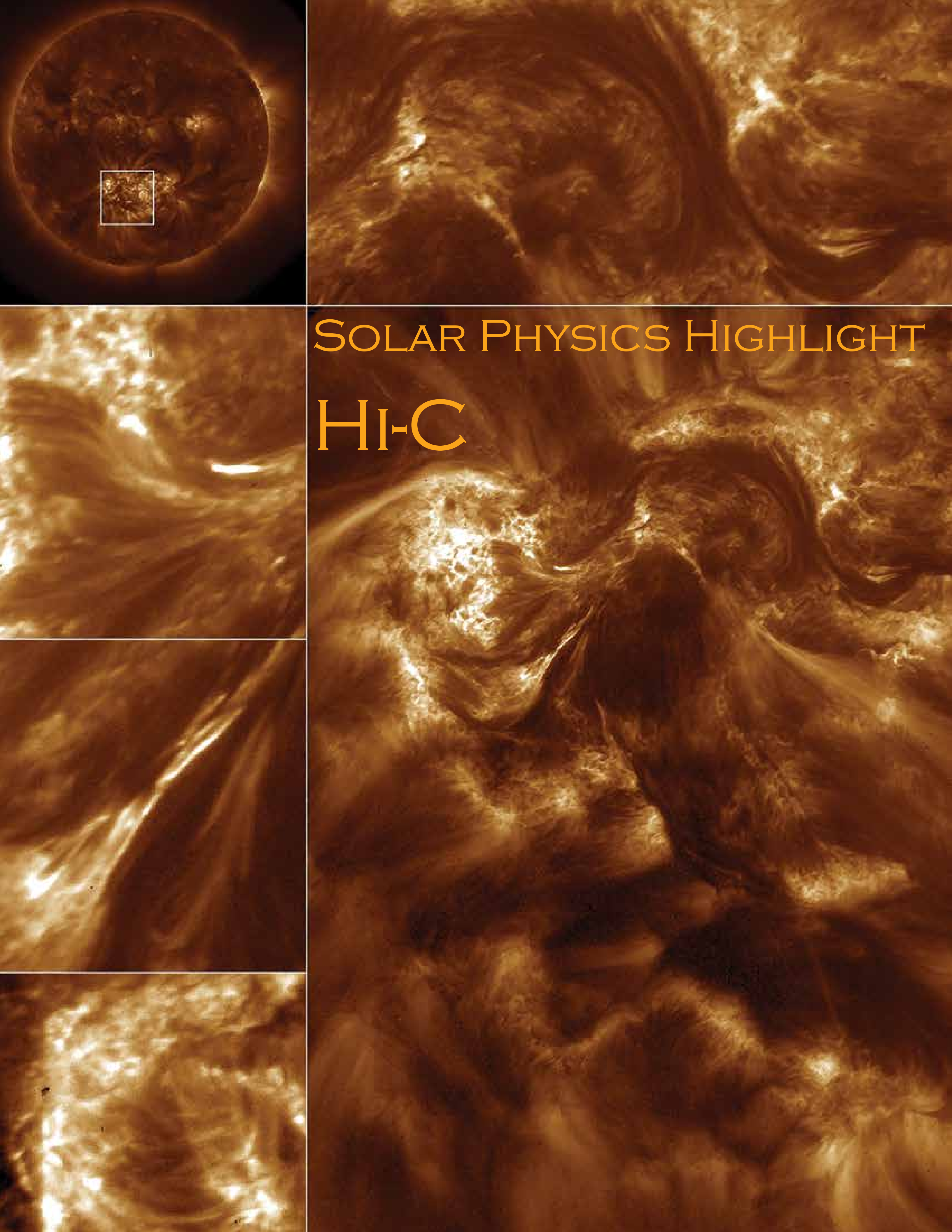


PI Steven Powell/Cornell University preparing Cornell wire–boom instrument for testing.

The electronics assembly of a Cornell designed and built scientific–grade GPS receiver that measures TEC (Total Electron Content). The MICA payload provided the first space flight opportunity for this new science instrument.

Solar Physics Highlight

Hi-C



High Resolution Coronal Imager

Hi–C

Principal Investigator:
Dr. Jonathan Cirtain
NASA Marshall Space Flight Center

Mission Number:
36.272 NS

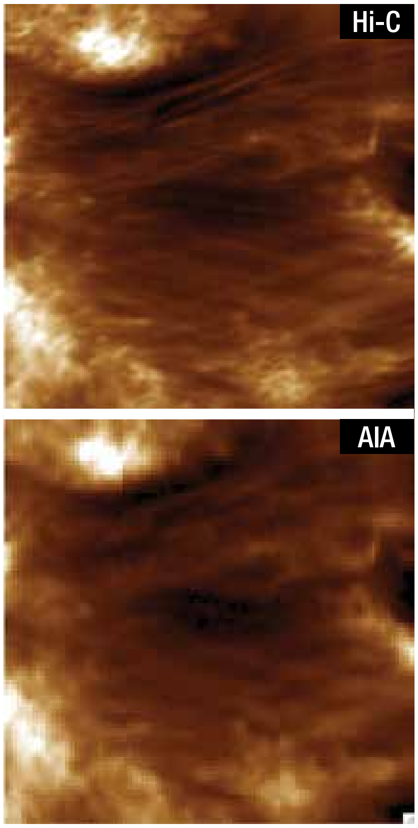
Launch site:
White Sands Missile Range, NM

Launch date:
July 11, 2012

The Hi-C mission launched on July 11, 2012 from White Sands Missile Range, NM captured the highest-resolution images ever taken of the sun's million-degree atmosphere called the corona. The clarity of the images can help scientists better understand the behavior of the solar atmosphere and its impacts on Earth's space environment. The high-resolution images were made possible because of a set of innovations on Hi-C's optics array.

The Hi-C instrument took 165 images during its 620-second flight, or roughly one image every 5 seconds. The telescope focused on a large active region on the sun with some images revealing the dynamic structure of the solar atmosphere in fine detail. These images were taken in the extreme ultraviolet wavelength. This higher energy wavelength of light is optimal for viewing the hot solar corona. Using a resolution 5 times greater than any previous imager, Hi-C observed the small-scale processes that exist everywhere in hot magnetized coronal plasma. Additionally, the mission was designed to study the mechanisms for growth, diffusion and reconnection of magnetic fields of the corona, and to help understand the coupling of small-scale dynamic and eruptive processes to large scale dynamics.

The collection of high resolution images obtained by Hi-C, may have a major scientific impact by placing significant new constraints on theories of coronal heating and structuring, by establishing whether or not there is additional fine structure below the current level of resolution. This instrument could push the limits on theories of coronal heating, answering questions such as why the temperature of the sun's corona is millions of degrees higher than that of the surface.



Images from the HI–C telescope (top) are the highest–resolution images ever taken of the sun's corona in the extreme ultraviolet wavelength. Bottom image shows the same region of the sun captured by the Solar Dynamics Observatory Atmospheric Imaging Assembly.

Solar Ultraviolet Magnetograph Investigation

SUMI

The SUMI mission was successfully launched on July 5, 2012 from White Sands Missile Range, NM to study the intricate, constantly changing magnetic fields on the sun in a hard-to-observe area of the sun's low atmosphere called the chromosphere.

Magnetic fields, and the intense magnetic energy they help marshal, lie at the heart of how the sun can create huge explosions of light such as solar flares and eruptions of particles such as coronal mass ejections (CMEs). While there are already instruments – both on the ground and flying in space – that can measure these fields, each is constrained to observe the fields on a particular layer of the sun's surface or atmosphere. Moreover, none of them can see the layer, in the chromosphere, SUMI observed.

Understanding the structure of the magnetic fields in this region will then allow us to understand how the corona is heated and how the solar wind is formed. It is also an area believed to be where flare accelerated particles originate, so understanding the processes at play in the transition region can help with models to predict such eruptions on the sun.

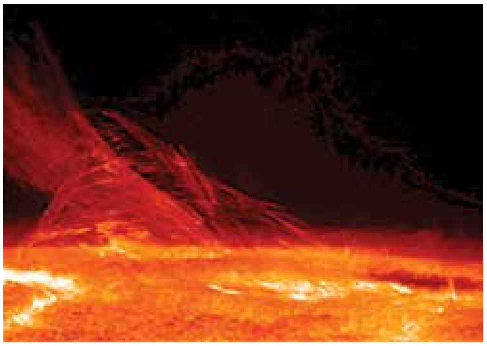
To measure magnetic fields in the chromosphere, SUMI observed the ultraviolet (UV) light emitted from two types of atoms on the sun, Magnesium 2 and Carbon 4. Through established methods of measuring how the light is affected as it travels through the magnetic environment of the solar atmosphere towards Earth, scientists can measure the original strength and direction of the magnetic fields, thus creating a three-dimensional magnetic map of the region.

Principal Investigator:
Dr. Jonathan Cirtain
NASA Marshall Space Flight Center

Mission Number:
36.284 NS

Launch site:
White Sands Missile Range, NM

Launch date:
July 5, 2012



The sun's chromosphere captured by the Hinode satellite. SUMI also studies the magnetic fields on the sun.

EUV Variability Experiment

EVE

The Solar Dynamics Observatory/Extreme ultraviolet Variability Experiment (SDO/EVE) calibration rocket (PI: Tom Woods, University of Colorado) was launched from the White Sands Missile Range (WSMR) in New Mexico on June 23, 2012. This NASA 36.286 rocket flight successfully provided the third underflight calibration for the SDO/EVE instrument, which was launched into geosynchronous orbit on Feb. 11, 2010. This calibration payload includes solar extreme ultraviolet (EUV) irradiance instruments built at Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado (CU) and at the Space Sciences Center (SSC) at the University of Southern California (USC). The CU/LASP instruments provide solar EUV spectra from 5 nm to 105 nm at 0.1 nm spectral resolution, and the USC/SSC instruments provide solar EUV irradiance in broad bands from 0.1 nm to 37 nm.

The rocket calibration flight occurs about once a year to accurately determine the long-term drifts of the flight EVE channels and thus making the long-term variations of the solar EUV irradiance as accurate as possible. In addition to the EVE measurements, solar X-ray spectra in the 0.01-4 nm range were obtained with a new rocket instrument, and these higher resolution spectra will be used to improve upon the lower resolution SDO/EVE observations in this wavelength range.

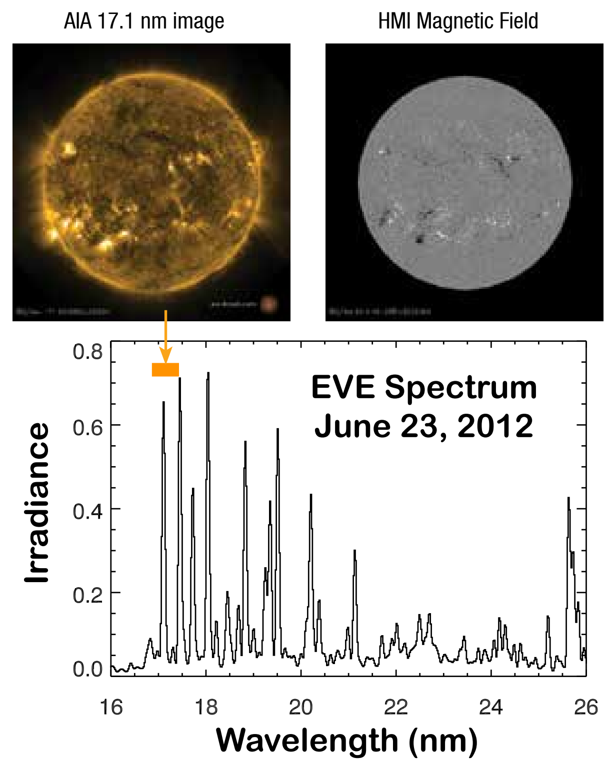
In addition to the studies of solar flares with SDO/EVE data, the solar EUV irradiance observations are used in a variety of space weather applications, such as modeling the response of Earth's ionosphere and thermosphere to the solar flares and how these atmospheric changes affect our high frequency (HF) communication and GPS navigation systems.

Principal Investigator:
Dr. Tom Woods
University of Colorado

Mission Number:
36.286 UE

Launch site:
White Sands Missile Range, NM

Launch date:
June 23, 2012



The SDO EVE calibration rocket flight on June 23, 2012 was during quiet solar activity (no large or flaring active regions), which is optimal for accurately transferring the calibrated rocket measurements to the SDO flight instruments. The solar images are from the SDO Atmospheric Imaging Assembly (AIA) and SDO Helioseismic and Magnetic Imager (HMI). The EVE spectrum is over a limited EUV range to highlight the many spectral features that are mostly from highly ionized iron (Fe) in the solar corona.

Degradation Free Spectrometers

DFS

The July 24, 2012 Degradation Free Spectrometers (DFS-Figure 1) sounding rocket mission's ultimate objective was to significantly advance the state of the art in short wavelength observing solar spectrometers to permit more detailed investigation and understanding of the physics, and hence behavior, of our dynamic sun. Such spectrometers must be capable of high cadence measurements of the highly variable Extreme Ultraviolet (EUV) solar flux and have minimal degradation over multi-year time scales while observing the sun 24/7, in order to improve previous state of the art instruments such as the still active SEM instrument on the Solar and Heliospheric Observatory (SOHO) spacecraft launched in December of 1995.

The present flight met this observational challenge, and carried two newly developed spectrometers, the Optics Free Spectrometer (OFS-Figure 2) [Didkovsky, et. al., SPIE Proc. 66890Q (2007)] and the Dual Grating Spectrometer (DGS-Figure 3) [Wieman et. al., SPIE Proc. 66890R (2007)], to demonstrate their flight readiness. Through energy analysis of photoelectrons from ionization of a neon target gas by incoming EUV photons, the OFS produces a solar spectrum without the use of any thin film filters or reflective optics. With the DGS, incoming EUV photons are diffracted twice before reaching the detectors providing excellent rejection of out of band (i.e. visible) photons, thus isolating specific EUV bands also without the use of reflective optics or thin films. Elimination of these degradation-prone optical elements represents a highly desirable advance in degradation free spectrometer technology. A further important outcome of the present flight is the confirmation of the robustness of the DGS filter-free design for observing solar EUV spectral lines of interest without degradation, e.g. the He II 30.4 nm line which has been widely used by solar and Earth atmosphere com-

Principal Investigator:
Dr. Darrell Judge
University of Southern California

Mission Number:
36.263 US

Launch site:
White Sands Missile Range, NM

Launch date:
July 24, 2012

Website: www.usc.edu/dept/space_science/whatsnew.html

Figure 1 – The DFS instrument prior to flight.


Figure 2 –The Optics Free Spectrometer flown on flight 36.263


Figure 3 –The Dual Grating Spectrometer flown on flight 36.263

munities since 30.4 nm data became available from SOHO/CELIAS/SEM [Judge, et. al., Sol. Phys., 177 (1998)].

The mission also included a clone of the SOHO Solar Extreme Ultraviolet Monitor (SEM) which is calibrated at the National Institute of Standards and Technology, both before and after flight, to provide a calibration check on the on-orbit SEM. Additionally, the sounding rocket payload included a rare gas ionization cell (RGIC) which integrates the solar flux over much of the EUV spectral range to provide independent absolute solar flux data, and further validation of the underflight calibration. Raw flight data from several of the DFS instruments are shown in Figure 4. Pre-flight calibrations of the OFS instrument using a monochromatic EUV source at the NIST/SURF synchrotron facility demonstrate its ability to resolve nearby EUV spectral lines.

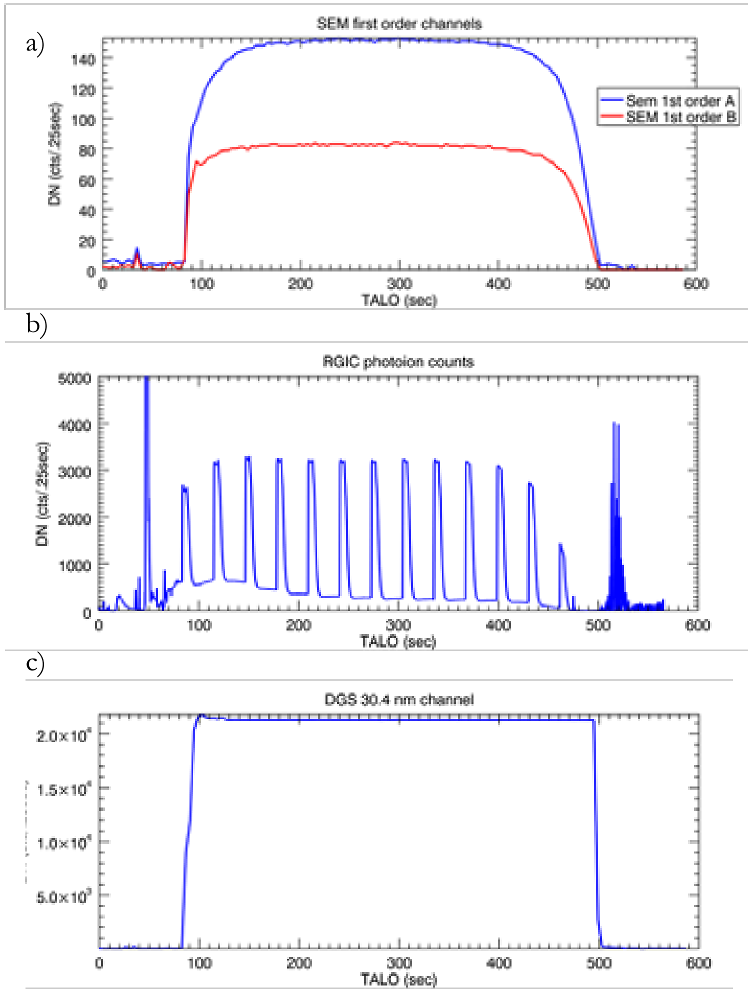
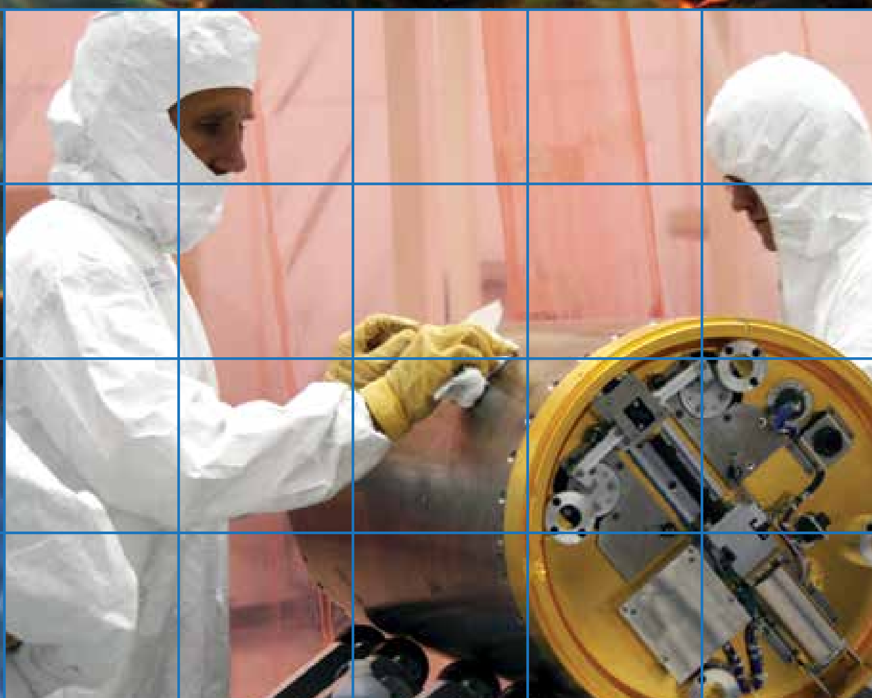


Figure 4: Raw sounding rocket data from a) the Solar EUV Monitor symmetric +/– first order channels A and B both of which cover the 26–34 nm bandpass, b) the Rare Gas Ionization Cell, and c) the Dual Grating Spectrometer will be used to determine solar irradiance in several EUV spectral bands [Didkovsky et. al., SH33A–2220 AGU Fall (2012)]

Astrophysics Highlight

CIBER



Cosmic Infrared Background Experiment

CIBER

Principal Investigator:
Dr. Jamie Bock
California Institute Of Technology

Mission Number:
36.277 UG

Launch site:
White Sands Missile Range, NM

Launch date:
March 22, 2012

Web: http://ciber.caltech.edu

When did the first stars and galaxies in the universe form and how brightly did they burn their nuclear fuel? The Cosmic Infrared Background ExpeRiment (CIBER) seeks to address these questions by studying the Extragalactic Background Light (EBL), the total sky brightness coming from beyond our Galaxy, a measure of the total production of photons over cosmological history. Astronomers are starting to pin down the epoch when the first stars formed, by studying the gas between galaxies. The first massive stars to form in the universe produced copious ultraviolet light that ionized this gas from neutral hydrogen. CIBER searches for these photons directly, observing in the near-infrared, as the expansion of the universe stretched the original short ultraviolet wavelengths to long near-infrared wavelengths today. (see Fig. 1).

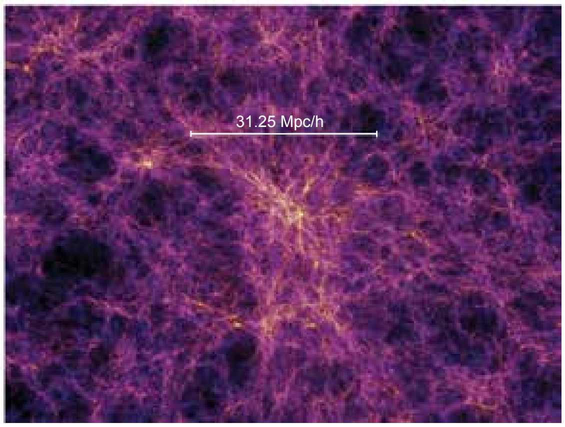


Fig. 1. Numerical simulation of the density of matter when the universe was 1 billion years old. Galaxies formation follows the gravitational wells produced by dark matter, where hydrogen gas coalesces, and the first stars ignite. CIBER studies the total sky brightness, to probe the component from first stars and galaxies using spectral signatures, and searches for the distinctive spatial pattern seen in this image, produced by the large–scale structures formed from dark matter.

Earlier measurements by the NASA *Cosmic Background Explorer* (*CoBE*) satellite have shown that near-infrared EBL measurements are complicated by a bright local foreground – Zodiacal light produced by sunlight scattering off dust grains in our solar system. CIBER carries out its search using three new and different techniques (see Fig. 2): precisely measuring the spectrum of the sky brightness; measuring a characteristic solar Fraunhofer line to help monitor Zodiacal light; and imaging the sky to carefully study its spatial properties.

The imaging technique exploits the fact that Zodiacal light is spatially very smooth. EBL fluctuations were first reported by a team analyzing near-infrared data from the NASA *Spitzer* satellite. CIBER observes at shorter wavelengths than *Spitzer* and can determine if the fluctuations are consistent with the expected spectrum of first stars and galaxies.

CIBER has been flown three times. The first flight, which experienced some technical problems, discovered absorption bands in the Zodiacal light spectrum characteristic of silicate dust grains (Tsumura et al. 2010, ApJ 719, 394). This measurement showed the spectrum of Zodiacal light is dominated by dust made in asteroid collisions, although much of the dust material may be produced by comets. The second and third flights were technically successful, and the data quality (see Fig. 3) matches pre-flight expectations. In the third flight we observed the same fields at a different time of year, through a different Zodiacal foreground due to the Earth's motion around the Sun, to check how the measurements are affected by Zodiacal light. The payload was recovered after each flight for post-flight calibrations and re-flight. Our team is hard at work on the flight data, but our end-to-end analysis clearly demonstrates the instrument has the necessary sensitivity and calibration stability to achieve CIBER's scientific goals. Our team expects to publish scientific findings in the coming months.

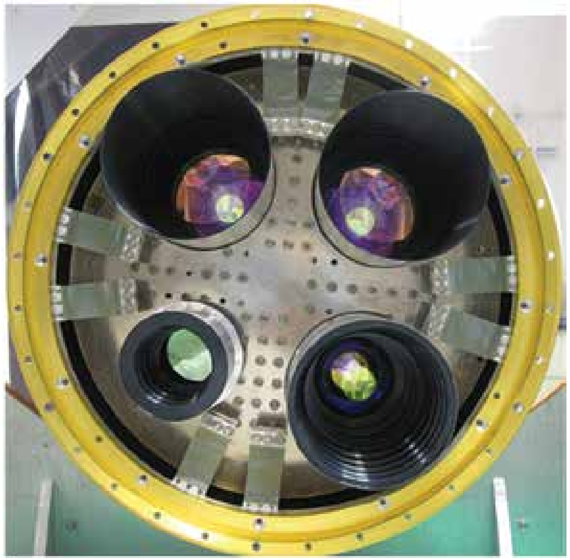


Fig. 2 a. The entrance of the CIBER optics, showing two near–infrared wide–field cameras (top), an absolute spectrometer (lower left) and a Fraunhofer line spectrometer (lower right).

Fig. 2 b Preparing the instrument for flight. The optics and detectors are cooled by liquid nitrogen to –196 C (77 K, –321 F) during the flight to eliminate infrared emission from the instrument and to achieve the best detector sensitivity.

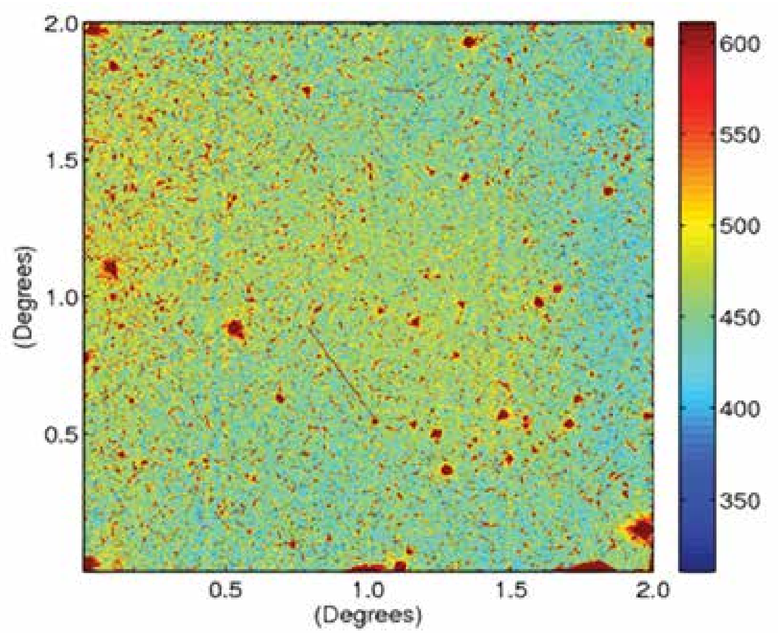


Fig. 3. Raw science image obtained in flight, over a wide 2 degree field of view with 1024 x 1024 spatial pixels. The image shows bright stars, many fainter galaxies, and a few cosmetic defects in the arrays. CIBER has obtained 10 deep images between two flights in July 2010 and March 2012 which allows us to remove discrete sources and systematically evaluate the sky and detector properties, and assess the effects of Zodiacal light. The image is displayed in units of surface brightness intensity.

Planet Imaging Concept Testbed Using Sounding Rocket

PICTURE

Principal Investigator:
Dr. Supriya Chakrabarti
Boston University

Mission Number:
36.225 UG

Launch site:
White Sands Missile Range, NM

Launch date:
October 8, 2011

The Planet Imaging Concept Testbed Using Sounding Rocket (PICTURE) was designed to take the first step towards developing and maturing key technologies for direct imaging of exoplanets using nulling interferometers. It was a collaboration between Boston University, Jet Propulsion Laboratory, NASA Goddard Space Flight Center and Charles Stark Draper Laboratory. PICTURE's science goal was to directly image the debris disk around Epsilon Eridani in visible light. The properties of debris disk, which is similar to the asteroid belt of our Sun, can tell us about the process of planet formation and evolution around stars. PICTURE attempted to flight qualify several key technologies necessary for exoplanet exploration such as, extremely lightweight mirror, visible nulling coronograph, deformable mirror and 5 milli arc-sec pointing. Science data from the flight were not retrieved from this mission, due to the failure of a critical telmetry component at ignition, however the pointing system's performed flawlessly. The experiment was recovered and returned to the core science team for refurbishment.

PICTURE integration at Wallops.

X–ray Quantum Calorimeter

XQC

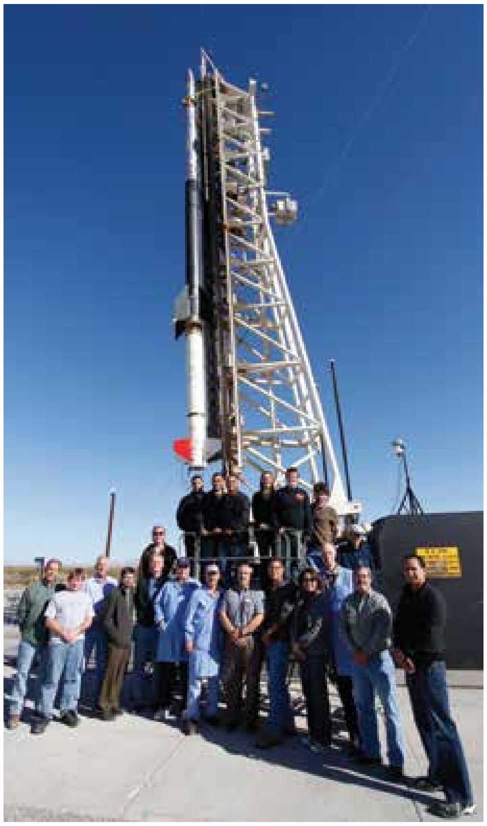
Principal Investigator:
Dr. Dan McCammon
University of Wisconsin

Mission Number:
36.264 UH

Launch site:
White Sands Missile Range, NM

Launch date:
November 6, 2011

The purpose of this mission was to measure the spectrum of the diffuse X-ray emission from the interstellar medium over the energy range 0.07 to 1 keV. The Soft X ray Background (SXRB) has been studied for about twenty years, primarily with proportional counters. The source of the SXRB has long been modeled as a hot, low-density interstellar plasma (T ~ 10^6 K). However, recent models (e.g. I. P. Robertson and T. E. Cravens, Journal of Geophysical Research, 108 (A10), 8031, 2003) suggest that a substantial fraction of the 0.07 to 1 keV emission may be originating from the interaction of our solar wind with interplanetary neutral gas. The mechanism for such heliospheric emission is called Solar Wind Charge Exchange (SWCX). This mechanism is thought to be responsible to X-ray emission observed from comets and the earth's extreme outer atmosphere. Using a large-area array of microcalorimeter detectors with a 60° field of view operating at a temperature of 0.05 K, this experiment captured a spectrum of the SXRB with enough resolution and statistics to place limits of the amount of SWCX contribution to the SXRB. The previous flight, 36.223, was targeted at a high galactic latitude position (l,b = 90°, +60°) where interstellar emission from million-degree gas should dominate by at least a factor of two. The current flight aimed at a target near the Galactic plane in the direction of the anticenter (l,b = 165°, –5°). Interstellar X-ray emission is a minimum in this direction, and the best theoretical calculations of SWCX estimate that it provides all of the observed X-rays. Therefore a comparison of this spectrum with the one from 36.223, should show a distinct difference if SWCX is as strong as expected. Unfortunately, an event occurred shortly after opening the experiment gate valve that contaminated the outer infrared blocking filter with a coating of ice. Some science data was recovered, but the expected results are severely compromised.



XQC ready to launch.

Extended X–ray Off–plane Spectrometer

EXOS

Principal Investigator:
Dr. Webster Cash
University of Colorado

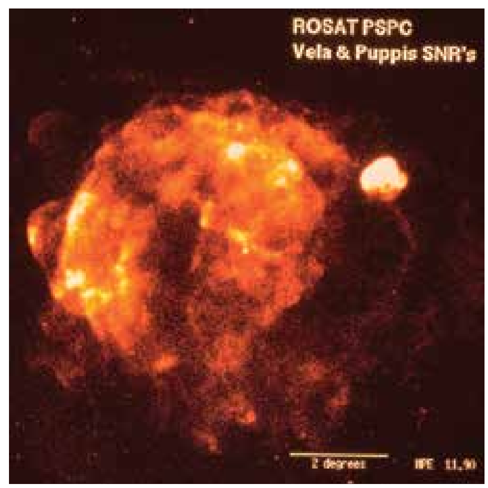
Mission Number:
36.274 UH

Launch site:
White Sands Missile Range, NM

Launch date:
December 10, 2011

As there is no efficient, well developed technology that permits high resolution x-ray spectroscopy from large solid angle sources, spectra of diffuse x-ray sources are rare. The few existing spectra, however, have established there is a rich trove of science waiting. These include results from the sounding rocket payloads CyXESS and EXOS, which targeted the Cygnus Loop supernova remnant (SNR); suggest the possibility of a previously unknown phase of SNR cooling. With our instrument we can address the radiative cooling of hot gas in supernova remnants and the hot phase of the interstellar medium, testing theories by observing different SNR with improved sensitivity. Future flights can obtain physical diagnostics of the galactic halo and the local x-ray background.

Cygnus loop imaged by ROSAT.



Vela & Puppis supernova remnants imaged by ROSAT

The scientific goal of the latest flight (36.274) was to obtain x-ray spectral diagnostics of the nearby extended SNR in Vela. The mission was a rebuild and reflight of a previously flown payload (Cash 36.224, 36.252). The initial flights targeted the Cygnus Loop, yielding results that could have significant ramifications for the theory of supernova cooling and radiative processes in the interstellar medium (ISM), since the spectra suggested an unexpectedly high fraction of continuum radiation. The goal of the most recent investigation, successfully launched on December 10th, 2011, was to obtain high resolution soft x-ray spectra of the Vela supernova remnant, to confirm the results from flights targeting the Cygnus Loop, and to improve the instrument sensitivity for future flights of the same instrument.

Technology Mission Highlight

IRVE-3

Inflatable Reentry Vehicle Experiment–3

IRVE–3

Principal Investigator:
Dr. Neil Cheatwood
NASA Langley Research Center

Mission Number:
_39.011 NR_

Launch site:
Wallops Island, VA

Launch date:
July 23, 2012

The Inflatable Reentry Vehicle Experiment-3 was launched from Wallops Island, VA on July 23, 2012. This was the third in a series of flights to demonstrate inflatabe reentry technologies. The IRVE flight tests are part of the Hypersonic Inflatable Aerodynamic Decelerator (HIAD) Project within the Game Changing Development Program, part of NASA's Space Technology Program.

The test demonstrated that lightweight, yet strong, inflatable structures may become practical tools for exploration of other worlds or a way to safely return items from the International Space Station to Earth. During this technology demonstration test flight, NASA's IRVE-3 payload came through Earth's atmosphere at hypersonic speeds -- Mach 10, or 7,600 mph.

The two Mission Science Objectives were to:

1. Demonstrate the reentry survivability of an inflatable aero dynamic decelerator with a flight relevant Thermal Protection System (TPS) in a flight environment with a peak reentry heat rate greater than 12 W/cm2 (cold wall), and
2. Demonstrate the effectiveness of an offset CG on the flight L/D of an inflatable aerodynamic decelerator.

The launch vehicle and the IRVE-3 experiment performed as predicted and valuable aerodynamic data was obtained.

IRVE–3 inflated as it will appear after deployment from the rocket.

IRVE–3 launches from Wallops Island onboard a three stage Black Brant XI sounding rocket.

Terrier Improved Malemute test flight

Vehicle Testflight

Principal Investigator:
Mr. Brian Hall
NASA Wallops Flight Facility

Mission Number:
12.074 GT

Launch site:
Wallops Island, VA

Launch date:
January 11, 2012

This mission was the second test flight of the Terrier/Improved Malemute vehicle configuration. The primary objectives were to characterize the performance of this vehicle configuration and verify compliance properties of an improved forward joint design. The improved joint design enables the forward motor lap joint to function similar to a radax joint with large improvements in compliance properties. Shortly after the successful test flight the new vehicle was utilized for two of the launches supporting ATREX investigation in March. The new stack was also used in support of the RockSat-X launch in September. This vehicle is showing great promise as a low cost higher performing all surplus configuration.

Terrier Improved Malemute launches from Wallops Island.

Talos Terrier Oriole test flight

Vehicle Testflight

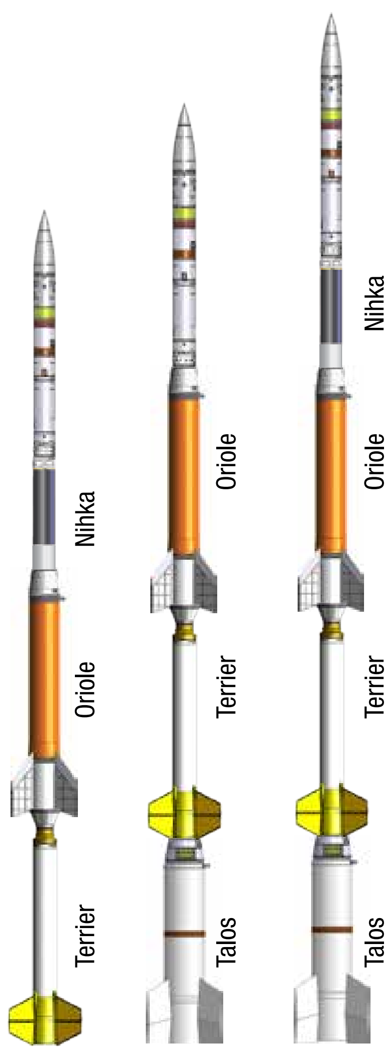
Principal Investigator:
Mr. Charles Brodell
NASA Wallops Flight Facility

Mission Number:
_12.075 NT_

Launch site:
Wallops Island, VA

Launch date:
September 22, 2012

The 12.075 GT Brodell mission represented the inaugural flight of the Talos/Terrier/Oriole launch vehicle. The payload and vehicle were developed in a rapid 11 month time frame from mission initiation to launch. The payload was representative of a typical science mission with the addition of an "inert" Nihka. This configuration enabled determination of flight dynamics at time of "theoretical" fourth stage ignition. The mission's primary objectives were to verify performance and stability of this vehicle stack with the Terrier Mk 70 as the 2nd stage and the Oriole as the 3rd stage. The successful flight test also validates the four stage stack with a "live" Nihka and a Terrier/Oriole/Nihka stack to be flown on its first science mission this winter at PFRR. Utilization of this stack with a fourth stage offers the potential of a 30% improvement over the current configuration. The well behaved flight has allowed the SRPO to eliminate the requirement for a thrust termination system on upcoming missions resulting in significant reduction of effort and expense. A critical component allowing the second stage Terrier is the new load bearing tailcan. This tailcan allows for new booster stacks and enables other new high performance motor combinations utilizing both surplus and commercial assets. An additional benefit was to remove the Taurus motor from the stack improving reliability, performance, and reducing logistical/safety concerns associated with the 50 year old motor. This mission also incorporated rideshare experiments including an Air Force APRA Experiment, the NSROC GL-NMAC containing new navigation software, and a new six event digital ignition system for the Navy.



Talos Terrier Oriole lift–off from Wallops Island.

Education Missions

RockOn!

Principal Investigator:
Mr. Chris Koehler
University of Colorado/Space Grant

Mission Number:
41.101 UO

Launch site:
Wallops Island, VA

Launch date:
June 6, 2012

This mission was the fifth flight of the hands-on, University level rocket flight workshop known as "RockOn!," which is an annual collaborative effort conducted by the Colorado Space Grant Consortium (COSGC), the Virginia Space Grant Consortium (VSGC), and NASA Wallops Flight Facility. Since its beginning in 2008, 192 people participated in the RockOn! from 36 states and over 70 universities and colleges. The primary objective of the RockOn! workshop is to provide university undergraduate students and instructors with a space flight opportunity on a sounding rocket for a minimal cost and at a relatively low level of technical complexity. The RockOn! workshop is intended to be an introductory flight opportunity to provide exposure to and spark interest in space-based science missions. The long-term goal of this program is to provide a low cost, self-sustaining, annual training program for the university community. This is accomplished by flying two classes of experiments. The first time participants fly the simpler kit experiments built during the RockOn! Workshop known as the RockSat-W experiments, and as they gain more experience, they progress toward developing their own unique experiments known as the RockSat-C class experiments. The 2012 RockOn! mission included 14 standardized experiments built by 42 participants and 10 custom-built RockSat-C experiments developed by 10 universities and colleges. The workshop was conducted at Wallops Flight Facility during the students' summer break with the actual launch occurring on June 21. The launch vehicle performed nominally and the payloads were successfully recovered as planned. The vast majority of the student built experiments functioned as planned and collected good data, resulting in a highly successful mission. More details on the RockOn! Workshop can be found at http://spacegrant.colorado.edu/rockon. More information on the RockSat-C program can be found at http://spacegrant.colorado.edu/rocksatc.

RockSat–C experiment groups with their payload.

RockSat–X

RockSat-X is a follow on mission to RockOn! and involves more complex student experiments. RockSat-X provides more advanced sounding rocket payload support services, including telemetry and deployable instruments. The 2012 RockSat-X mission was launched on September 21, 2012 and the programs education goals were successfully accomplished. Four universities participated in this mission. This was the second flight of the RockSat-X student opportunity.

University of Colorado flew a payload to record HD video of flight and all experiments and also demonstrated new experiment hardware for RockOn, RockSat-C/-X. Seven HD videocameras are included; four downward looking and three looking horizontally.

University of Puerto Rico selected an experiment that includes mass spectroscopy to analyze molecular species and their respective partial pressures in near space.

University of Colorado Boulder designed and tested a system that deployed the Roll Out De-Orbiting Device (RODEO) that provides a possible means to de-orbit future small satellites.

Virginia Tech and Baylor University teamed up and designed experiments to Measure Nitric Oxide (NO) concentrations at high altitudes (VATech) and collect space dust and measure impact energy using Baylor University's Piezo Dust Detector (PDD) (Baylor).

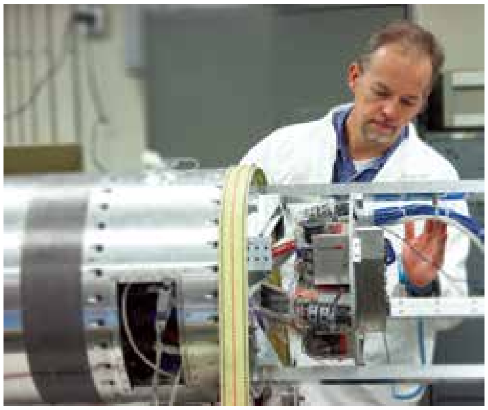
Principal Investigator:
Mr. Giovanni Rosanova
NASA Wallops Flight Facility

Mission Number:
46.004 GO

Launch site:
Wallops Island, VA

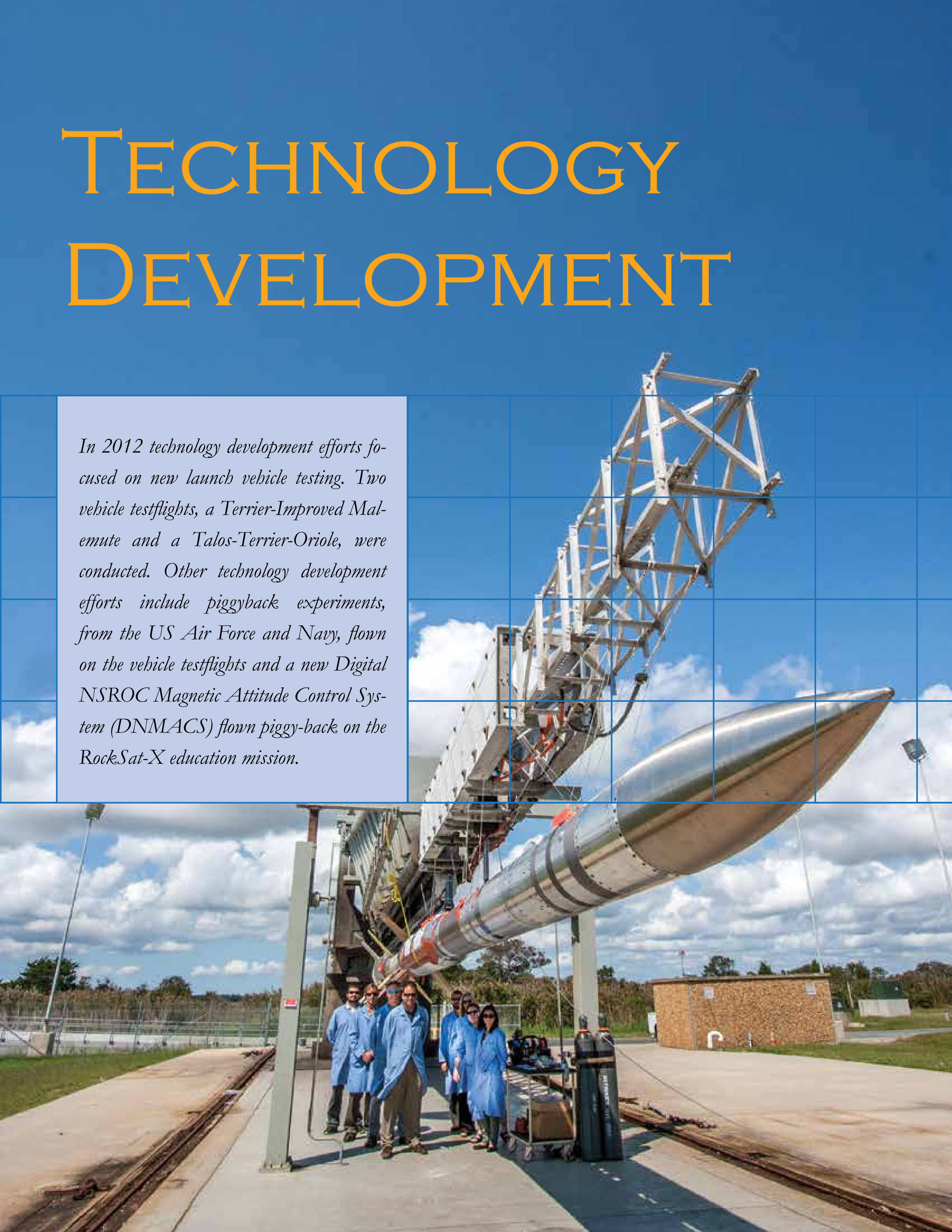
Launch date:
September 21, 2012

RockSat–X payload integration.



RockSat–X camera payload check.

Technology Development



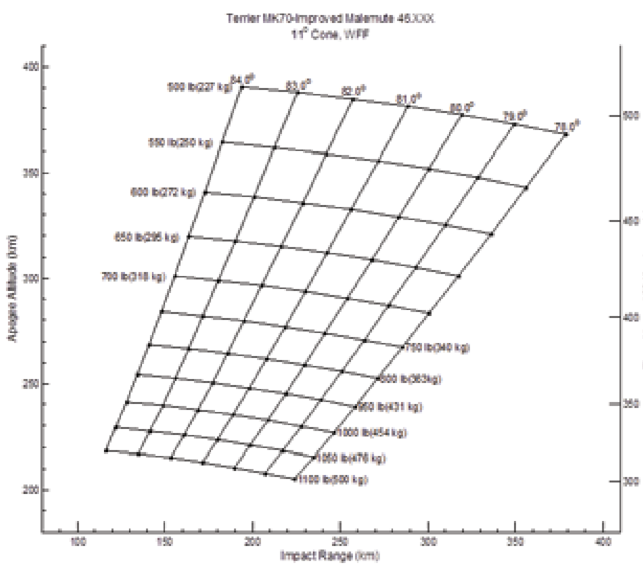
In 2012 technology development efforts focused on new launch vehicle testing. Two vehicle testflights, a Terrier-Improved Malemute and a Talos-Terrier-Oriole, were conducted. Other technology development efforts include piggyback experiments, from the US Air Force and Navy, flown on the vehicle testflights and a new Digital NSROC Magnetic Attitude Control System (DNMACS) flown piggy-back on the RockSat-X education mission.

Launch Vehicle Development

Two new launch vehicles have been developed over a period of two years. A two stage Terrier-Improved Malemute was flown in early January in a second testround flight. In September 2012 a new three stage launch vehicle, the Talos-Terrier-Oriole, was flown from Wallops Island.

Terrier-Improved Malemute

A Terrier Mk12 or Mk70 first stage and an Improved Malemute second stage launch vehicle can carry payloads weighing between 500 and 1,100 lbs to altitudes between 200 and 390 km. This launch



vehicle is based on two surplus motors from the Department of Defense.

The above carpet plot shows apogee and impact range of payload weights between 500 and 1,100 lbs at quadrant elevation angles (QE) from 78 to 84 degrees.

Terrier Improved Malemute ready to launch on Wallops Island.

Four Terrier-Improved Malemutes were flown in fiscal year 2012. The first in January of 2012 was the second and final testround for this vehicle. The first two operational flights occurred in March for the ATREX mission. The two ATREX launches included deployments of trimethylaluminum at various altitudes. The Terrier Improved Malemutes performed as predicted, reaching altitudes of approximately 200 km and 250 km respectively. The payload weights were approximately 600 and 750 lbs.

Talos-Terrier-Oriole

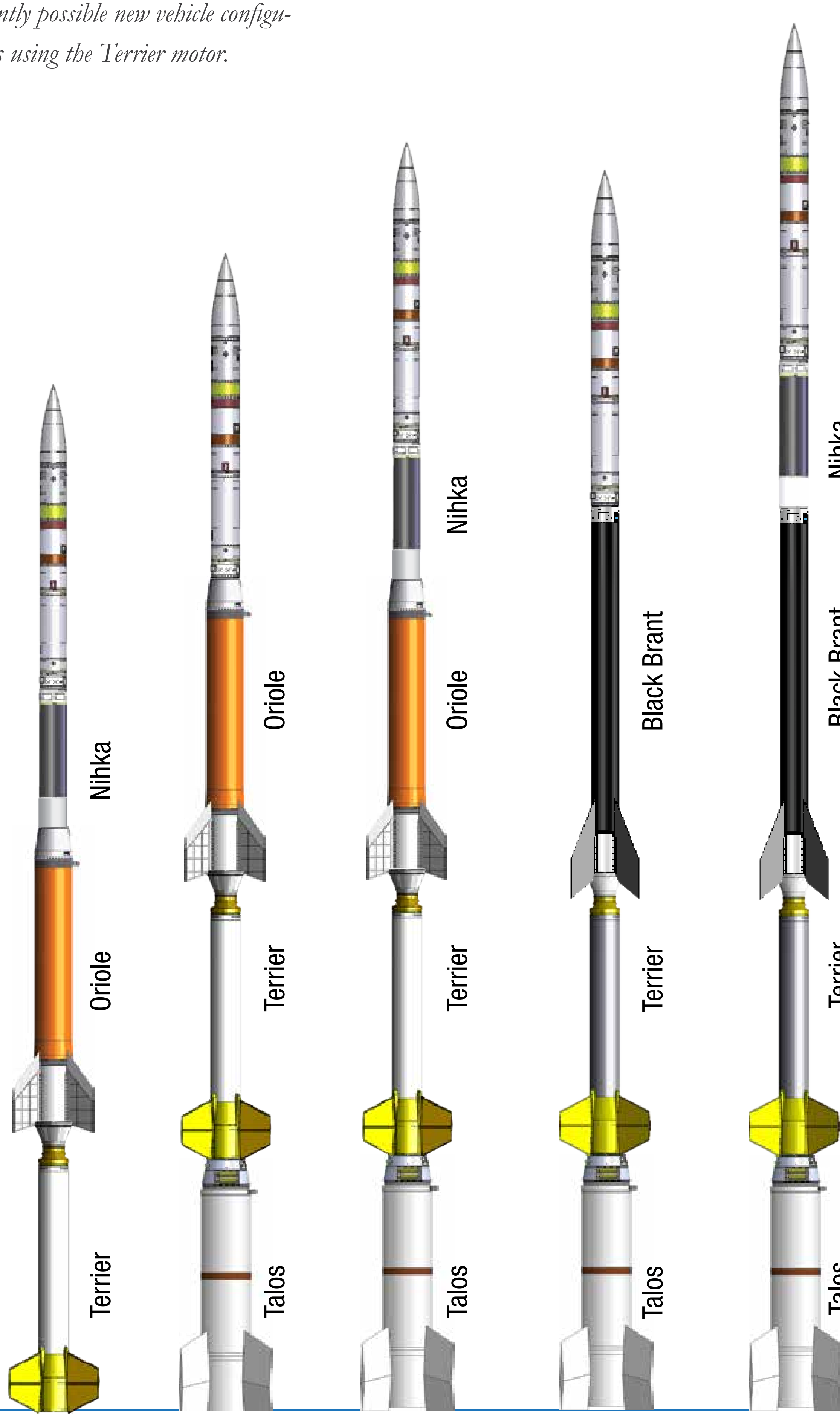
A new three or four motor combination launch vehicle was developed in Fiscal Year 2012 The first testflight verified performance and stability of a vehicle stack with a Talos 1st stage, a Terrier Mk 70 as the 2nd stage and the Oriole as the 3rd stage. The successful flight test also provided the confidence for two additional launch vehicles with slight variations including the Talos-Terrier-Oriole-Nihka and Terrier-Oriole-Nihka.

These vehicle configurations significantly enhance the capabilities of the Sounding Rockets Program by increasing the vehicle options for high altitude/longer duration science missions. In the four stage configuration, Talos Terrier Oriole Nihka, the performance increases by approximately 30% compared to other currently available vehicles.

Using the Terrier as a second stage, with a new loadbearing tailcan, provides additional benefit by enabling other Terrier based vehicles to be designed using the same technology. This may lead to future sub-orbital vehicles with Terrier motors as both the first and second stages.

Additional vehicle configurations based on a Terrier second stage include a three stage vehicle, Talos-Terrier-Black Brant and a four stage vehicle, Talos-Terrier-Black Brant-Nihka. In both cases the Terrier replaces the Taurus motor as the second stage.

Currently possible new vehicle configurations using the Terrier motor.



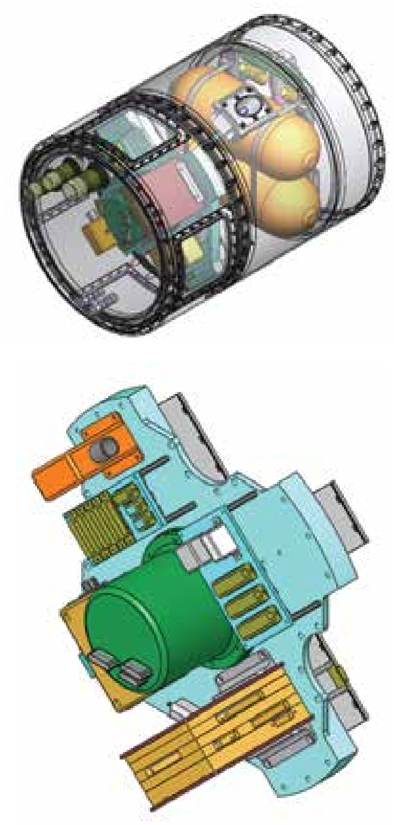
Capacitive Discharge Ignition (CDI) system

The new NSROC Capacitive Discharge Ignition system is an upgrade to the standard WFF CDI that has been used in the Sounding Rocket Program for many years. The new system continues to use capacitive discharge technology which has proven to be extremely reliable and provides a high level of safety. However, many of the mechanical switching components utilized by the heritage CDI have been replaced by solid state devices. This upgrade will increase system reliability and reduce the size and weight of the CDI hardware, potentially yielding increased payload capacity and higher trajectories.

The NSROC CDI is a modular system. All components, including cable assemblies, will be manufactured in bulk and submitted to program inventory. This modular design allows for a more efficient manufacturing process, a very consistent product, and it eliminates custom wiring. Once all components are in the stock system, electrical assembly of the system can be accomplished in less than one day. The fourth test of the CDI system was conducted on the RockSat-X mission, September 2012. The system fired actual critical vehicle events: second stage ignition, de-spin and motor separation for the first time during this test flight.

Digital NSROC Magnetic Attitude Control System (DNMACS)

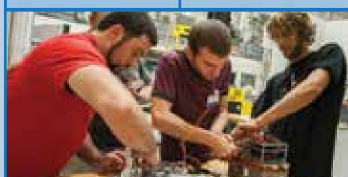
The DNMACS is a new control system that uses digital input sensors to align to the local magnetic field. The system uses a digital three-axis magnetometer and a digital three-axis IMU to perform the field alignment and settle body rates. The digital sensors have many advantages, such as noise resiliency, which is especially important when dealing with signals from a remotely mounted magnetometer. In addition, the calibrations are performed within the sensors which makes the sensors more plug and play while offloading processing from the main processor. The main processing for the ACS is performed by the same processor used in the NSROC Inertial Attitude Control System (NIACS) and Celestial Attitude Control System (CACS), resulting in increased performance and greater reusability of software algorithms. Control is performed using the same control valves used in the NIACS and analog NMACS systems. Less noise from the input sensors results in improved alignment capability. The DNMACS demonstrated successful performance on the RockSat-X mission.

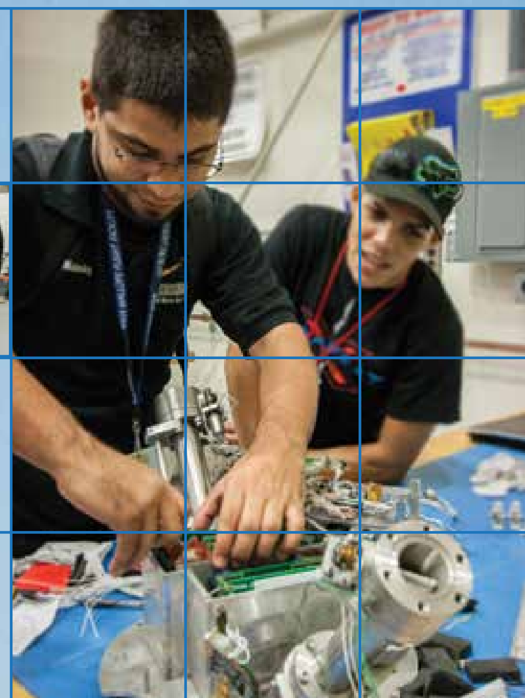


SolidWorks models of the DNMACS.

Education

The Sounding Rockets Program Office provided two University class flight opportunities, RockOn! and RockSat-X. in 2012. The Wallops Rocket Academy for Teachers and Students (WRATS) teacher workshop was attended by 22 High School teachers from around the country. Additionally, the program supported a local High School rocket club. NSROC continued the very successful intern program.





University level sounding rocket missions

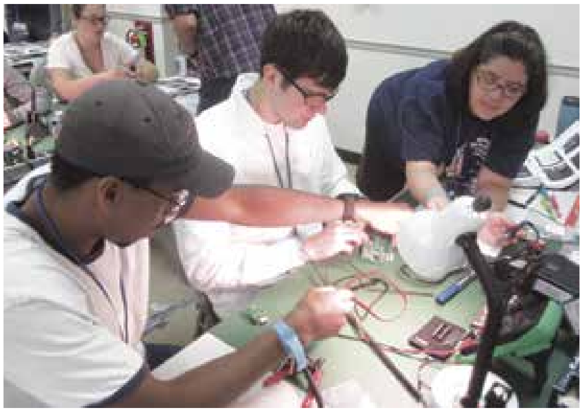
Three different university level experiment opportunities were offered; RockOn!, RockSat-C and RockSat-X.

RockOn!

2012 was the 5th consecutive year the RockOn! workshop was held at Wallops. Approximately 80 college students and educators spent a week completing and integrating their experiments to fly on a sub-orbital rocket. The 2012 RockOn! mission included 14 standardized experiments built by 42 participants and 10 custom-built RockSat-C experiments developed by 10 universities and colleges. The workshop experiments are built from kits, created by the Colorado Space Grant Consortium, consisting of an AVR microprocessor, various sensors, mounting hardware and programming software. Teams of faculty members and students work together to build the experiments. Attending the workshop is the first step toward more elaborate future experiments.

RockOn! workshop participants 2012.

By mid-week all RockOn! teams had completed their experiment construction, programming and integration. The experiments were installed in the payload structure and transported to Wallops Island for mating with the rocket motors, a two-stage Terrier-Improved Orion. The launch occurred early in the morning on June 21st.



RockOn! team constructing payload.

The payload reached an apogee of 117 km and was recovered in the ocean and brought back to Wallops for de-integration. The experiments were returned to the students for postflight checks and data analysis.

RockSat-C

RockSat-C experiments, flying in the same payload with the RockOn! experiments, are completely designed and built by students. Nine RockSat-C teams participated in the 2012 mission.

Harding University designed, built, tested and flew a spectrometer that measured transmission spectra of gases in Earth's atmosphere at lower altitudes and the Sun's irradiance at higher altitudes. The students also tabulated and interpreted spectra and created a technical report summarizing the findings. The ultimate goal of this experiment is to evaluate spectrometers for use on Mars.

Frostburg University's Zero Tilt experiment provided, for the first time, a stable environment throughout the flight of a Sounding Rocket via two concurrent objectives, a tilt correction system and a despun platform system. The Zero Tilt platform will benefit scientific experiments that require stabilization to collect data.

The purpose of **Minnesota University** project was to develop a mechanical and electrical design for removing rocket noise that gets transferred to the test chamber. The method uses active noise cancellation with mechanical isolation of the system. The anticipated result is a decrease of rocket engine noise by at least 90%.

The **University of Puerto Rico** payload measured selected gases in the near space environment, and surveyed inorganic and organic aerosols. The organic fraction of the collected aerosols are expected to show evidence that sustains the presence of amino acids and microorganisms in the atmosphere.

Measurement of high-energy particles, low-energy (plasma) density, magnetic field, gravitational field, flight dynamics, greenhouse gases, and the effects of microgravity on dusty plasma were the goals of the **West Virginia University** RockSat-C payload. Measuring the intensity of various species of high energy particles can reveal much about the source of these emissions, as well as, the atmospheric composition. The plasma experiment compared the instantaneous plasma density and frequency distribution to current atmospheric models. Measuring magnetic field intensity yields information about how Earth's magnetic field traps and reflects charged particles.

The goal for the **Mitchell Community College** experiment was to design and implement various generators to passively collect energy for possible use for space based instrumentation. The expectation was to harvest energy from the flight of the rocket, solar, magnetic and other various sources. The payload was designed to: harvest electrical energy from various sources during flight, measure electricity generated and then dispose/store of excess energy and measure various environmental factors throughout flight such as humidity, magnetic field and acceleration.

Pre–flight electrical checks of a RockSat–C eperiment.

Pre–flight mechanical checks.

Northwest Nazarene University studied the feasibility of using superhydrophobic materials in the presence of high acceleration and vibrations for possible use on space missions. When water is in contact with the superhydrophobic surface (diatomaceous earth) it is more attracted to its own surface tension than it is to the material. This is because the material works like a microscopic bed of nails. Diatomaceous earth is a new material developed by John Simpson at Oakridge National Laboratory and is exceptional due to its high contact angle with water and low price. The goal of this launch was to prove that this diatomaceous earth can survive a rocket launch and still be functional post-flight.

The **New Jersey Space Grant Consortium at Stevens Institute of Technology and Rutgers University** designed an experiment to measure atmospheric composition, specifically Ozone (O3), Carbon Dioxide (CO2) and Methane (CH4). Additionally, the experiment included vibrometers, an infrared thermometer and gyroscope to measure the rotational frequency of the rocket.

RockSat–C participants in the T&E lab at Wallops.

The **Temple University** payload measured the earth's magnetic field as a function of altitude, took biological samples in the stratosphere and lower mesosphere, and measured flight dynamics of the rocket. An inertial measurement unit (IMU), an electrical device consisting of accelerometers and gyroscopes, was used to measure the rocket's flight dynamics (roll, pitch, and yaw). A magnetometer was included to measure the strength and direction of Earth's magnetic field, as was a filtration system to collect organic and inorganic material suspended in the atmosphere.

Installation of electrical connectors on a RockSat–C experiment.

Drexel University developed and tested a system to use piezoelectric materials to convert mechanical vibrational energy into electrical energy to trickle charge on-board power systems. The payload was designed to demonstrate feasibility of power generation via piezoelectric effect under Terrier-Orion flight conditions, determine optimal piezoelectric material for energy conversion in this application and classify relationships between orientation of piezoelectric actuators and output voltage. The data is expected to benefit future RockSAT and CubeSAT missions as a potential source of power

RockSat-X

The RockSat-X mission expands the opportunities for student developed experiments and payloads by providing access to the space environment through deployable doors and openable ports. 2012 was the second year for the RockSat-X mission with participation from five Universities in four experiment platforms.

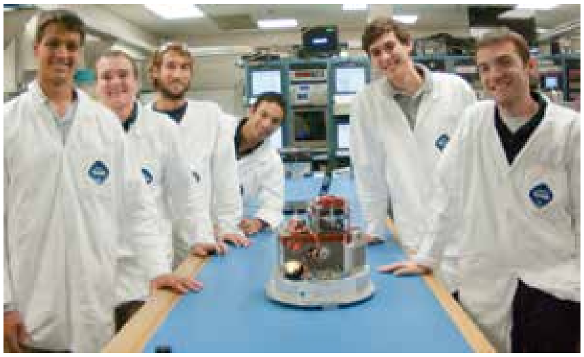
University of Puerto Rico

Mass spectroscopy to analyze molecular species and their respective partial pressures in near space was the focus of the University of Puerto Rico experiment. The instrument was designed to determine the abundance of different types of gas molecules that exist in the outer atmosphere and near outer space and to demonstrate that future space voyagers could use gas molecules present in outer space to synthesize necessary resources such as water and fuel.

University of Puerto Rico team working on their spectrometer prior to RockSat–X payload integration.

Virginia Tech & Baylor University

The **Virginia Tech** experiment was designed to measure Nitric Oxide (NO) concentration at high altitudes. The NO sensor collects wavelength data around 220nm and is oriented at 45 degrees to catch light off of the upper atmosphere. An on-board IMU collected acceleration, angular rate, and magnetic field data. This mission is expected to provide useful data of NO concentration in the upper atmosphere. **Baylor University** designed an instrument, the Piezo Dust Detector (PDD), to collect space dust and measure impact energy. Stacked webs of charged wires filter particles and measure dust velocity & energy measure and velocity and energy of dust particles in space.



Students from Virginia Tech and Baylor with their experiments.

University of Colorado Boulder

The goal of the University of Colorado Boulder experiment team was to design and test a system that deploys the Roll Out De-Orbiting Device (RODEO) to provide possible means to de-orbit future small satellites. This payload was also designed to validate the Attitude Determination System (ADS) flown on a previous RockSat C mission and evaluate its potential use for future RockSat-C missions.

Colorado Space Grant Consortium

The Colorado Space Grant Consortium flew seven cameras to capture the flight in high-definition. Additionally, new experiment hardware for RockOn! and RockSat-C were tested in this flight.

NRSOC Internship Program

Over 140 students have participated in the internship program managed for the Sounding Rockets Program Office by NSROC. The program, now in its 14th 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 business environment. Almost 90 percent of undergraduate students who intern or participate in the co-op program return for additional employment. Several participants in the program have gone on to pursue higher education in the engineering and science fields.

Intern Ryan Olmsted (left) assisting Tommy Russell in T&E with a payload lift.

Lindsey Buck, Vehicle Systems intern, getting ready to conduct battery drop tests to evaluate impact forces.

Intern Randy Persaud conducting a spin–balance test.

Jared Whaley, Attitude Control Systems intern left, with Tim Wilson preparing for sequence testing for the ATREX missions.

Wallops Rocket Academy for Teachers and Students (WRATS)

For the second time a WRATS High School teacher workshop was held at Wallops, utilizing the newly established education workshop area. Twenty-two educators, representing twelve states, attended the workshop and spent June 18 - 22, 2012 learning about sounding rockets, model rockets, electronics, rocket physics and aerodynamics. The participants also attended the RockOn! Terrier-Orion launch on June 21st.

Rockets nearing completion.

Teachers built and flew model rockets and payloads measuring acceleration, temperature and pressure. Each teacher was provided a model rocket kit with all necessary accessories for constructing the rocket. The payload used the Arduino Uno for sensor integration and data collection and the teachers received complete Arduino kits with a sensor package specifically selected for model rocket flight. Pre-flight testing of the rocket included measurement of Cg, stability and moments of inertia. Additional activities included parachute construction and testing. The rockets were successfully flown and recovered on the Wallops airfield on June 21.

WRATS 2012 participants.

During the WRATS workshop teachers also attended an overview of wind tunnels and several interactive presentations about rocket physics by SRPO Chief Phil Eberspeaker. Tours of Wallops Flight Facility were also part of the week. Orbital Sciences Corporation provided the stipends giving the teachers the financial means to participate in the workshop.

Preparing to launch.

Alex Berenguer (left in the photo on right) writes: *"I just wanted everyone to know that I incorporated what we learned and launched model rockets with a couple of my classes this week. The students loved the experience and we are continuing to create s tudent interest by having them now build non kit rockets and doing the NASA water bottle rocket activities. I have wanted to do this for many years but the workshop provided me with the training I needed and the experiences and insights to really create a student interest in rocketry. Thanks to NASA and Orbital Sciences Corporation for allowing me to be a part of this experience."*

Payload construction.

Parachute construction.

Arcadia High School Rocket Club

As a result of attending the first WRATS workshop in 2011, Carol Osmon, a science teacher at Arcadia High School, started an after school rocket club with her students.

The first task for the Arcadia High School Rocket Club participants was to build a small, A-engine powered model rocket. After having successfully launched these small models the team constructed “WRATS rockets”. Over the course of the spring semester the students constructed the larger rockets, suitable for E size model rocket motors, used software to predict flight performance, measured stability of their rockets and integrated altimeter payloads to determine apogee. The program culminated with the flight operations at Wallops Flight Facility where the students learned about safety aspects of rocketry prior to launching their rockets.

In addition to the hands-on rocketry activities the students also toured Wallops Flight Facility and had an opportunity to learn about career opportunities at NASA.

Chris Hernandez preparing his rocket for flight.

Arcadia Rocket Club at Wallops for launch.

Facilities

Late 2012 early 2013, the SRPO will complete a multi-year upgrade to the Vehicle Assembly Building (VAB) at WSMR. Originally built in the 60's to support the Little Joe program and later transferred to the SRPO, the VAB has been serving the solar and astrophysics science community for over 40 years. Together with the "N-200" facilities located at LC-35, these facilities have served the program well for many years with our team making the most of what with what they had. Beginning in 2007, the SRPO began a strategic multi-year project to upgrade the VAB with more modern and "clean" integration and testing labs with the ultimate goal of consolidating all SRPO activities into one larger more efficient facility. The decision to consolidate was driving by several factors: the Navy's desire to reclaim their facilities at LC-35, the need to replace/repair the antiquated VAB facility infrastructure, and the SRPO's desire to reduce cost by maintaining only one facility owned, operated, and maintained by NASA.

Phase I integration laboratory with two new clean tents. Cirtain payloads 36.284 and 36.272 are shown during integration one in each clean tent.

The Phase I addition to the VAB was completed in the summer of 2011 and included a new larger "clean" integration laboratory, a new command uplink room, office space for the NSROC staff and visiting payload teams (2nd floor), and a much needed small conference room. The design of the integration laboratory was such that it would be a "clean" facility just short of a certifiable clean room. Vestibules on all external entry and exit points, positive pressure/ well filtered HVAC systems, and access controls were designed in to help maintain a much cleaner facility than was previously available. In the Spring of 2012 two new, Class 10K ,clean tents were added to the laboratory.

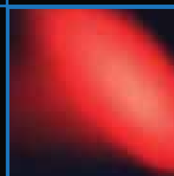
Newly ESD Epoxy Coated Floor in VAB High Bay.

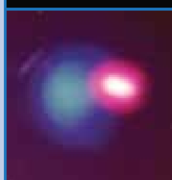
The Phase II addition to the VAB was completed in the fall of 2012. As of this writing, the final punch list of cosmetic corrections are being addressed by the contractor with NASA about to take full ownership/occupancy. This facility will have rooms to house most of the technical functions conducted at the N-200/LC-35 facility including: an air bearing room, an interconnected heliostat room with solar port, an optics lab, Celestial ACS lab, and both pneumatics and electronics labs.

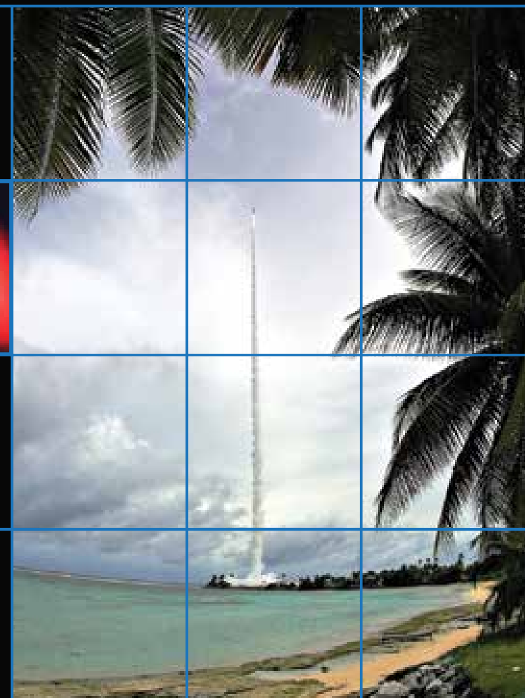
The final phase, Phase III, provides upgrades to the Telemetry ground station, new offices for administration/reception, Safety, and Telemetry technicians. This phase is about 80% complete as of this writing and is expected to be complete by the end of November. 2012

The SRPO and NSROC staff are busy strategically planning consolidation activities to minimize the impact on mission operations. While NSROC office's have already been moved, much of the GSE at LC-35 remains in tact as it is needed to support active missions. Following a series of launches in December, the SRPO will suspend launch operations until mid-February in order to move equipment. This time frame coincides with closure of the WSMR for the Holidays and takes advantage of a lull in our launch manifest. It is planned to move all equipment from N-200/LC-35 with the exception of the Telemetry ground station and the 10 ft antenna. A Terrier-Orion technology demonstration mission is being planned for mid-February as the first mission following consolidation activities. This mission will test the new SPARCS upgrades and will be utilized to certify the newly relocated command uplink station prior to its use on science missions. The final step will involve the relocation of the 10 ft telemetry antenna and the remaining ground station equipment.

The Sounding Rockets Program is preparing for the upcoming Marshall Islands equatorial ionosphere campaign, currently scheduled for April 2013. Two investigations, the Equatorial Vortex Experiment (EVEX) and Metal Oxide Space Cloud (MOSC) experimentt, will be conducted during this campaign. A total of four vehicles will be launched from Roi Namur.







On The Horizon

Kwajalein campaign 2013

After nearly 10 years, researchers are poised to return to the South Pacific and the Reagan Test Site (RTS) to once again conduct investigations in the equatorial ionosphere. Led by Dr. Erhan Kudeki/ University of Illinois, the Equatorial Vortex Experiment (EVEX) science mission consists of a pair of sounding rockets whose scientific objective involves a study of the circulation of ionospheric plasma just after sunset. The intensity of circulation in the equatorial ionosphere is assumed to be related to post sunset ionospheric disturbances or "storms" which are known to affect satellite communication and navigation systems. This experiment will measure electric fields, plasma velocity, neutral winds and plasma densities during the early development stages of these ionospheric storms.

Winds at very high altitudes carry a tremendous amount of energy and are known to have a direct effect on the ionospheric disruptions that are the focus of the EVEX experiment. Due to the low atmospheric density at these altitudes, measuring these winds is quite difficult. Thus the EVEX experiments will each use a chemical tracer technique to measure the direction and velocity of these winds. Lithium vapor and trimethyl aluminum (TMA) gas will be released and optically tracked from 3 remote optical sites to make these critical measurements. These techniques have been perfected over the last five decades and have proven to be highly effective. They also produce clouds that will be visible for up to 30 minutes after launch.

Located in the Kwajalein Atoll, the Reagan Test Site is ideally suited for conducting these experiments as it is very close to the magnetic equator where these iononspheric disturbances are most frequent and intense. Another reason RTS is an attractive location to conduct ionoshperic studies is the ability to utilize the ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR). This very large and powerful UHF/VHF radar is a Department of Defense (DoD) asset utilized to track space objects and other orbiting space debris. Using slightly modified wave forms, scientists have been using ALTAIR for many years to conduct ground based observations of various ionospheric phenomena. It will be used in this experiment to help characterize the state of the post sunset ionospheric region and determine when conditions are suitable to launch.

Barium (blue) and lithium (redish–purple) releases conducted at Wallops Flight Facility in 1983. Lithium is released from the Terrier–Oriole payload flying from Kwajalein during the EVEX mission.

A trimethyl aluminum release conducted from Wallops Island, VA, on March 27, 2012.

The ALTAIR radar on Roi–Namur.

The Air Force Research Lab (AFRL), which has long history of collaboration with NASA and the Sounding Rockets Program, will also be using this opportunity to launch two scientific research missions. The Metal Oxide Space Cloud (MOSC) mission will also use a pair of sounding rocket experiments to study the effects of artificially generated ionized layers in the Earth's ionosphere on radio frequency (RF) propagation. This experiment will release a vapor of the metal Samarium (Sm) into the ionosphere that will react with background oxygen atoms creating a cloud of charged particles. Researchers will probe and diagnose the characteristics of this artificially generated plasma cloud with a host of ground and space-based assets. The Principal Investigator for this mission is Ronal Caton of the AFRL. The DoD Space Test Program is assisting with the execution of this mission by working with the SRPO on the launch vehicles, logistics, and launch site infrastructure.

A Samarium cloud released during a mission from Hawaii in 1989.

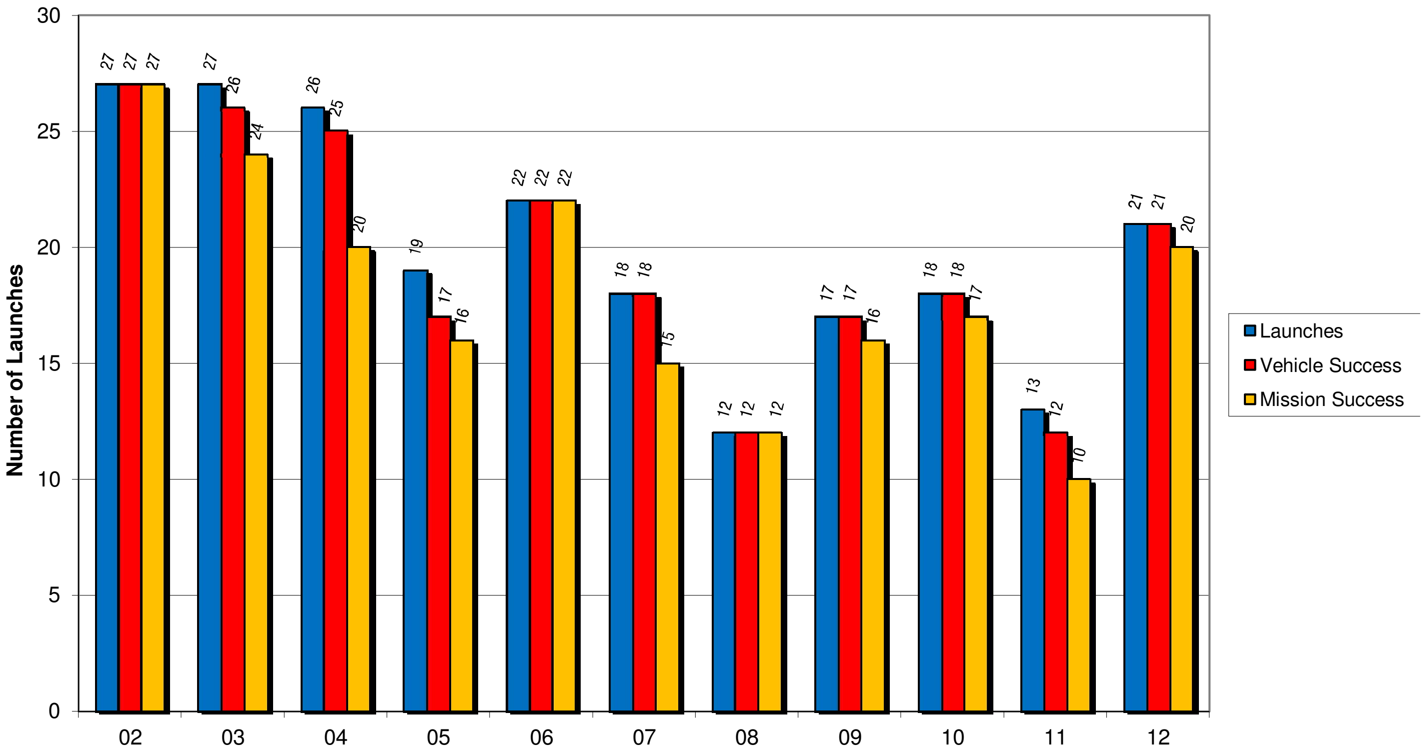
Originally planned for late summer/early fall of 2012, the EVEX/MOSC campaign had to be postponed due to a conflict with a large DoD mission utilizing the RTS. After much analysis, the science teams have elected to reschedule for late April/early May. Based on historic data collected from ground based sensors, the science teams believe ionospheric conditions during this period will once again be conducive to conduct these experiments.

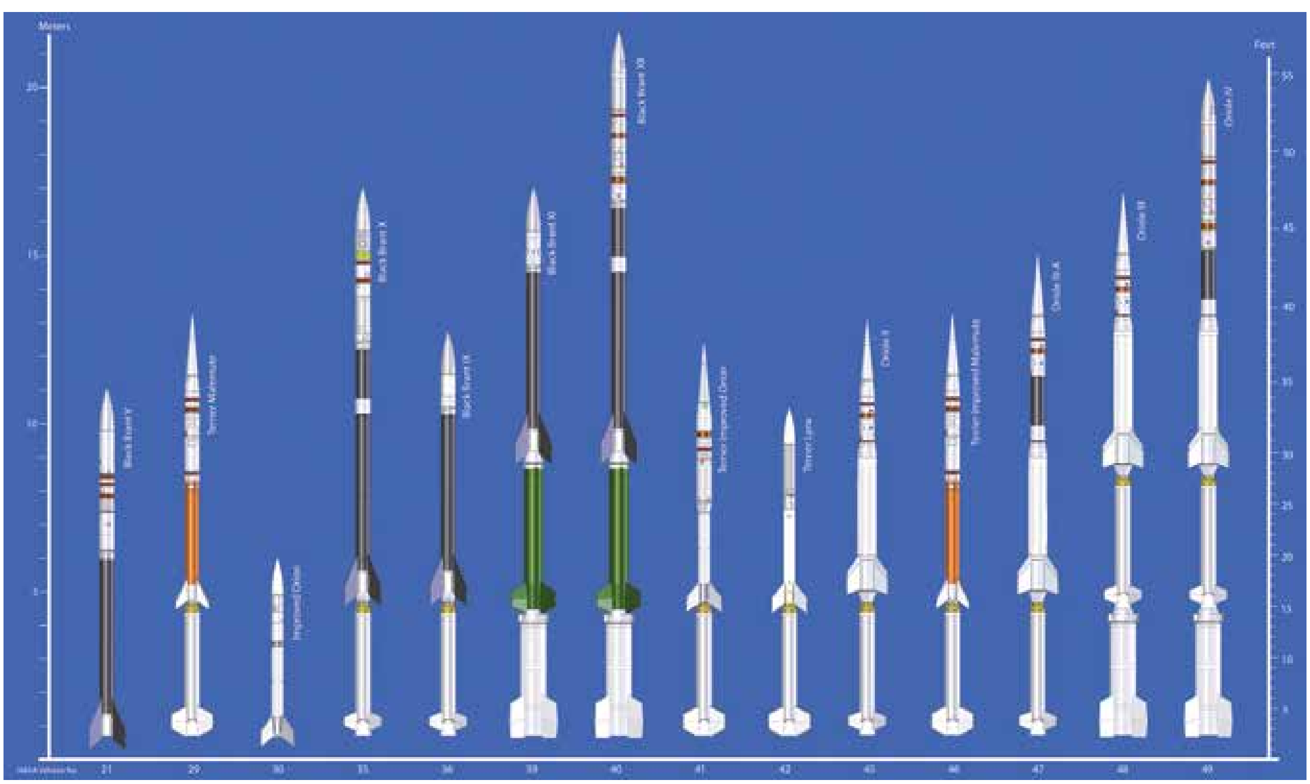
Collaborating scientists on the EVEX missions include Dr. Robert Pfaff of the Goddard Space Flight Center and Dr. Miguel Larsen of Clemson University. Collaborating scientists on the MOSC missions include Dr. Keith Groves of Boston University and Dr. Paul Bernhardt of the Naval Research Laboratory. The campaign is managed by John Hickman of the Sounding Rockets Program Office.

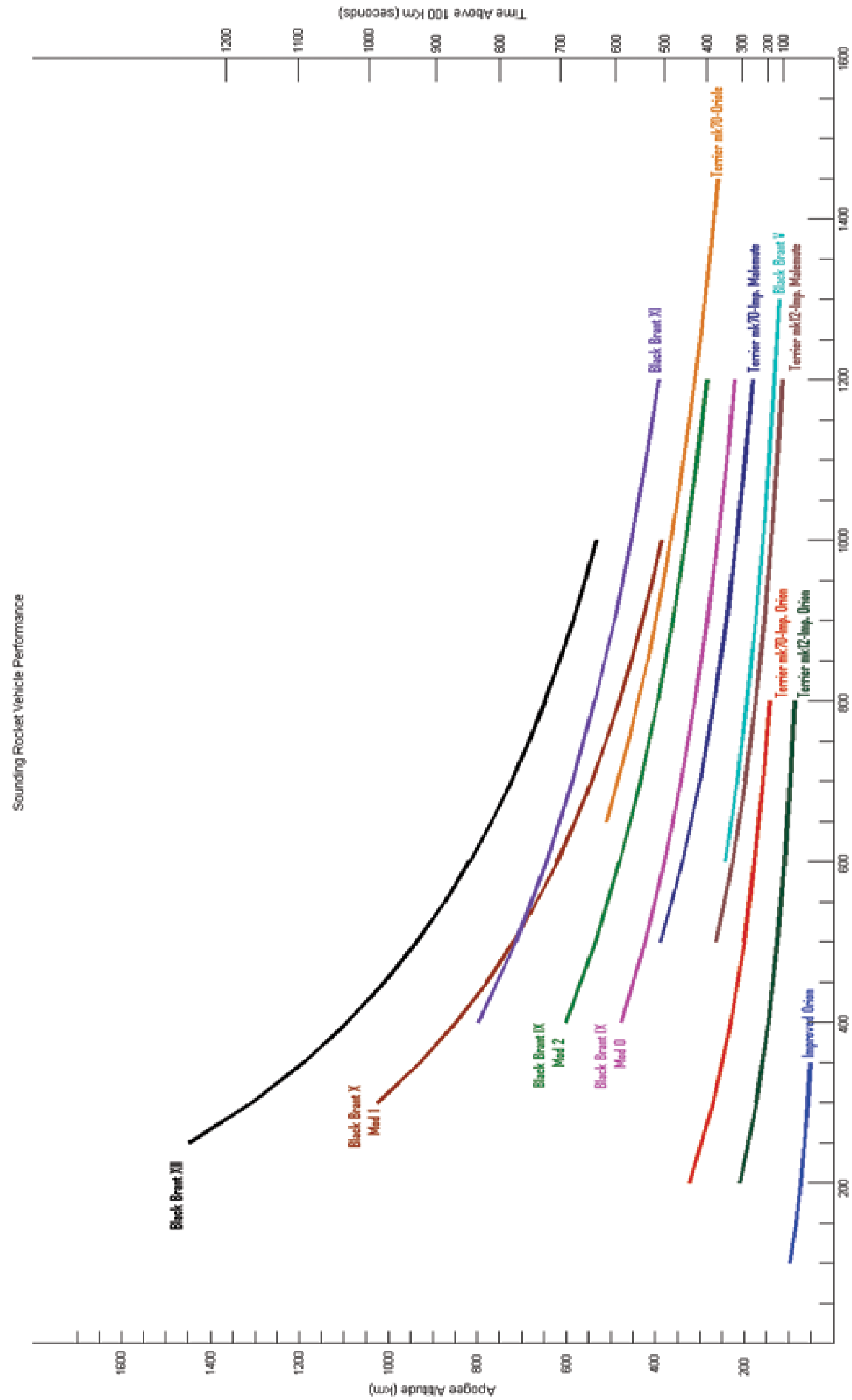
Charts

A total of 16 investigations using 21 vehicles were launched in 2012. The current vehicle stable includes 15 different vehicle configurations to be selected depending on mission requirements. These range from single stage to four stage combinations, including the recently developed Terrier-Improved Malemute and Talos-Terrier-Oriole. The charts inlcude launch data from 2002 through 2012, vehicle configurations, perfomance charts and launch ranges used by the sounding rockets program.

Sounding Rocket Launches
FY 2002 - 2012
Total number of launches: 220







Sounding Rocket Vehicle Performance
Payload Weight (lbs)
Apogee Altitude (km)
Time Above 100 Km (seconds)
Black Brant XII
Black Brant X Mod 1
Black Brant XI
Black Brant IX Mod 2
Black Brant IX Mod 0
Terrier mk70-Oriole
Terrier mk70-Imp. Malemute
Black Brant V
Terrier mk12-Imp. Malemute
Terrier mk70-Imp. Orion
Terrier mk12-Imp. Orion
Improved Orion

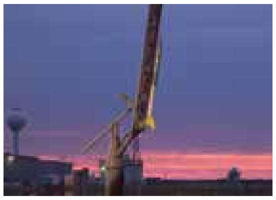

Poker Flat, Alaska

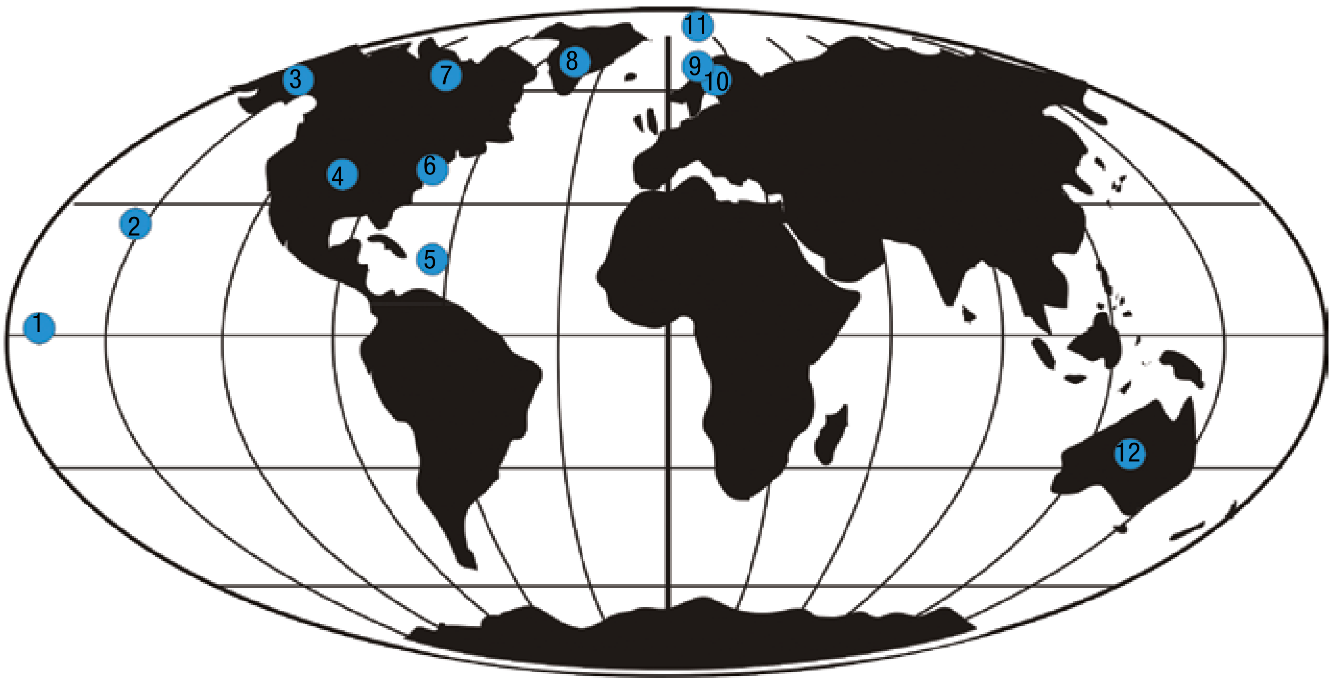

Esrange, Sweden


Kwajalein, Marshall Is.


Andoya, Norway


Woomera, Australia


Wallops Island, Virginia



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. Camp Tortuguero, Puerto Rico *
6. Wallops Island, VA
7. Fort Churchill, Canada *
8. Greenland (Thule & Sondre Stromfjord) *
9. Andoya, Norway
10. Esrange, Sweden
11. Svalbard, Norway
12. Woomera, Australia

* Inactive launch sites

Sounding Rockets Program Office

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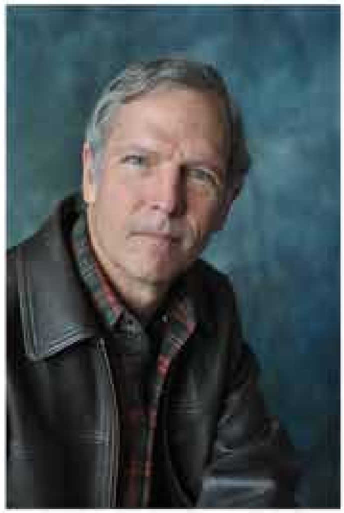

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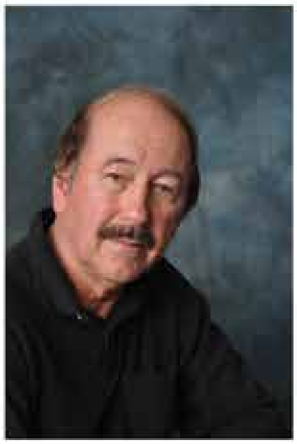

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Credits:

Cover - Rocket launch image: Wallops Imaging Lab, IRVE -3 image: Sean Smith/NASA LRC, Reionization John Wise, Renyue Cen and Tom Abel yt project http://hg.yt-project.org/, Solar image - Jonathan Cirtain/NASA MSFC

Page 6: All images NASA Wallops Imaging Lab

Page 7 - 11: All images (except Space Shuttle) and figures: Miguel Larsen/Clemson University, Shuttle Image: NASA

Page 12: CHAMPS launch image: Kohlbjorne Dahle/Andoya Rocket Range, Payload Image: Berit Bland

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Page 20: Background image - John Wise, Renyue Cen and Tom Abel yt project http://hg.yt-project.org/, Group photo with rocket - White Sands Miisile Range Visual Information Branch

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Page 24: White Sands Missile Range Visual Information Branch

Page 25 - Vela & Puppis ROSAT imsge credit: Max-Planck-Institut für extraterrestrische Physik (MPE)

Cygnus loop credit: Levenson et al.

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Page 28: NASA Wallops Imaging Lab

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Page 35: Kohlbjorn Dhale, Andoya Rocket Range

Page 37: Vehicle photo - Jamie Adkins, NASA Wallops Imaging Lab

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Page 49 - 50: All images - White Sands Miisile Range Visual Information Branch

Page 52: Launch image - nowhereatoll.com

Page 52 & 54: Samarium release photo - General Sciences, Inc.

Page 59: All images - John Brinton/SRPO

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Principal Investigator Steven Powell/Cornell University checks instrument booms after deployment. Nate Wroblewski/NSROC assists.

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