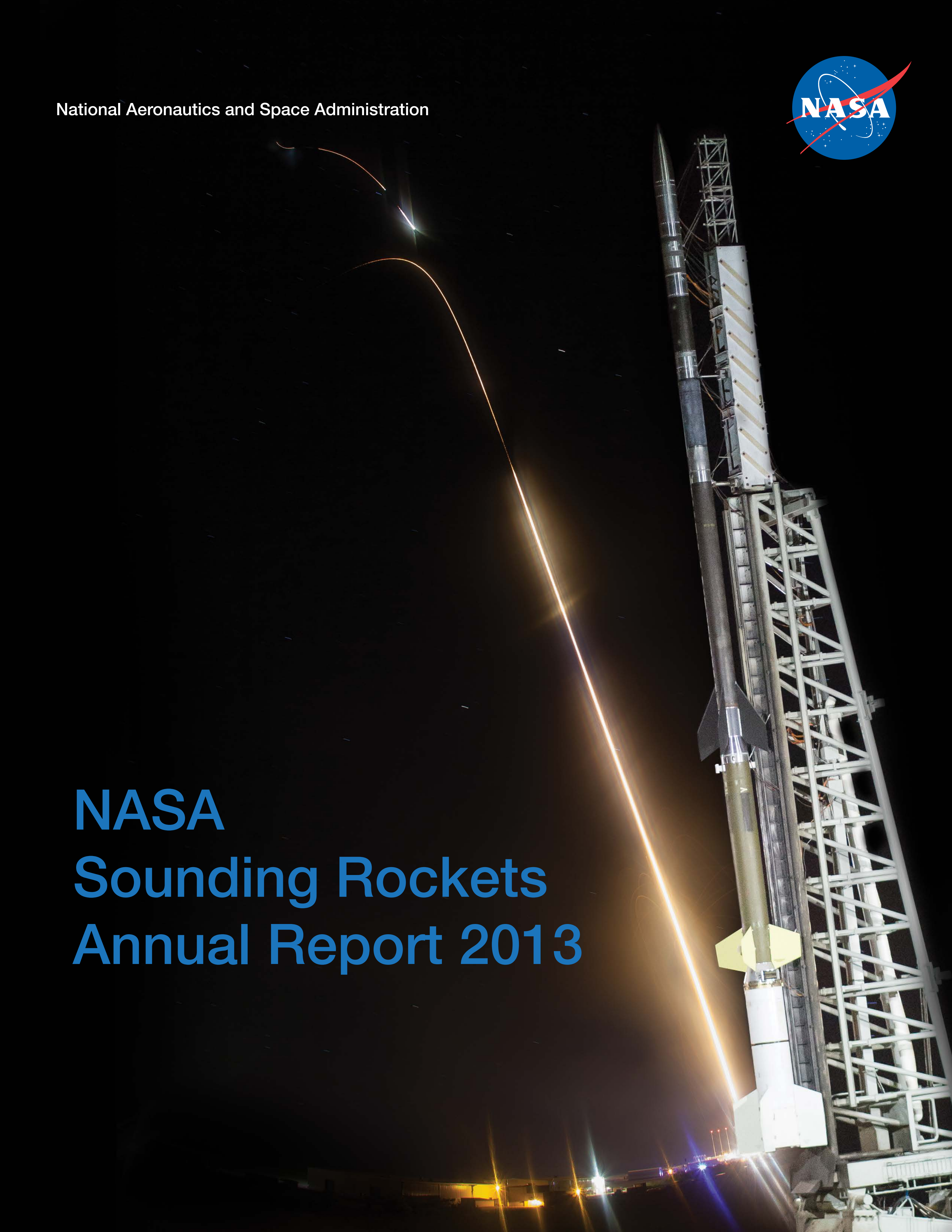
National Aeronautics and Space Administration



NASA Sounding Rockets Annual Report 2013

Phil Eberspeaker
Chief, Sounding Rockets Program Office

Message from the Chief

The NASA Sounding Rockets Program has closed another highly successful operational year with the completion of 19 successful flights. As of October 2013, the program has had 100% success on 38 flights over a period of 24 months. This is an impressive accomplishment. The scientific teams, the technical and administrative sounding rocket staff, and the launch ranges are to be congratulated on a job well done! This year involved flights from Wallops Flight Facility (Virginia), White Sands Missile Range (New Mexico), the Kwajalein Atoll (Marshall Islands), and Poker Flat Research Range (Alaska). The Kwajalein campaign involved four rockets designed to probe the equatorial ionosphere and gain a better understanding of plasma energies and particle dynamics affecting the Earth. Multiple telescope missions were flown from White Sands Missile Range to study the Sun, the interstellar medium, and distant galaxies. Flights from Wallops and Alaska have furthered our understanding of how the Earth and Sun interact. With every flight, NASA added to the body of scientific knowledge that will help unravel a host of scientific mysteries.

The Sounding Rockets Program also continued to cultivate young minds by offering two university-level flight opportunities. Approximately 250 students from universities around the country had the opportunity to fly experiments aboard two-stage sounding rockets in 2013. The Sounding Rockets Program once again provided a unique teacher training workshop known as WRATS. With the knowledge obtained from this experience, teachers returned to the classroom with exciting options for enhancing their STEM curriculum. In this way we are able reach thousands of students around the country with minimal investment. Additionally, over the last 15 years, the NSROC contractor has hosted 150 university interns and Co-Ops. These students enter the workforce with valuable experience and many return to the sounding rocket program as full-time employees after graduation. As an interesting and inspiring diversion to their day, many employees of the program support other educational outreach activities in the community. This includes school visits, community events, and summer camp activities. This educational gold mine is made possible by the creative and dedicated personnel who support the Sounding Rockets Program. You can read all about these activities and more in the following pages.

As I think about the technical and scientific accomplishments and the people that make them a reality, I feel nothing but admiration and pride. I look forward to another productive year and embrace the unknown challenges that await.

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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), RHESSI, Hinode and SOHO.


Missions 2013


GEOSPACE SCIENCE

Equatorial Vortex Experiment - EVEX

Principal Investigator:
Dr. Erhan Kudeki
University of Illinois
Mission Number(s):
46.001 & 45.006 UE
Launch site:
Kwajalein, Marshall Islands
Launch date:
May 7, 2013

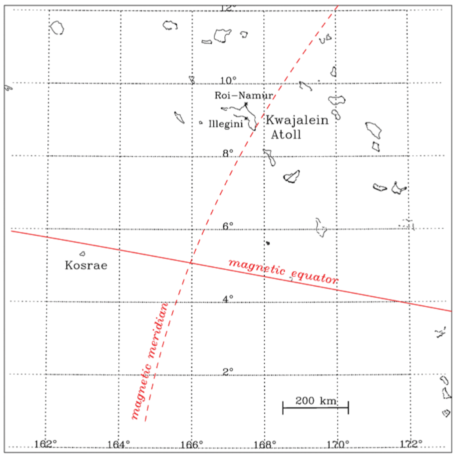


Figure 1 – Roi–Namur, Kwajalein is ~ 5 degrees from the magnetic equator.

Figure 2 – Altair radar on Roi Namur.

A. Background and Scientific Motivation

The Equatorial Vortex Experiment (EVEX) science mission, led by Dr. Erhan Kudeki/University of Illinois, consisted of a pair of sounding rockets, launched from Roi-Namur in the Kwajalein Atoll, Marshall Islands. The EVEX mission aimed to study the electrodynamics and plasma circulation in the equatorial ionosphere just after the E-region sunset in the altitude region extending from the E-layer to the F-region peak. The intensity of post-sunset equatorial plasma circulation or vortex has been conjectured to control the initiation of post-sunset ionospheric storms known as spread-F. The Kwajalein Atoll in the Marshall Islands is ideally suited for testing this conjecture as it is very close to the magnetic equator (see **Figure 1**) where spread-F storms are most intense and have severe impact on satellite communication and navigation systems and signals. EVEX experiments on a pair of instrumented rockets launched to 183 and 330 km apogees measured electric and magnetic fields, plasma velocity, neutral winds and plasma densities during the initiation stages of these storms.

An important element of these experiments involves measurements of the atmospheric winds at high altitudes. Just as on the ground, theromospheric winds at F-region altitudes carry energy and momentum that are known to have a direct effect on the ionospheric disruptions that are the focus of EVEX. Wind measurements at these altitudes are difficult because of the very low atmospheric density. Over the past five decades, several tracer techniques have been perfected to accomplish this by optical tracking of visible gases released from the rockets. Lithium vapor and trimethyl aluminum (TMA) gas have been particularly effective. TMA reacts spontaneously on contact with oxygen to produce a pale white glow visible from the ground. Lithium produces a strong red resonance light emission when illuminated by sunlight. Both gases move with the background atmosphere and thus releasing these vapors along the rocket trajectories and observing their "trails" in space can be used to determine the wind speeds and direction.

Another critical aspect of the experiment is the radar data gathered at Kwajalein before, during, and after the rocket launches. Radar observations from the ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR), as shown in **Figure 2**, was used to monitor the state of the upper atmosphere/ionosphere in order to determine when the large-scale disruptions occur and thus when to launch the rockets. The ALTAIR measurements are also critical for the interpretation of the rocket data by providing measurements of the large-scale structure and time history of the conditions in which the rockets fly.

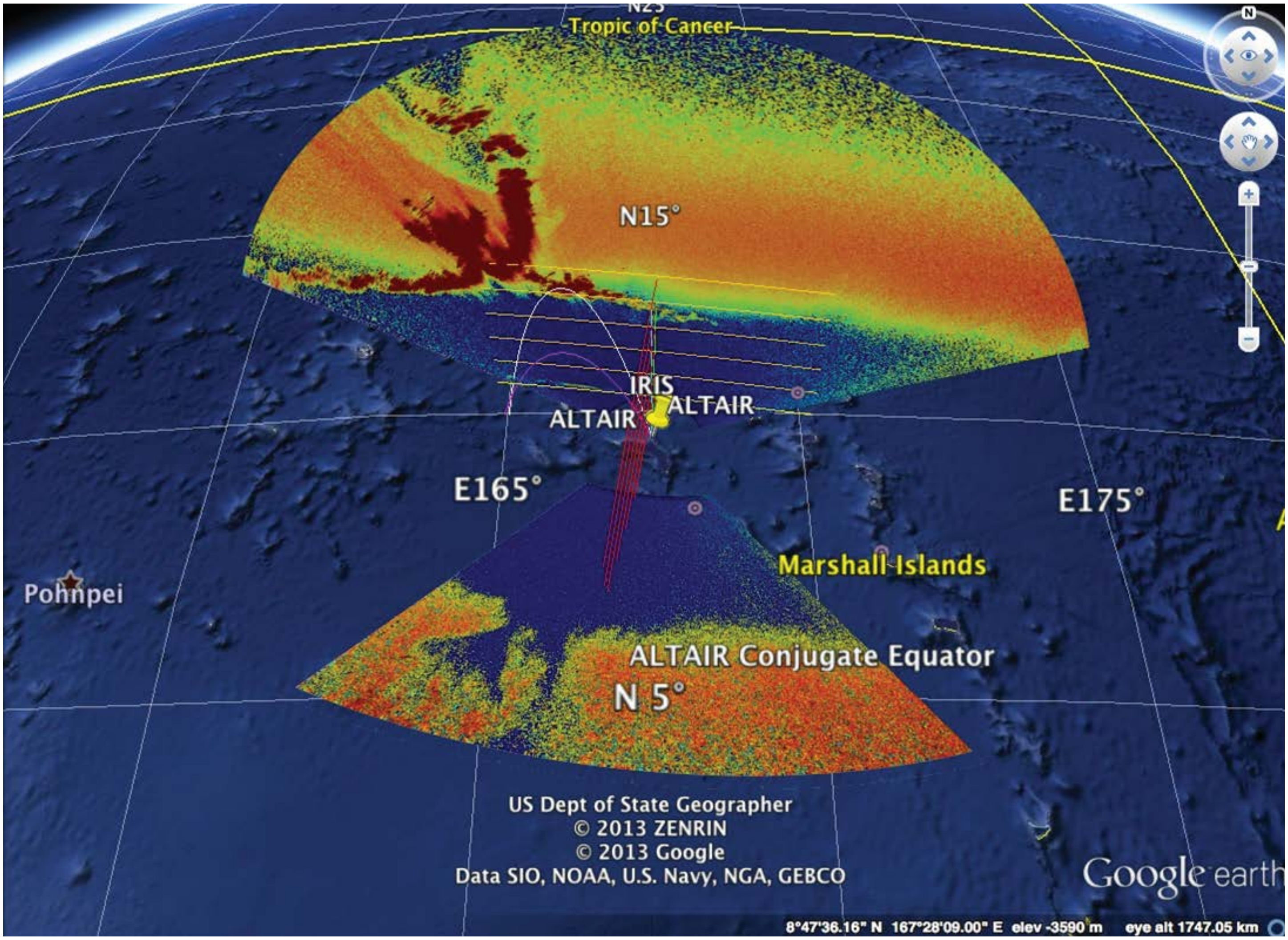


Figure 3 – ALTAIR density scans to north and south of Roi–Namur including sketches of the field lines (red lines) and the nominal EVEX rocket trajectories.

Figure 4 – The EVEX High Flyer Rocket on the rail. The plastic bag helps control humidity.

ALTAIR scan maps of electron densities conducted during the development stage of spread F plasma depletions or "bubbles" (after the launches) are shown in **Figure 3** in terms of 2D scan surfaces embedded in a Google Earth image. The two scan surfaces displayed in Figure 3 were obtained 20 minutes apart. The scan to the north is perpendicular to the magnetic field and provides enhanced backscatter from field aligned Bragg scale density irregularities. The scan to the south is off-perpendicular and thus the incoherent scatter reveals the ionspheric depletions associated with the irregularities.

Whereas ALTAIR was used to scan the ionosphere over a broad range of azimuth angles from east to west, the University of Illinois Radar Imaging System (IRIS) was set up on Kwajalein to gather very high time resolution observations of the unstable ionosphere along a fixed beam pointed perpendicular to the geomagnetic field. The location of the IRIS beam is shown in **Figure 3**.

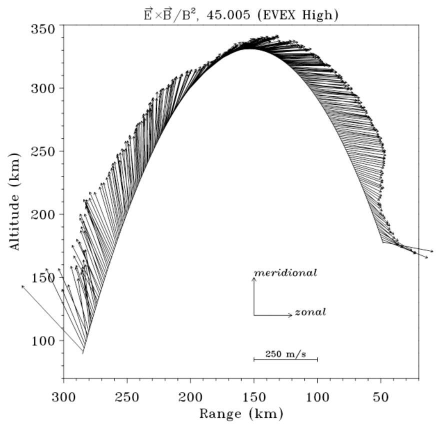


Figure 5 – Plasma drifts (preliminary) from the electric field experiment on the high flyer show changing drift velocities at different ranges (local times).

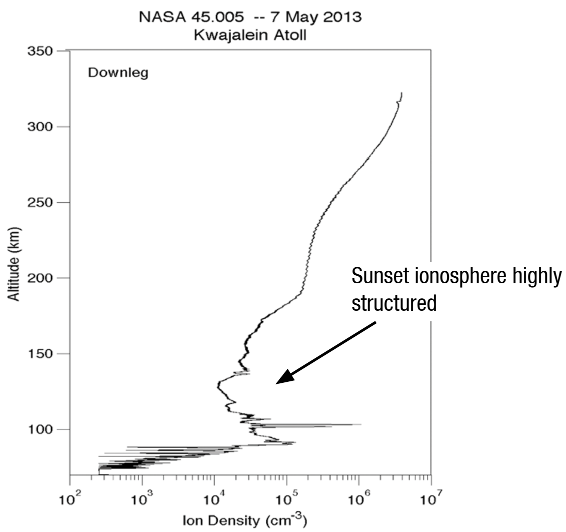


Figure 6 – Langmuir probe reveals structured density

Figure 7 – Lithium (red cloud) and TMA trails (blue and white trails) provide winds as a function of altitude.

B. EVEX Launches and Some Initial Results

Both rockets, a Terrier-Improved Malemute and a Terrier-Oriole, were success- fully launched on May 7, 2013. The Terrier-Oriole was first off the pad, flying to an altitude of ~ 330 km, followed by the Terrier-Improved Malemute, launched 90 seconds later, reaching an altitude of 183 km. The launches of the two rockets were timed so that they gathered data in the lower and upper ionospheres at the same time, as shown in the trajectory traces in **Figure 3**. The high flyer rocket is shown on the rail in **Figure 4** before launch.

The instrumentation on the two rockets was nearly identical, except for the wind measurements which used different chemicals. Each carried electric field double probes to measure the DC electric fields, which when combined with the magnetic field data, yield the **E x B** velocities or the plasma drifts. **Figure 5** shows preliminary **E x B** velocities along the flight trajectory of the higher apogee rocket. Notice immediately that the velocities changed between the upleg and downleg, as well as with range and local time, yielding important clues concerning the circulation of the ions and electrons preceding an ionospheric storm.

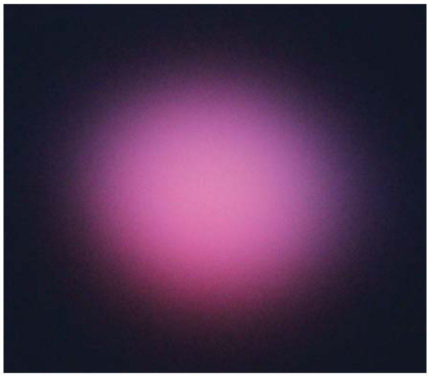
The plasma density of the ionosphere is shown in **Figure 6**, also from the high altitude rocket, and reveals a highly structured medium at the lower altitudes.

The neutral wind information is provided by the lithium and TMA trails shown in **Figure 7**. In this case, the lithium is the red "cloud". It was released by the high-flyer rocket near 300 km altitude. The fainter blue and white traces represent the TMA trail that was released by the lower altitude rocket on its upleg trajectory.

The simultaneous observations gathered by the instruments and wind measurements provided by the two rockets, when combined with the ALTAIR and IRIS observations, provide an unprecedented view of the equatorial ionosphere. The combined measurements promise to advance our understanding of how gases comprised of charged particles (plasma) and the upper atmosphere interact to create the ionospheric F-region density structures in the post-sunset environment.

METAL OXIDE SPACE CLOUD EXPERIMENT - MOSC

Principal Investigator:
Mr. Ronald Caton
Air Force Research Laboratory
Mission Number(s):
41.100 & 41.102 DR
Launch site:
Kwajalein, Marshall Islands
Launch date(s):
May 1, 2013 & May 9, 2013



Samarium vapor cloud.

The Metal Oxide Space Cloud experiment (MOSC) reimbursable science mission, led by Mr. Ronald Caton/Air Force Research Laboratory (AFRL) and executed for the DoD Space Test Program, consists of a pair of sounding rockets launched from Roi-Namur on Kwajalein Atoll in the Republic of the Marshall Islands.

The scientific objective of the MOSC mission involved an investigation of the effects of artificially generated ionized layers in the Earth's ionosphere on radio frequency (RF) propagation with the release of the metal element, Samarium (Sm), in vapor format. The samarium vapor reacts with background oxygen atoms creating a cloud of charged particles, referred to as a plasma cloud, that diffused and dissipated over the period of several hours.

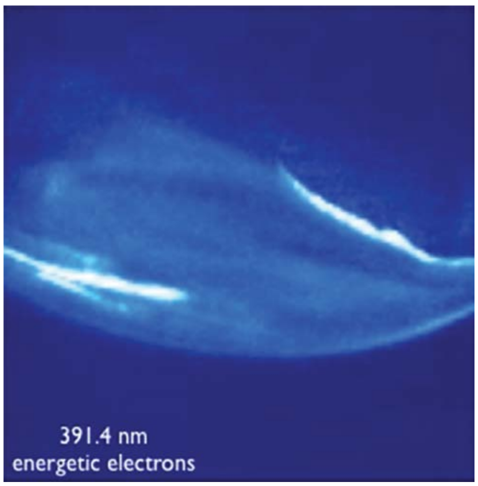
During the MOSC experiment, researchers probed and diagnosed the characteristics of the artificially generated plasma cloud with a host of ground and space-based assets. For each flight, the MOSC payload included a Coherent Electromagnetic Radio Tomography (CERTO) beacon, provided by the Naval Research Laboratory, that transmitted VHF and UHF tones recorded on an array of ground-based receivers located on Kwajalein and other nearby atolls. Additional observations included optical and spectral measurements of the cloud from multiple camera sites and HF ionosondes with vertical and oblique soundings of the ionosphere.

The ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR) on Roi-Namur was used to monitor the state of the ionosphere throughout the mission and was critical in tracking and diagnosing the plasma cloud as it drifted with the background ionosphere along the Earth's magnetic field lines. During this experiment, ALTAIR was also used to provide highly detailed information on the presence of large-scale structures in the ionosphere that most often occur in the nighttime hours in the equatorial region causing disruptions on radio wave propagation.

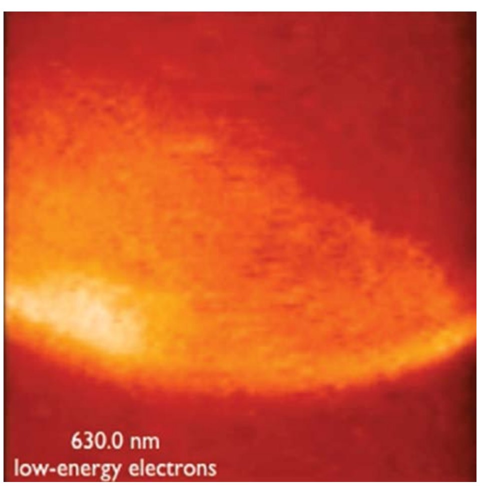
The two MOSC payloads were successfully launched on May 1st and May 8th respectively.

Visualizing Ion Outflow via Neutral Atom Imaging During a Substorm - VISIONS

Principal Investigator:
Dr. Douglas Rowland
NASA Goddard Space Flight Center
Mission Number(s):
49.001 GE
Launch site:
Poker Flat Research Range, Alaska
Launch date:
February 7, 2013



VISIONS RAI images of the aurora, taken from onboard the rocket, as it moved through regions of bright aurora. The Earth's northern limb is the arc at the bottom of the plot.



VISIONS RAI image of the aurora, taken in the 630.0 nm wavelength band. Regions of intense 630.0 nm emission experience intense low–energy electron precipitation.

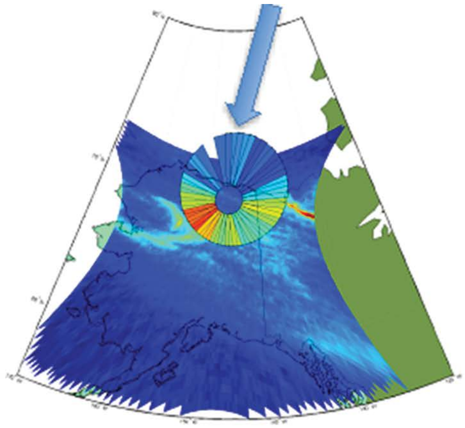
The "auroral wind" is a gusty, patchy flow of hot oxygen out of the Earth's upper atmosphere. Driven by the fluctuating electrical currents and intense electron precipitation in the aurora, ionized oxygen is hurled out of the ionosphere into near-Earth space.

Though many mechanisms have been proposed to explain how the auroral energy heats and pushes the oxygen out of the atmosphere, previous experiments could not distinguish the extent to which the auroral wind was spatially "patchy" versus temporally "bursty". VISIONS is a sounding rocket mission that combines imaging of the auroral wind and the auroral light together in order to better understand what drives this wind and heats oxygen from a few hundred degrees to a few hundred thousand degrees.

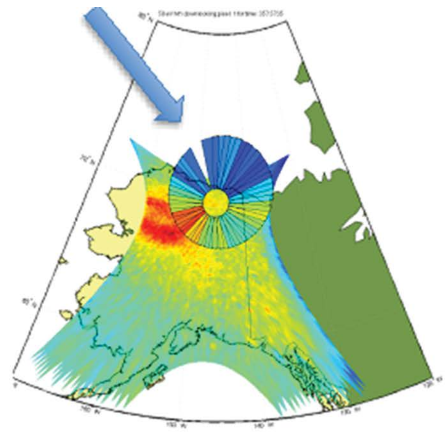
VISIONS launched from Poker Flat, AK, in February 2013, and carried a new instrument, MILENA (Miniaturized Imager for Low Energy Neutral Atoms), developed by NASA GSFC, which can gather "pictures" of the intensity of the auroral wind. MILENA spins with the rocket motion, and catches oxygen coming from each direction. By counting how many oxygen atoms are coming as a function of the look angle, MILENA can build up an image of how the auroral wind is varying. VISIONS carried a second novel instrument, the RAI (Rocket-borne Auroral Imager), developed by the Aerospace Corporation. RAI had four narrowband optical cameras, each tuned to a particular wavelength of light emitted by the aurora. By comparing ratios of these lines, RAI's data can build up a picture of where the electrons in the aurora are most intense, and where the electrons are low in energy or higher in energy. Some models predict that the auroral wind will be strongest from regions of intense low energy electron precipitation, which tend to emit bright red light.

With MILENA and RAI onboard, as well as an electric fields package from NASA GSFC and energetic particle detectors from Aerospace, VISIONS launched into the aftermath of a bright auroral display. VISIONS was able to demonstrate that the auroral wind is both "patchy" and "bursty" and that it is strongest where there are intense low-energy electrons raining down the magnetic field.

MILENA imaging of ion outflows.



Auroral emissions at 391.4 nm
(high energy electrons, low altitude)



Auroral emissions at 630.0 nm
(low energy electrons, high altitude)

Combined MILENA and RAI images demonstrating that the auroral wind (dial plot) is strongest in regions where the 630.0 nm auroral light is most intense (right hand plot). This suggests that most of the auroral wind is driven at higher altitudes in the ionosphere, as the low-energy electrons destabilize waves that resonate with the oxygen ions as they gyrate around the magnetic field.

The VISIONS team at Poker Flat, on the day of the launch. VISIONS can be seen in the background.

Principal Investigator:
Dr. Robert Pfaff
NASA Goddard Space Flight Center
Mission Number(s):
21.140 & 41.090 GE
Launch site:
Wallops Island, Virginia
Launch date:
July 4, 2013

Figure 1: The Earth's Lower ionosphere is the seat of a system of "dynamo" currents that form global scale current loops.

Figure 2: Launch of two Dynamo rockets 15 seconds apart.

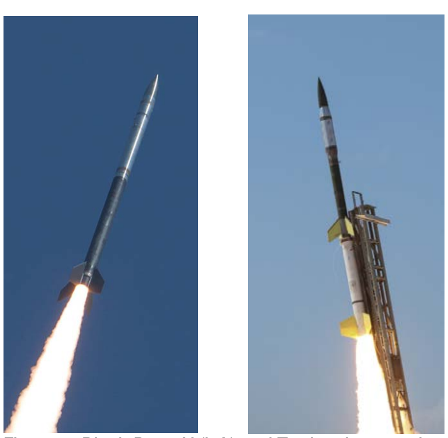


Figure 3: Black Brant V (left) and Terrier–Improved Orion (right).

Daytime Dynamo Experiment

The "Daytime Dynamo" rockets enabled a fundamental study of the characteristics of the earth's upper atmosphere and lower ionosphere including the first comprehensive measurements of the atmospheric dynamo, its detailed electrodynamics, and the daytime neutral wind that drives this current system.

A. Background and Scientific Motivation

The Atmospheric Dynamo and Large Scale Electrodynamics. The earth's atmospheric dynamo sets up a system of global ionospheric currents and intrinsic DC electric fields at mid and low latitudes (Figure 1). Neutral winds, driven by solar heating and to a lesser extent lunar gravitational tides, drag plasma across the earth's magnetic field which produce currents, J, as the ions and electrons drift in different directions. The primary dynamo is in the lower ionosphere (90–130 km), since here the conductivities are greatest, as are the gradients in the neutral wind.

As the winds, **U**, blow across the magnetic field, **B**, dynamo electromotive fields are set up equivalent to $\mathbf{U} \times \mathbf{B}$. In order to restrict the current flow to be non-divergent (i.e., $\nabla \cdot \mathbf{J} = 0$), global polarization electric fields, **E**, are created. The total current is thus given by

$$\mathbf{J} = \underline{\sigma} \cdot (\mathbf{E} + \mathbf{U} \times \mathbf{B}) \tag{1}$$

where $\underline{\sigma}$ is the conductivity tensor. These currents combine to form the global current loops at mid-latitudes which close in the equatorial electrojet.

Although scientists believe that the currents, winds, electric fields, and conductivity must combine via equation (1) to produce the earth's global current system, the actual relationships of these parameters, particularly as a function of altitude, are not well-understood and have never been tested. NASA's Daytime Dynamo rockets enabled local measurements of each parameter in equation (1) to be examined as a function of altitude and simultaneously for the first time.

The Daytime Neutral Wind and Wind Shear Profiles. The neutral wind is believed to be the prime driver of the mid-latitude dynamo currents discussed above. Measurements of this wind as a function of altitude in the daytime lower ionosphere are exceedingly rare. Furthermore, the many nighttime neutral wind profiles provided by chemical release experiments on previous sounding rockets have consistently shown that the winds are *much larger* than those predicted by tidal theory and that they contain *unexpected large shears* that may be unstable. This may be true for the daytime case as well.

B. The Dynamo Rocket Launches and Initial Results

NASA successfully launched two sounding rockets from Wallops Research Range on July 4, 2013 within 15 seconds of each other to study the earth's daytime dynamo **(Figures 2 and 3).** The rockets were launched into a strong dynamo current, as measured by a ground-based magnetometer located at Wallops.

The first rocket, Black Brant 21.140, achieved an apogee of 135 km and carried instruments to measure earth's electric and magnetic fields, as well as plasma and neutral gases. The instruments were provided by Goddard, the Aerospace Corporation, the Jet Propulsion Laboratory, and UCLA.

Profiles of the dynamo currents measured by Goddard's magnetometer are shown in **Figure 4** for the upleg and downleg.

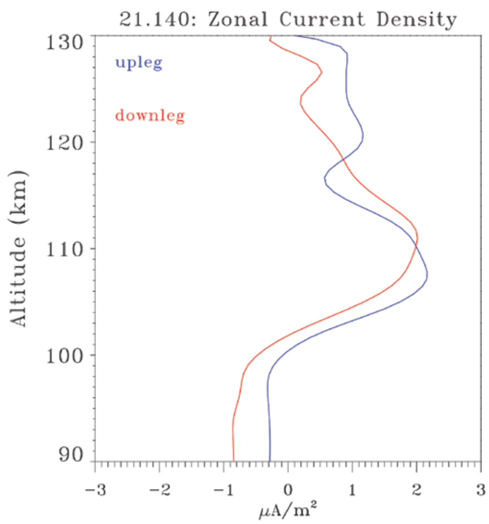
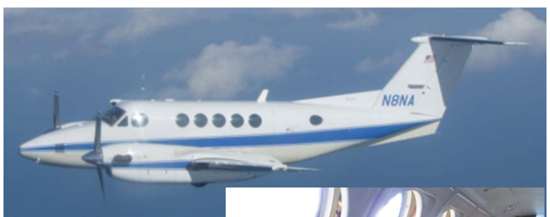


Figure 4: Dynamo currents measured using Goddard's magnetometer on the upleg and downleg on rocket 21.140.

The second rocket, a Terrier-Orion (41.090), achieved an apogee of 143 km carried six canisters which released a lithium vapor trail along the upleg trajectory to illuminate neutral winds in the upper atmosphere. This vapor trail technology was developed jointly by researchers at JAXA and Clemson University. The rocket also carried a "falling sphere" experiment built by Utah State University and Clemson University.

The lithium release was clearly visible in cameras with infrared filters operated by US and Japanese researchers in a NASA airplane **(Figure 5)** that gathered photographs at 31,500 feet (9.6 km).



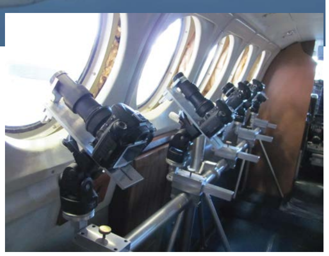


Figure 5: The NASA–8 King Air used to observe lithium trails (above) and the cameras onboard the plane used for the observations (right).

The vapor trails revealed powerful neutral winds that drive the dynamo current as well as evidence for neutral wind shears that may produce instabilities in this region of space **(Figure 6).**

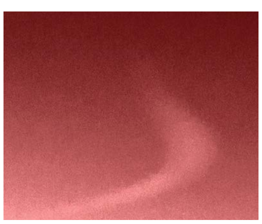


Figure 6: Observations of the lithium trails made from the NASA–8 Plane reveal powerful winds in the dynamo region (left) and neutral wind shears and turbulence at the base of the ionosphere (right).

When the wind profiles and in situ measurements are combined, the data gathered by the two Daytime Dynamo rockets promise to advance our understanding of the earth's atmospheric dynamo by a considerable degree.

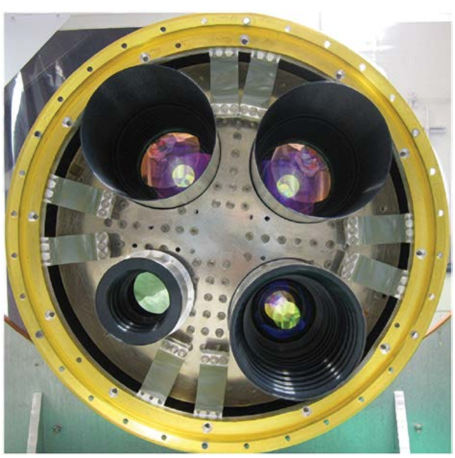
The Dynamo Project is a joint undertaking of NASA and JAXA (Japan Aerospace Exploration Agency).

ASTROPHYSICS

Cosmic Infrared Background ExpeRiment - CIBER

Principal Investigator:
Dr. Jamie Bock
California Institute of Technology
Mission Number(s):
40.030 UG
Launch site:
Wallops Island, Virginia
Launch date:
June 6, 2013

CIBER flight preparations at Wallops Fligth Facility.



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).

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.

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: 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.

During this, its final flight, a four-stage Black Brant XII rocket was used to carry CIBER to an altitude of about 350 miles. The flight pioneered a new direction in the astrophysics program in that the instrument was flown on a non-recovered Black Brant XII. The BB XII provides a significantly higher trajectory, providing about 560 seconds of flight time above 250 km altitude. In the near-infrared waveband appreciable emission from the atmosphere can be seen up to 250 km. The higher trajectory enables enough independent images of the sky to directly determine the in-flight gain of the infrared cameras, which allow measurement of background fluctuations in single exposures. This provides a much more direct way to compare with satellite data than the statistical combinations used to date.

CIBER is a cooperative instrument designed and built by the California Institute of Technology, University of California Irvine, the Japan Aerospace Exploration Agency (JAXA), and the Korean Astronomy and Space Science Institute (KASI). The same team is also developing an improved follow-on experiment, with more capable optics and detector arrays, that will be completed next year.

Interstellar Medium Absorption Gradient and Extinction Rocket - IMAGER

Principal Investigator:

Dr. Timothy Cook

Boston University

now University of Massachusetts – Lowell

Mission Number(s):

36.260 UG

Launch site:

White Sands Missile Range, New Mexico

Launch date:

November 21, 2012

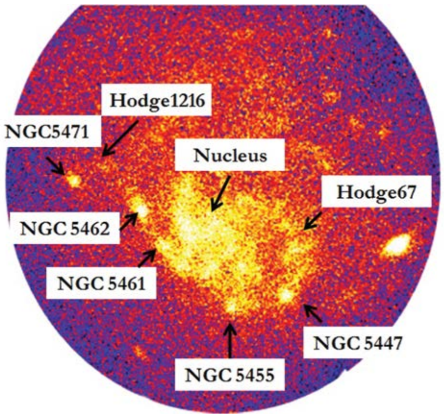


Figure 1: IMAGER imaged the nearby galaxy M101 in order to better understand the role of dust in shaping galaxies throughout cosmic time. This data from the first flight of IMAGER clearly shows the HII regions that we will use to determine the strength of the 2175°A bump as a function of metalicity and radiation hardness.

The IMAGER sounding rocket completed its maiden flight on November 21, 2012. The flight returned image data in three colors of the galaxy M101. The data are currently being analyzed and will form the basis of a Ph. D. thesis for Meredith Danowski. The effort has already resulted in several conference posters (Cook et al., 2013; Danowski et al., 2013; Cook et al., 2012; Cook, 2011; Danowski et al., 2011b,a), a refereed publication (Hicks et al., 2013), and partially supported a Ph. D. thesis (Mendillo, 2013). Several more papers are in preparation. During this effort the IMAGER program moved from Boston University to the University of Massachusetts – Lowell (UML). At UML the program has generated considerable interest and has been the subject of numerous campus press articles, classroom presentations, and presentations to alumni and prospective students.

The IMAGER system produced data in three bands which is allowing us to assess the effects of the metallicity and radiation field of the local environments in M101 on the interstellar dust in those locations. These data are critically important for the interpretation of Spitzer and JWST images of the distant universe. Because of the redshift, such observations are made in the rest ultraviolet and necessarily have limited resolution. As a result, the effects of reddening must be removed using some assumed extinction curve. Unfortunately, the shape of the reddening curve is dependent on both metallicity and the radiation field of the distant galaxy in a poorly understood manner. The primary objective of IMAGER is to correct this deficiency. Figure 1 shows preliminary data from the first flight of IMAGER.

The sounding rocket was designed to hold costs low by making extensive use of existing hardware. The detector electronics were developed as part of the TERRIERS small satellite effort. They flew three times as part of the SPINR, sounding rocket and have now flown on IMAGER. Using an electronics package with such extensive history greatly facilitated the construction of the experiment and the integration with the NASA telemetry system. The telescope structure was produced using tooling developed for the PICTURE sounding rocket. This allows IMAGER to incorporate a large aperture (20 inch clear aperture), extremely stable telescope.

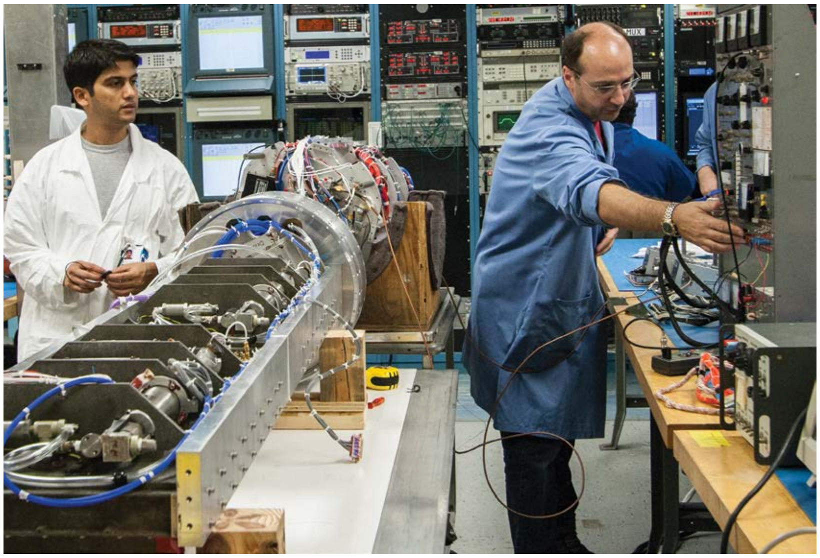
Diffuse X-Ray Emission from the Local Galaxy - DXL

Principal Investigator:
Dr. Massimiliano Galeazzi
University of Miami
Mission Number(s):
36.283 UH
Launch site:
White Sands Missile Range, New Mesico
Launch date:
December 13, 2012

Related publications:
SPIE Proceedings Vol. 8859 UV, X-Ray, and Gamma-Ray Space Instrumentation for Astronomy XVIII, DOI: 10.1117/12.2024438

The goal of the Diffuse X-Ray emission from the Local galaxy (DXL) mission was to identify how much of the diffuse x-ray emission comes from our solar system from the solar wind charge exchange (SWCX) process, and how much comes from outside our solar system from hot interstellar plasmas located in interstellar space. The signal that DXL measured is the sum of the SWCX emission due to the solar wind interactions with He and H, and the cosmic background emission. By observing in the downstream direction of the interstellar neutral flow DXL minimized both the total contribution and the spatial variation of the hydrogen SWCX. The payload incorporated an upgraded University of Wisconsin Aerobee IV instrument (flown on several Aerobee IV rockets from 1973 through 1980) and a prototype wide field-of-view soft x-ray camera.

The secondary payload, The Sheath Transport Observer for the Redistribution of Mass (STORM), was the first wide field-of-view, solar wind charge exchange, soft X-ray imager for heliophysics applications. The instrument used a new soft X-ray focusing technology called micropore reflectors (lobstereye optics) which flew for the first time on the sounding rocket instrument. STORM was built at NASA's Goddard Space Flight Center through the Internal Research and Development (IRAD) program.



Science project team, Youaraj Uprety, Graduate student (left) and PI Massimiliano Galeazzi (right) with the DXL instrument at Wallops during integration.

Far-Ultraviolet Off-Rowland Telescope for Imaging and Spectroscopy - FORTIS

Principal Investigator:

Dr. Stephan McCandliss

Johns Hopkins University

Mission Number(s):

36.268 UG

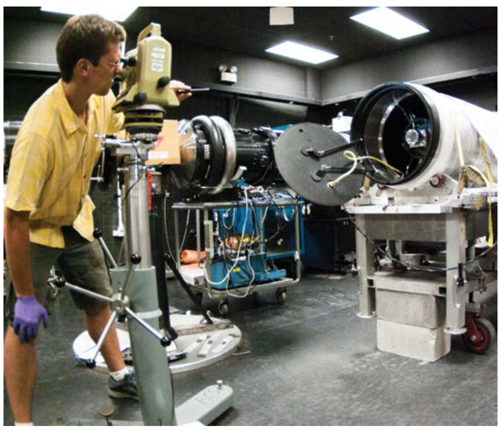
Launch site:

White Sands Missile Range, New Mesico

Launch date:

May 10, 2013

Related publications:
SPIE Proceedings Vol. 8859UV, X-Ray, and Gamma-Ray Space Instrumentation for Astronomy XVIII, DOI: 10.1117/12.2024189



Brian Fleming, Graduate Student, aligning the FORTIS spectro/telescope as part of the pre–launch integration and testing activities.

The Far-uv Off Rowland-circle Telescope for Imaging and Spectroscopy (FORTIS) flew for the first time on May 10, 2013 on a mission to search for Lyman alpha radiation escaping from star forming galaxies. FORTIS uses a prototype version of the microshutter array (MSA), developed by NASA's Goddard Space Flight Center for the Near-Infrared Spectrograph (NIRSpec) instrument onboard the James Webb Space Telescope (JWST). FORTIS expands the use of this technology from the near Infrared (NIR) to the far Ultraviolet (far-UV) range of the spectrum. The MSA is placed at the prime focus of an innovative yet minimalist Gregorian telescope, which uses a diffraction grating as the secondary optic. The microshutter array allows acquisition of images over a 1/2 degree field-of-view and to autonomously target (on-the-fly) 43 different regions within the field for spectroscopic follow up in the 900 -- 1800 Angstrom bandpass. In all, four different technological innovations are matured on this experiment. In addition to the MSA, the instrument includes a holographically ruled grating with a triaxial elliptical surface figure as the telescopes secondary optic, along with a large microchannel plate detector featuring an on-axis imaging channel and two "outrigger" spectroscopic channels. Graduate student Brian Fleming was instrumental in developing the on-the-fly targeting system that processes the imaging data during flight to determine which microshutters to leave open for spectral acquisitions.

The flight in May of 2013 was an engineering success; all of the minimum and most of the comprehensive success criteria were met. The detector worked as designed and demonstrated that the microshutter array could be opened and images were collected. However, the stray light baffling on the telescope proved to be inadequate and saturated the spectral channels with scattered geocoronal Lyman alpha, frustrating the primary science goal of detecting Lyman alpha escape. The payload impact caused the shutter door, designed to protect the instruments, to implode allowing sand to enter the instrument section contaminating the MSA.

A re-built FORTIS with improved baffles is schedule for a second flight in November 2013 to study Comet ISON. The wide field-of-view and multi-object far-UV spectroscopic capability is ideal for investigating questions as to the primordial nature of the volatile emissions from this unique dynamically new comet. Sounding rockets can make unique far-UV observations at solar elongation angles as low as 25 degrees when volatile output is beginning to rapidly increase. In comparison, the Hubble Space Telescope (HST) has a solar elongation limit of 50 degrees.

Principal Investigator:

Dr. Kevin France

University of Colorado

Mission Number(s):

36.271 UG

Launch site:

White Sands Missile Range,

New Mesico

Launch date:

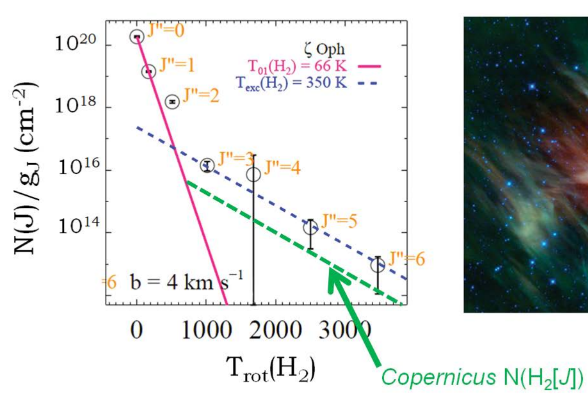
April 21, 2013

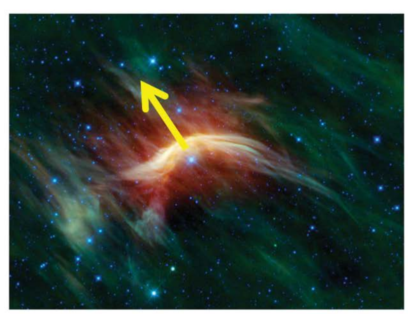
Related publications:
SPIE Proceedings Vol. 8859UV, X-Ray, and Gamma-Ray Space Instrumentation for Astronomy XVIII, DOI: 10.1117/12.2023400

Suborbital Local Interstellar Cloud Experiment - SLICE

NASA and the University of Colorado at Boulder collaborated to launch an astrophysics experiment into Earth's near-space environment in order to study the life-cycle of stars in our Milky Way galaxy. The NASA/CU 36.271 UG – France mission launched successfully at 02:00am MDT on April 21st from Launch Complex 36 at the White Sands Missile Range in the deserts of southern New Mexico. The mission's Principal Investigator, Dr. Kevin France of the University of Colorado is a NASA research fellow and research professor in the Department of Astrophysical and Planetary Sciences in Boulder. Dr. France led the science team consisting of a graduate student and three engineers who originally joined the team as undergraduate research assistants with Colorado's Ultraviolet Rocket Group. The science experiment operated nominally during launch and throughout the 15-minute suborbital flight, where a member of the science team sent commands to the rocket in real-time to maneuver the science targets into alignment with the payload. The payload achieved an apogee of approximately 200 miles, and landed approximately 55 miles downrange of the launch pad. The science team flew with an Army reconnaissance team at first light the morning after launch to retrieve the instrument which is now undergoing post-flight testing at Dr. France's laboratory in Boulder.

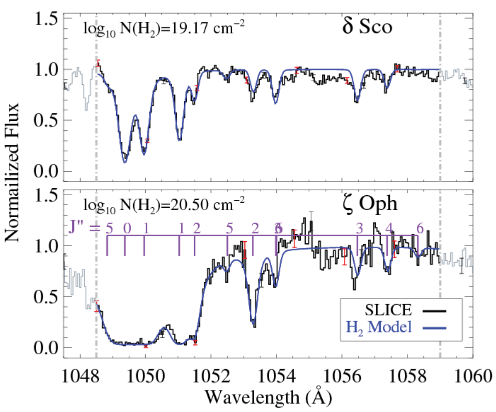
This was the first flight of the Sub-orbital Local Interstellar Cloud Experiment (SLICE). SLICE is an astrophysics payload carrying an 8" diameter telescope and spectrograph covering the far-ultraviolet wavelength range from 102 – 107nm. SLICE observed four hot stars in the constellations of Ursae Majoris, Virginis, Scorpius, and Ophiuchus. These massive stars are used as background sources to study the composition, temperature, and ionization state of material in the interstellar medium, the space between the stars in the Milky Way. This particular ultraviolet spectral window can only be accessed from space, and taking spectra in this window enabled





SLICE flight data (left) show evidence for more material in the interaction region between ζ Oph and its environment. SLICE has returned tentative evidence for structure in the interaction between runaway massive stars and the ambient material that pervades the Milky Way. The size scale is approximately the diameter of the Solar System.

Experiment and Wallops Flight Facility payload teams with the SLICE payload.



SLICE flight data from two of the targets (black), and model spectra of the molecular material that will form the next generation of stars. The modeled molecular cloud absorption is shown in blue.

the team to measure the various phases of the interstellar medium: from the cool molecular gas that will eventually form the next generation of stars, to the hot gas that is driven into the interstellar medium when massive stars die in supernova explosions. SLICE therefore allows the Colorado experiment team to simultaneously study the entire lifecycle of the material that makes up stars (and ultimately, people) in the Milky Way: from the raw gas and dust for future star-formation to the by-products of stellar death.

The first scientific results from the 36.271 SLICE mission have been published in The Astrophysical Journal Letters (France et al. 772, 6, 2013). SLICE has also characterized the interaction between the ambient interstellar medium and the massive runaway star ζ Ophiuci. ζ Oph is approximately 20 times more massive than the Sun and is moving supersonically through the galaxy after having been flung out of its birth cluster in an interaction with other massive young stars. ζ Oph is currently carving a broad bow-shock through the Milky Way and the SLICE observations present tentative evidence for small-scale structure (130 astronomical units, approximately the diameter of the Solar System) in the interaction region between the star and its galactic environment.

Post–flight recovery of the SLICE payload. Left to right: Robert Kane (Colorado), Greg Springle (WFF), Kevin France (PI – Colorado), and Nico Nell (Colorado)


SOLAR PHYSICS

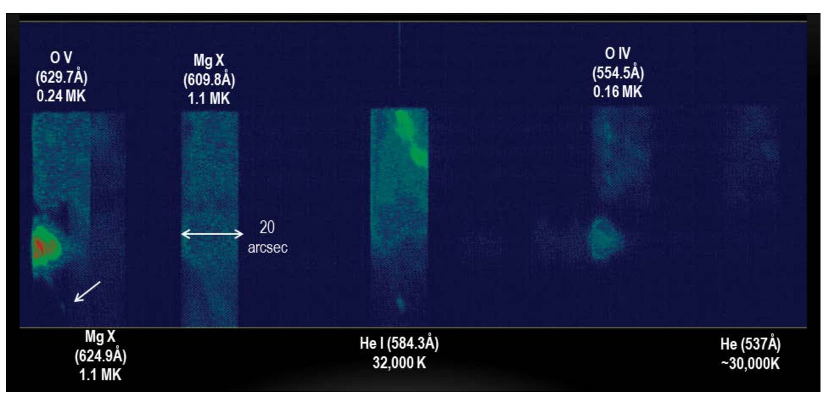
Very High Resolution Imaging Spectrometer - VERIS

Principal Investigator:
Dr. Clarence Korendyke
Naval Research Laboratory
Mission Number(s):
36.239 DS
Launch site:
White Sands Missile Range, New Mesico
Launch date:
August 8, 2013

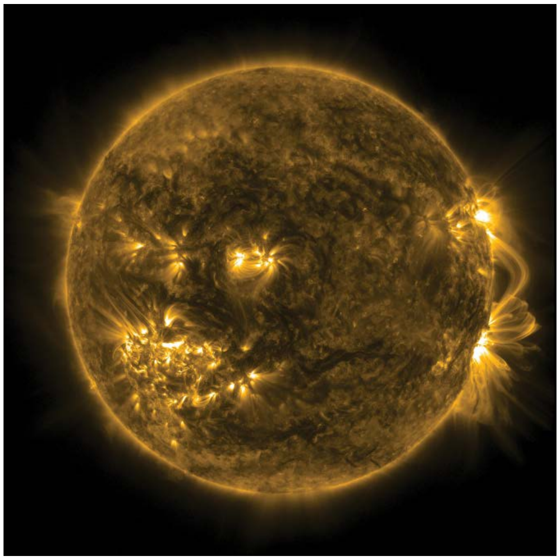
The Naval Research Laboratory's (NRL) VEry high angular Resolution Imaging Spectrometer (VERIS), a fast, high resolution, imaging spectrometer for solar studies, was successfully launched from White Sands Missile Range, NM on August 8, 2013. The first engineering flight obtained the first subarc-second EUV spectra and spectrally pure images taken of the solar atmosphere.

VERIS was designed by NRL's Space Science Division and sponsored by NASA. Its goal is to uncover the fundamental structure of the solar atmosphere by obtaining sub-arcsecond Extreme Ultraviolet (EUV) solar spectra. Early results from VERIS show that the payload-imaged solar features less than one arc-second in size. VERIS measures properties of the structures in the sun's upper atmosphere with a factor of four higher resolution than similar instruments already in orbit.

As part of the NASA Low Cost Access to Space, VERIS is a testbed for observing from the solar chromosphere through the solar corona with ultra-high spatial and spectral resolution. The VERIS instrument, with a mirror that is 6 inches in diameter, spans almost 10 feet in length and weighs almost 500 pounds. An instrument of this size is too large to fly on a satellite, but is a good match for a sounding rocket. It was designed and built by NRL's Dr. Clarence Korendyke and his team to observe the properties of the building block structures of the solar atmosphere in solar active regions, the quiet part of the sun, and in solar flares, over the full temperature range of the solar atmosphere. "On the sun, large scale energy releases are driven by small scale physical processes," explained Dr. Korendyke, VERIS Principal Investigator, "So we need to look at and understand the details of those processes." Knowledge of solar EUV emission variability gained from VERIS, Dr. Korendyke explains, will provide improved ability to forecast space weather at earth that adversely affects satellite communications and space asset tracking and situational awareness.



VERIS first light image. VERIS is able to image multiple lines simultaneously covering the temperature range from the chromosphere to the corona. The white arrows mark the location of a sub–arcsec feature emitting in two widely different temperatures simultaneously (MgX and HeI).



The bright regions in this solar image, known as active regions in the solar atmosphere, are areas that can spawn giant eruptions on the sun. The VERIS rocket studied the physical properties of these regions in exquisite detail during its 15–minute flight in early August 2013.

A first look at the data captured by VERIS shows a spatially resolved Helium spectrum and spectrally pure images in a number of EUV emission lines. Some of the measured solar structures were less than one arc-second in size. Although the VERIS flight only obtained six minutes of observing time above the earth's atmosphere, scientists will spend years analyzing the data collected during the flight.

The NRL VERIS launch team consisted of Clarence Korendyke, Angelos Vourlidas, Kevin Eisenhower, Samuel Tun, Dave Roberts, Jeff Morrill and Damien Chua, from the Space Science Division's Solar and Heliospheric Physics Branch.

To support the VERIS observations, scientists will also turn to data sets gathered simultaneously by other solar observatories, such as the joint NASA-Japanese Aerospace Exploration Agency's Hinode and NASA's newly-launched Interface Region Imaging Spectrograph, which observes the lower, cooler layers of the sun's atmosphere. VERIS continues NRL's strong tradition in solar UV spectroscopy, starting with the SO-82A and SO-82B instruments on Skylab, and continuing with the highly successful HRTS and VAULT sounding rocket experiments and more recently the Extreme Ultraviolet Imaging Spectrometer on Hinode.

About the U.S. Naval Research Laboratory

The U.S. Naval Research Laboratory is the Navy's full-spectrum corporate laboratory, conducting a broadly based multidisciplinary program of scientific research and advanced technological development. The Laboratory, with a total complement of nearly 2,500 personnel, is located in southwest Washington, D.C., with other major sites at the Stennis Space Center, Miss., and Monterey, Calif. NRL has served the Navy and the nation for over 90 years and continues to meet the complex technological challenges of today's world. For more information, visit http://www.nrl.navy.mil/.

Focusing Optics X-Ray Solar Imager - FOXSI

Principal Investigator:

Dr. Sam Krucker

University of California Berkeley

Mission Number(s):

36.255 US

Launch site:

White Sands Missile Range,

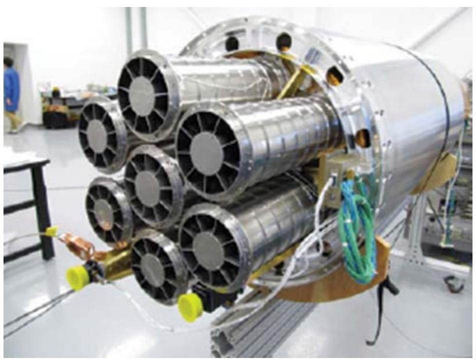
New Mesico

Launch date:

November 2, 1012

Related publications:
Proc. SPIE 8862, Solar Physics and Space Weather instrumentation V, 88620R (September 26, 2013); doi:10.1117/12.2024277

American Astronomical Society, SPD meeting #44, #100.88

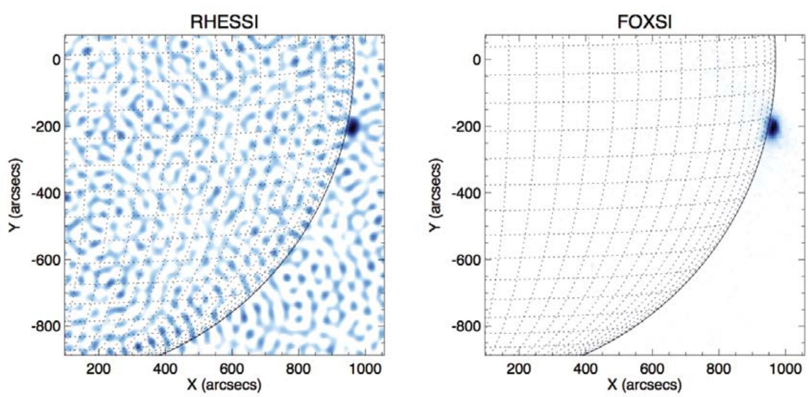


The FOXSI instrument is composed of seven grazing–incidence telescope modules, each with seven nested shells.

The FOXSI instrument is a solar hard X-ray telescope and spectrometer. Combining recent advances in grazing incidence telescopes and pixelized solid state detectors, FOXSI observed the Sun in hard X-rays with unprecedented sensitivity and high dynamic range. The grazing-incidence replicated nickel optics were made by the NASA Marshall Space Flight Center and the fine-pitch silicon strip detectors were developed by the Astro-H team at JAXA/ISAS.

The successful flight on November 2, 2012, produced images and spectra of a microflare and performed a search for nonthermal emission (4-15 keV) from nanoflares in the quiet Sun. Nanoflares are a candidate for providing the required energy to heat the solar corona to its high temperature of a few million degrees.

A future satellite version of FOXSI, featuring similar optics and detectors, could make detailed observations of hard X-rays from flare-accelerated electrons, identifying and characterizing particle acceleration sites and mapping out paths of energetic electrons as they leave these sites and propagate throughout the solar corona.



Comparison of RHESSI (left) and FOXSI (right) images of a solar microflare during FOXSI 's first flight on 2012 Nov 2 (solid curve is solar limb). RHESSI is indirectly imaging system, and the imaging noise is visible across the entire image. Since FOXSI is a direct imager, the image on the right does not include this imaging noise providing a much clearer image with a much–enhanced dynamic range.

Extreme Ultraviolet Normal Incidence Spectrograph - EUNIS

Principal Investigator:

Dr. Douglas Rabin

NASA Goddard Space Flight Center

Mission Number(s):

36.269 GS

Launch site:

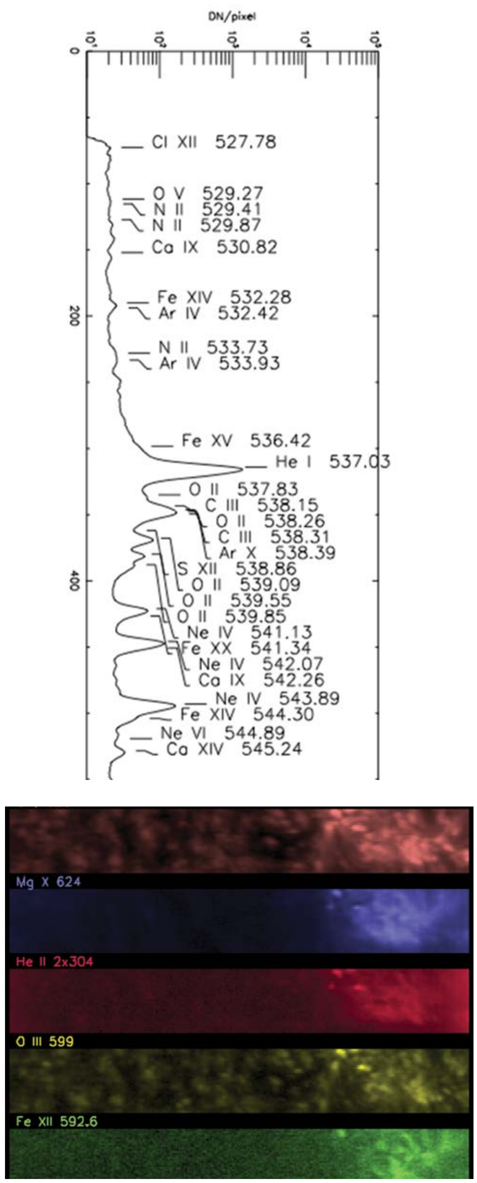
White Sands Missile Range,

New Mesico

Launch date:

April 23, 2013

Related publications:
American Astronomical Society, SPD meeting #44, #105.01



Top: a small part of the complex atomic spectrum obtained by EUNIS. Bottom: spatial images constructed from these spectra, showing the varying structure of the solar atmosphere at different temperatures.

The EUNIS mission successfully launched on April 23, 2013 from White Sands Missile Range, NM and captured the highest dynamic range spectral images ever taken in extreme ultraviolet wavelengths that reveal the ever-changing structure of the outer solar atmosphere. EUNIS is optimized to secure detailed physical diagnostics that only a spectroscopic instrument can provide while maintaining the rapid cadence necessary to explore the dynamic solar corona.

EUNIS acquired 235 images in each of two wavelength bands on three 1024×1024 active pixel sensors in each channel, for a total of over 1,400 images during 366 seconds of scientific observing. The instrument observed active and quiet regions on the solar disk as well as the corona above the solar limb, which was enabled by the first flight demonstration of cryogenically cooled "CMOS" array sensors. The observations fortuitously captured a small solar flare that was also seen by the Ramaty High-Energy Solar Spectroscopic Imager (RHESSI) satellite and co-observing instruments on the Solar Dynamics Observatory, the Solar and Heliospheric Observatory, and at the National Solar Observatory.

The analysis of this rich data set will provide new insight into the transient and small-scale heating events that are theorized to be the primary source of coronal heat. In addition, the careful radiometric calibration of EUNIS will allow several orbiting instruments to update their radiometric calibrations by comparing their data with contemporaneous EUNIS observations.

Technology Development

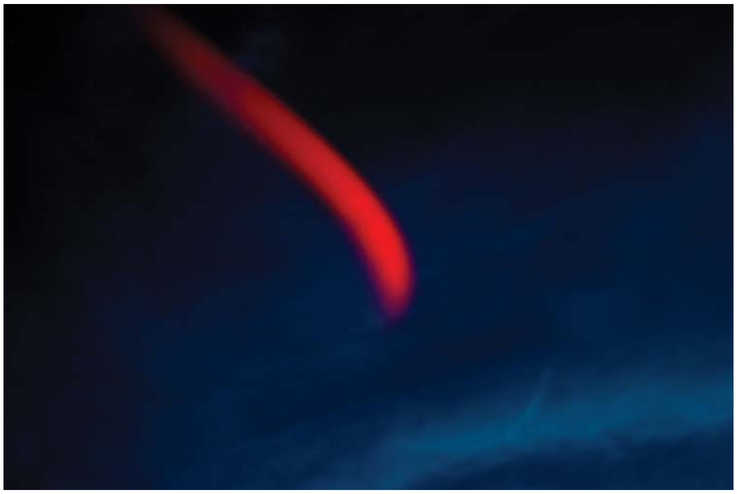
Lithium Vapor Release System Test

Principal Investigator:
Ms. Elizabeth West
NASA Wallops Flight Facility
Mission Number(s):
41.107 GT
Launch site:
Wallops Island, Virgina
Launch date:
January 30, 2013

The objective for this mission was to test two different methods for creating lithium vapor and to determine which configuration is best for observing various science phenomena in space. This test was conducted in preparation of two science missions, Equatorial Vortex Experiment (EVEX) and Daytime Dynamo, also flown in 2013.

Two canisters in the rocket's payload section contained solid metal lithium rods or chips embedded in a thermite cake. The thermite was ignited and produced heat to vaporize the lithium. The vapor was released in space to be detected and was tracked optically using camera equipment onboard an aircraft at an altitude of approximately 30,000 ft.

Both methods for igniting and deploying the lithium vapor were successful.



Lithium vapor releases.

Command Uplink Ground System Test

Principal Investigator:

Mr. Giovanni Rosanova

NASA Wallops Flight Facility

Mission Number(s):

41.104 GT

Launch site:

White Sands Missile Range, New Mexico

Launch date:

February 15, 2013

The primary objective of this flight was to verify the functionality of the White Sands Missile Range Command Uplink Ground System equipment after the facilities upgrades were completed in early 2013 and the equipment was moved from Launch Complex 35 to 36.

Additionally, the flight provided an opportunity to test several NSROC developed technologies. Principally, upgrades to SPARCS hardware were flown, including a new LISS housing/electronics board which will allow a "Super-Fine" pointing mode. A SPARCS firmware update improving system reliability and roll stability was also tested. Furthermore, new command system flight hardware, current sensors, NiMH batteries, new ORSA electronics, and GLNMAC software were tested on this mission. A High Data-rate Recorder, developed with the Wallops Applied Engineering and Technology Directorate, and a 20 Mb/sec TM MV Encoder completed the new technologies suite for this flight.

Both the primary objective and the secondary technology testing objectives were successfully accomplished.

Payload integration at White Sands Missile Range, NM.

EDUCATION

Principal Investigator:

Mr. Christopher Koehler

Colorado Space Grant

Mission Number(s):

41.106 UO

Launch site:

Wallops Island, Virgnia

Launch date:

June 20, 2013

Rock-On & RockSat-C

This mission was the sixth 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, 240 people participated in the RockOn! from 36 states (plus Washington, DC and Puerto Rico) and over 75 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 2013 RockOn! mission included 16 standardized experiments built by 48 participants and 9 custom-built RockSat-C experiments developed by 9 universities and colleges by ~120 students and faculty. The workshop was conducted at Wallops Flight Facility during the students' summer break with the actual launch occurring on June 20, 2013. 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 (including all the data recorded from the workshop payloads) can be found at http://spacegrant.colorado.edu/rockon- More information on the RockSat-C program (including the final reports for each team) can be found at http://spacegrant.colorado.edu/rocksatc.

Student team working on RockOn–W experiment.

Wallops and Colorado University team prepare RockOn! canister for vibration.

ROCkSAT-X

Principal Investigator:

Mr. Christopher Koehler

Colorado Space Grant

Mission Number(s):

46.005 UO

Launch site:

Wallops Island, Virgnia

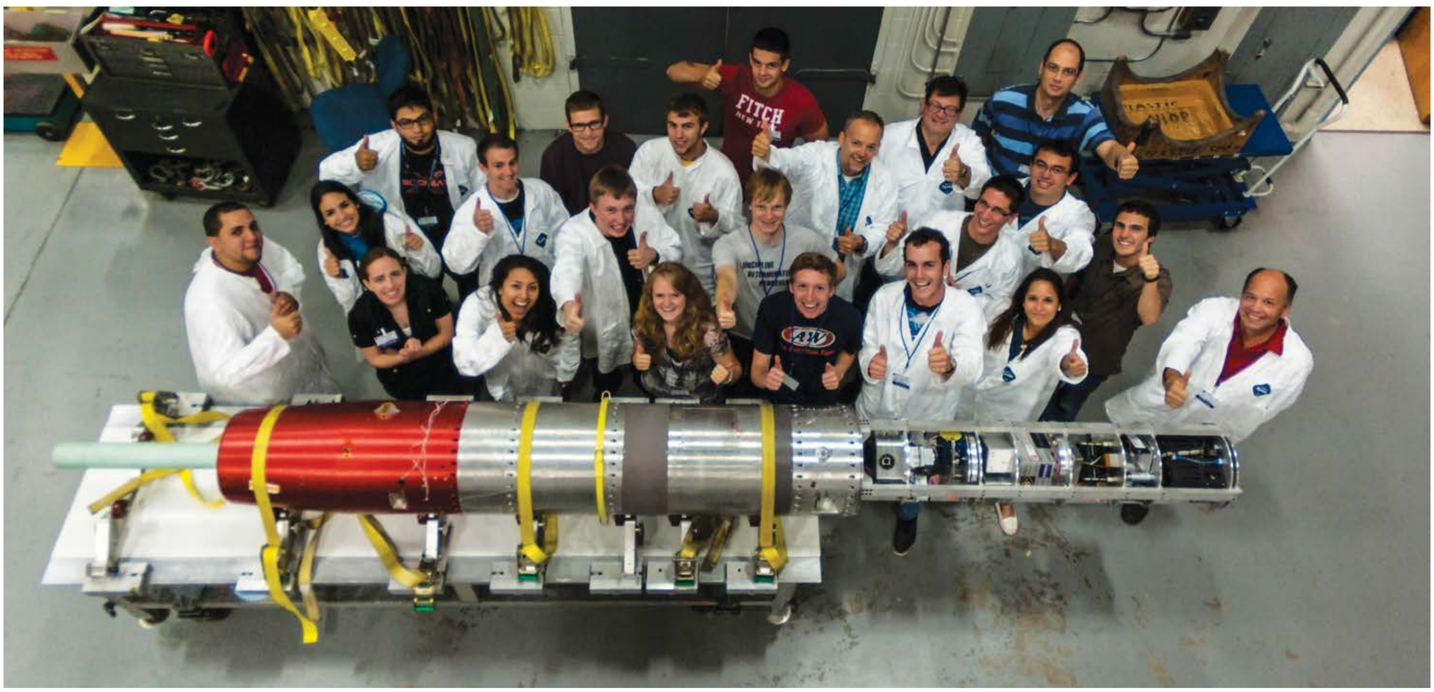
Launch date:

August 13, 2013

RockSat-X, a joint educational activity between NASA and the Colorado Space Grant, is a follow on mission to RockOn! and RockSat-C programs and involves more complex student experiments. RockSat-X provides more advanced sounding rocket payload support services, including telemetry, power, and full access to the space environment for deployable instruments.

The goal of the RockSat-X program, as well as RockOn! and RockSat-C, is to provide students a hands-on experience in developing experiments for space flight. This experience allows these students to apply what they have learned in the classroom to a real world hands-on project. In addition these students are getting practical experience that will assist them as they enter careers in science, technology, engineering and math (STEM). Past participants in the program have entered careers within the aerospace industry.

The third RockSat-X mission was launched on August 13, 2013 onboard a Terrier-Improved Malemute sounding rocket and the programs education goals were successfully accomplished. Approximately 80 students and faculty



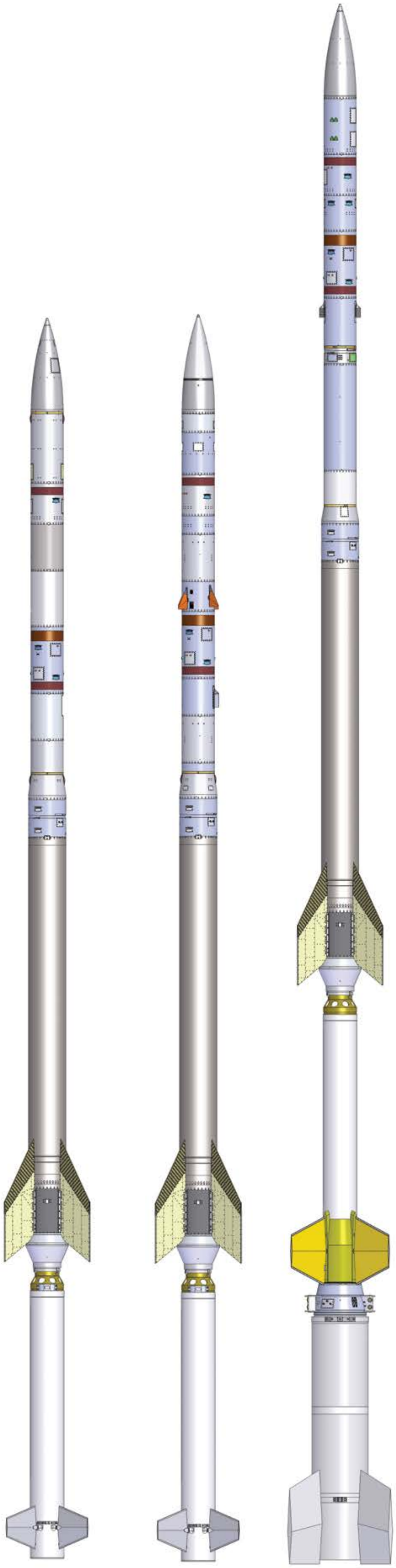
RockSat–X student teams with their experiments.

from seven universities participated in this year's mission with their seven experiments. The Colorado Space Grant Consortium flew a payload to record HD video of flight and all experiments in operation during the flight and re-entry. Eight HD video cameras were included; four downward looking and four looking horizontally. This year's video system extended (and retracted before re-entry) the four downward looking cameras to get a better view of the entire payload section of the rocket. University of Puerto Rico flew an experiment to measure the impact and approaching velocity of micrometeorite projectiles varying in size from 200 nm to 2 mm, with speeds of 1 to 20 km/s relative to the space vehicle. The Johns Hopkins University partnered with the University of Maryland to measure electron density in the E region (90-120 km) and test water-tight container for future use with aerogels in upper atmosphere research. The University of Minnesota's mission was to experimentally monitor radiation damage to electrical components during a suborbital rocket flight. West Virginia University flew a payload to measure the plasma density/frequency, magnetic field, flight dynamics, and magnetic effects on ferrofluids in microgravity. Their payload also flew a picosatelite payload consisting of an IMU and magnetometer, as well as a transceiver to transmit data back to earth. University of Colorado Boulder's mission was to prove the validity of microgravity crystalline experiments on sounding rockets. The objective for this mission was to analyze the differences between crystals grown in microgravity and crystals grown under normal conditions. Northwest Nazarene University's mission was to determine the durability of flexible electronics in the cryogenic/vacuum environment of space as well as create a de-spun video of the rocket flight. More information on the RockSat-X program (including the final reports for each team) can be found at http://spacegrant.colorado.edu/rocksatX.

Students with their RockSat–X experiment at Wallops before flight.

Technology Development

Peregrine Motor Development



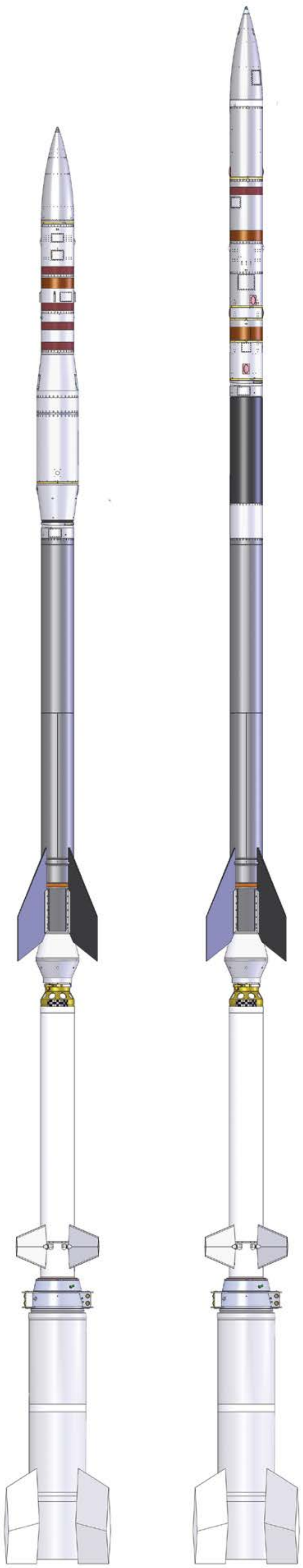
Three Peregrine configurations; Terrier–Peregrine (left), Terrier–Peregrine with an S–19 for White Sands Missile Range use (center) and a three stage Talos–Terrier–Peregrine (right).

NASA is developing a prototype sustainer motor and vehicle configurations that could potentially be used in support of future missions. This effort includes an internally developed NASA owned sustainer motor design that will be commercially manufactured. The project was initiated by the NASA Engineering Safety Center's (NESC) sponsorship to conduct an initial feasibility study. The initial study was followed with a second phase to generate manufacturing specifications and drawings. The development activity mitigates Sounding Rocket Program vehicle risk(s) and provides a hands on opportunity to hone NASA's internal propulsion expertise. The primary partners in this project are the propulsion group at the Marshal Space Flight Center (MSFC) developing the propulsion unit and the Sounding Rocket Program at the Wallops Flight Facility who are integrating the motor into different 1 to 4 stage vehicle configurations. Flight tests are scheduled for the upcoming year. The unique partnership between WFF and MSFC augments capabilities within both organizations. The project blends MSFC's advanced propulsion engineering with WFF's ability to conduct low cost fast response operations.

Hardware included in this effort are fabrication of six motor cases, one inert motor, and four live motors for qualification testing. The qualification testing includes a hydro proof test of the case, a static firing test at MSFC, and three flight tests to qualify all 1 to 4 stage configurations. The first flight will be a Terrier MK70 boosted Peregrine two stage configuration flown at the WFF range. The payloads will be heavily instrumented providing all data necessary to characterize the flight environment and evaluate performance predictions. The second flight is a three stage configuration consisting of a Talos first stage, Terrier MK70 second stage, Peregrine third stage, and an "inert" finless exo-atmospheric fourth stage. Inclusion of the "inert" fourth stage enables qualification of both three and four stage configuration in one test without expending a fourth stage motor. This flight will verify fourth stage hand-off conditions and body dynamics at the time of theoretical ignition of the final exo-atmospheric stage. The third test flight will be conducted at White Sands Missile Range (WSMR) to include utilization of the S-19 guidance system and qualification of a Flight Termination System. The WSMR flight is critical to allow recovery of the flight motor to evaluate insulation margins and determine erosion characteristics of the motor in the spinning vehicle configuration.

Each of the Peregrine test flights include secondary experiments selected by the Space Technology Mission Directorate's Flight Opportunities Program managed at the Dryden Flight Research Center. The intent is to optimize the return of the Peregrine test flight program and advance/qualify new technologies in a space flight environment. Experiment candidates include re-entry experiments, heat transfer systems, attitude control/guidance system instrumentation, and new technology/instrumentation to be flight tested to qualify designs and increase Technology Readiness Level (TRL).

Black Brant XI-A and XII-A



Three stage Black Brant XI–A left and four stage Black Brant XII–A right.

Two new Black Brant based launch vehicle have been added to the stable, a Black Brant XI-A (51.XXX) and the Black Brant XII-A (52.XXX). The second stage Taurus motor has been replaced by a Terrier Mk70 motor in both configurations. The Terrier Mk70 motor offers many advantages over the Taurus motor. The Terrier is newer, more readily available, safer to inspect and modify, has a more reliable igniter, and is easier to ship than the aging Taurus motor. The Terrier based vehicle stacks are expected to offer enhanced performance over the Taurus based stacks. The first flight of the Black Brant XII-A is expected to occur in late 2014. The Terrier Mk70 replacement for the Taurus as a second stage has been demonstrated previously in the Oriole III (Talos-Terrier-Oriole) and Oriole IV (Talos-Terrier-Oriole-Nihka) vehicle stacks on the recent 12.075 Brodell and 49.001 Rowland launches, respectively.

Ogive Recovery System Assembly (ORSA) next generation circuit

The development was completed for a NSROC design of a circuit to control three critical events on the Ogive Recovery System Assembly (ORSA). The ORSA Next-Gen circuit controls system enable, nose tip ejection, and heat shield deployment. The development of this critical circuit featured flight tests during which simulated events were executed. On the final flight test, 46.005 RockSat-X, the circuit was used to control actual recovery system events on a Forward Ignition-Recovery Module Assembly (FIRMA). The system performed successfully and is now considered ready to be incorporated into future operational science missions.

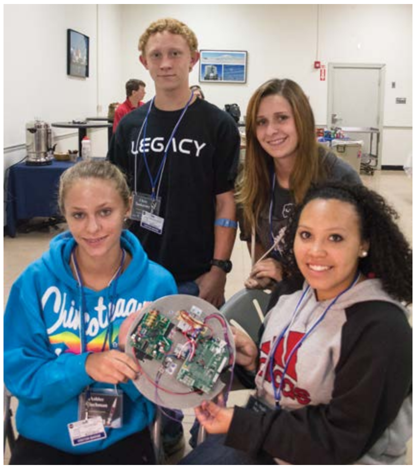
Three event Capacitive Discharge Initiator (CDI)

The development was completed for a NSROC design of a circuit to control three critical vehicle events on Black Brant IX missions conducted at White Sands Missile Range. The WSMR CDI controls Black Brant ignition (second stage), de-spin, and payload separation. The development of this critical circuit featured flight tests during which simulated events were executed. On the final flight test, 46.004 RockSat-X, the circuit was used to control actual vehicle events on a Terrier-Improved Malemute launch vehicle. The system performed successfully and was subsequently incorporated into the design of an operational science mission, 36.290 Woods, a Black Brant IX from WSMR. Again, all events were controlled successfully. The system is now considered operational and standard for such missions.

Magnetic NSROC Inertial Attitude Control System (MaNIACS)

The MaNIACS is a control mode extension to NIACS to allow for aligning to the local magnetic field. The flight heritage of the NIACS is preserved by using the same mechanical packaging and pneumatics system. The MaNIACS adds a digital magnetometer to determine the target pointing vector. The software is expanded to support the new control mode. The system will be the first NSROC ACS that can perform inertial pointing and true magnetic pointing within one mission. This allows the system to support situations in which sub-payloads are ejected based on inertial or velocity vector targets, and then the main payload is aligned to the local magnetic field. It can also control to the magnetic field and report 3-axis attitude in one system.

Education & Workforce Development



RockOn! team with finished payload.

RockOn experiment work.

RockSat–C experiment pre–flight inspection.

RockOn & RockSat-C

Experiments built by student in the RockOn and RockSat-C University level programs are flown on the same sounding rocket payload launched annually in June.

RockOn experiments are built and tested by students during a week long workshop held at NASA's Wallops Flight Facility in June. Students and faculty begin work on their payloads upon arrival at Wallops and complete the construction and testing approximately four days later. The RockOn payloads are standardized sensor suits consisting of an Arduino based datalogger interfaced with an accelerometer, pressure transducer and thermistor. The students complete the sensor integration, programming, and testing during the workshop. All experiment boards are fitted into a cannister specially developed for student missions. The highlight of the week is the launch of the experiments on a two-stage sounding rocket from Wallops Island, VA. The goal of the workshop is to provide the necessary training for students and faculty to return the following year to fly a payload of their own through the RockSat-C and RockSat-X Programs.

Part of the payload space in the RockOn mission is allocated to RockSat-C experiments. As with RockOn experiments are housed in standard cannisters but are developed entirely by students and can encompass any sensors and hardware approved for flight. The design and development guidelines are established by NASA and are similar to any requirements for any spaceflight mission. RockSat-C is a competitive opportunity and student groups submit proposals. After initial selection teams are guided through the design process that includes three design reviews and monthly progress reports. By December each team has taken its design to the Critical Design Review (CDR) level. Depending on the available space on the rocket, the most advanced and able payloads are selected for flight no later than early January. These final down selected participants then continue the process by making the first installment and begin payload construction. Over the course of five months, participants undergo numerous sub system reviews and teleconferences to ensure that designs are maturing as expected. The design reviews as well as sub system and progress teleconferences are lead by the RockSat program manager. The manager acts as the liaison between the customer and Wallops Flight Facility and also acts as a guide along the path to launch. The program culminates in late June when experiment teams travel to Wallops to launch their payloads into space.

Puerto Rico RockSat–X team members hand over their experiment for installation in the payload.

Attitude Control Systems group intern Jared Whaley pepares a system for vibration testing.

RockSat-X

The intent of the RockSat-X program is to provide hands-on experiences to University students and faculty advisors to equip them to respond to future technical workforce needs. Additionally, the program exposes participants to the excitement of spaceflight and to the potential career paths avaialble within the aerospace community in general and the sounding rocket community in specific.

RockSat-X is the most advanced of the University level flight oppotunities. While some modularity is inherited from the RockOn! payload structures, i.e. the payload deck system, the students are enabled to design and develop their experiments with fewer constraints than in the lower level programs. In contrast to the RockOn paylaod, RockSat-X allows experiments full exposure to the space environment through an ejectable skin and nose cone. NASA provides power to all sub-systems and experiments and also includes a telemtery system for experiment data retrieval during flight. Additionally, the rocket is de-spun to a reduced rate of ~ 0.5 Hz to allow for a greater range of experiments. The newly developed Magnetic NSROC Inertial Attitude Control System was flown operationally for the first time on the RockSat-X mission allowing alignment of the payload to the magnetic field.

The RockOn, RockSat-C and RockSat-X program are managed by the Colorado Space Grant Consortium: **http://spacegrant.colorado.edu/**

Internships

Over 150 students have participated in the internship program managed for the Sounding Rockets Program Office by NSROC. The program, now in its 15th 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.

WRATS rocket lift–off.

Measuring the center of gravity prior to the stability swing test.

NSROC intern Lindsey Buck (center) assists teacher Jackie Sheridan (right) during the payload programming activity.

Wallops Rocket Academy for Teachers and Students (WRATS)

For the third year the Sounding Rockets Program Office arranged the Wallops Rocket Academy for Teachers and Students (WRATS) workshop for High School educators. 20 high school teachers from Virginia, Maryland, Delaware, Pennsylvania, Tennessee and the District of Columbia learned about the dynamics of rocketry and the science gained from suborbital sounding rockets to reinforce STEM concepts they teach in their classrooms.

Starting with an overview of sounding rockets, the teachers learned about science applications, launch vehicles, operations and gained insight into payload testing procedures through a tour of the Testing and Evaluation lab. Model rocket construction activities were also accomplished on the first day of the workshop and each participant built an E-engine powered model rocket. Activities continued with the construction of an Arduino Uno based payload which incorporates three sensors; an accelerometer, a pressure transducer and a thermistor. The payloads were fitted into the model rockets and were flown later in the week to collect data during the flight.

Several interactive lectures with physics demonstrations were conducted by Phil Eberspeaker/Chief Sounding Rockets Program Office. The demonstrations enhance the understanding of rocket physics and provide participants with theoretical physics and math applications, as well as, hands-on activities to conduct with their students.

Recovery system (parachute) design, construction and testing familiarized the educators with the geometry of parachute shapes, size estimation and drag calculations. All parachutes were drop tested prior to flight. The rockets were tested for stability and the pitch moment of inertia was measured using a bifilar pendulum method. Additional activities during the week included a model rocket motor test firing, tours of Wallops Flight Facility and the launch of RockOn! a once in a life-time experience for many of the teachers. The model rockets were successfully flown and recovered on the Wallops airfield and the educators left Wallops with a rocket, a payload and new insight into aerospace and rocketry.

Arcadia High School Principal Rose Taylor (right) and student Toby Tapman III launch a rocket.

Arcadia High School students Norasia Handy, Trinice Duffy, and Charnece Morris stage their model rockets.

Joyce Winterton explaining NASA Wallops Flight Facility's capabilities and mission to students in the Marshall Islands.

Arcadia Rocket Class

As a result of attending the first WRATS workshop in 2011, Carol Osmon, a science teacher at Arcadia High School, has incorporated rocketry into her physics curriculum.

In 2013 approximately 35 students built model rockets as part of their physics class at Arcadia High School. Altimeters recorded flight data which was then plotted and evaluated by the students.

Local county officials and the Principal of Arcadia High School attended the launch and expressed support for STEM activities including rocketry.

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.

Kwajalein Outreach

Seven teacher workshops and nine student events were conducted on Majuro and Kwajalein Atolls and on the islands of Ebeye, Gugeegue, and Enubirr to inform them about the Equatorial Vortex Experiment (EVEX) and Metal Oxide Space Cloud experiment (MOSC) Sounding Rocket missions, the benefits and the safety of space weather research.

During the 2 weeks,129 educators, 430 students K-12, 101 college faculty and students participated in the several workshops and events. Four students from the College of the Marshall Island supported the EVEX and MOSC teams on the islands of Rongelap, Wotho and Likiep.

Students and faculty were exposed to a multitude of hands-on activities related to rocketry, engineering practices and science. NASA Beginning Engineering, Science, and Technology (BEST) materials provide an introduction to engineering and can be adapted to students from Kindergarten through Middle School. Science activities focused on the Earth's ionosphere and magnetoshpere as related to the research being conducted with the sounding rockets.

FACILITIES

Dr. Stephan McCandliss, Johns Hopkins University, at White Sands to integrate and fly the FORTIS mission, cut the ribbon inaugurating the new facilities on May 8, 2013.

Vehicle Assembly building.

Dark Room.

Clean Tents.

White Sands Facility Upgrades

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 Phase II addition to the VAB was completed in the fall of 2012. This facility has 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, completed in FY 2013 provides upgrades to the Telemetry ground station, new offices for administration/reception, Safety, and Telemetry technicians.

On The Horizon


The RENU rocket ready to launch from Andoya Rocket Range in Norway in

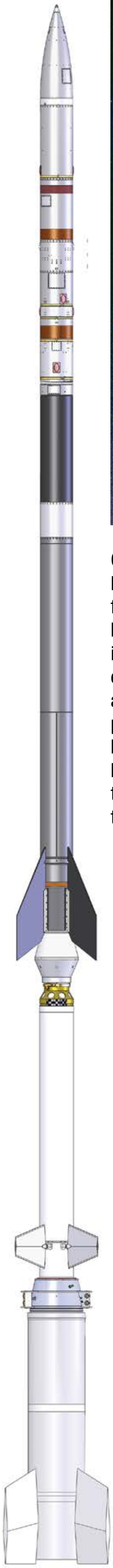
Two missions, one to study Plasma Electrodynamics and the other to study the enhanced neutral mass density in the Earth's cusp-region thermosphere.

Cusp Alfven and Plasma Electrodynamics Rocket (CAPER)
PI: Dr. Jim LaBelle/Dartmouth College

The Cusp Alfven and Plasma Electrodynamics Rocket (CAPER) investigation will establish the role and nature of Alfvén wave acceleration in the cusp and discover the causes of the observed differences in the Langmuir waves in the cusp versus the nightside.

While many previous rocket experiments have probed nightside processes such as polar substorms, the proposed Cusp Alfven and Plasma Electrodynamics Rocket (CAPER) will make significant advances in understanding of dayside magnetosphere-ionosphere (MI) coupling by building on the small number of previous rocket experiments in the cusp. The dayside high-latitude polar cusp is a unique environment where direct access of solar wind particles to low altitudes leads to similar particle precipitation and acceleration processes as on the nightside, but dominated by a rather different set of magnetospheric processes, such as dayside reconnection and interactions with interplanetary pressure pulses and discontinuities. In particular, direct measurements of Alfvén waves associated with electron acceleration, via their electric and magnetic fields, has not been reported in the cusp (as opposed to the nightside), and the detailed interaction of the electron beam with Langmuir wave electric fields, as well as statistics of the resulting complex structure in the fields, has not been directly measured in the cusp (as opposed to the nightside). CAPER also includes the first ever wave-particle correlator measurements in the cusp. The results affect a range of NASA programs in geospace, planetary, heliospheric and astrophysical sciences and are pertinent to multiple objectives of NASA's Heliophysics research program.

To achieve the science outlined above, a single instrumented payload is launched to 800 km or higher into cusp aurora. Apogee of 800 km is required to assure significant flight time in the altitude range where auroral Langmuir waves are excited and to have the best chance to penetrate the ionospheric Alfvén resonator, a region where Alfvén waves are trapped along the magnetic field and can lead to structured aurora via wave-particle interactions.



Clouds from an investigation carried out in Brazil in 1993 are similar to those planned for C–REX. The cloud on the left is the barium release (with a small strontium impurity). The red part is the ionized component which has become elongated along the magnetic field line. The bluish purple cloud that surrounds the red ionized barium is a combination of the neutral barium and the strontium. The bright blue trail on the right in this image is caused by trimethylaluminum (TMA).

The C–REX mission will fly on a newly developed BB XII–A sounding rocket.

Cusp-Region Experiment (C-REX)

PI: Dr. Mark Conde/University of Alaska

This mission is a collaborative project between the University of Alaska Fairbanks and Clemson University. Its scientific objective is to identify mechanisms responsible for creating a region of enhanced neutral mass density at 400 km altitude that appears to be a permanent feature of Earth's cusp-region thermosphere. Most observations of the density anomaly come from Challenging Minisatellite Payload (CHAMP), which saw mass density enhancements as large as 100%, although the typical factor was more like 30%. Enhancements were observed when CHAMP passed through latitudes similar to or slightly equatorward of the geomagnetic cusp at magnetic local times near noon. The anomaly was seen on almost all cusp passes, regardless of geophysical conditions which means our launch criteria will not require particular auroral or magnetic activity.

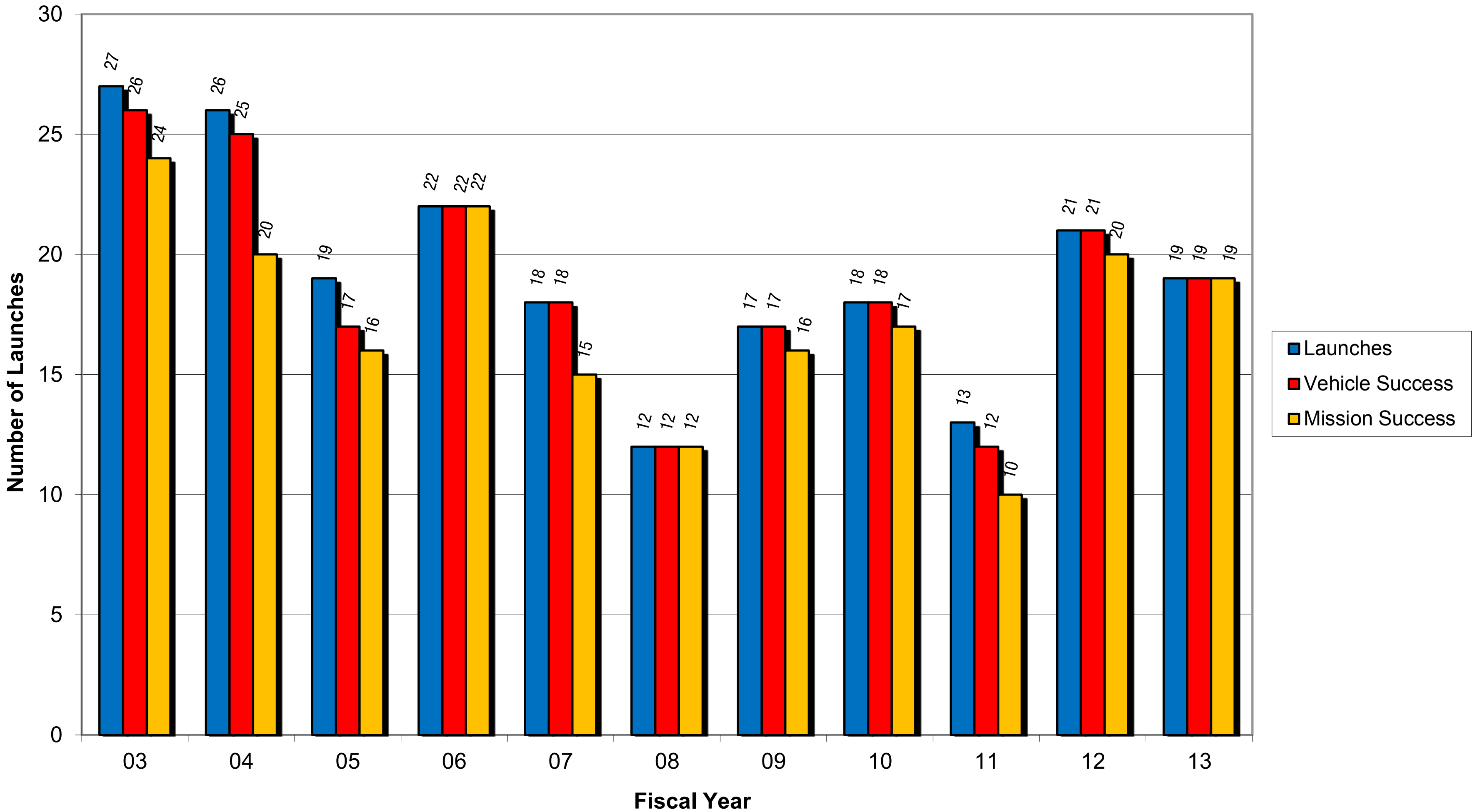
The leading candidates of the process that establishes the density anomaly at the moment involve soft precipitation driving neutral upwelling via several possible intermediate processes. Most viable candidate mechanisms act via upwelling, and possibly also horizontal divergence accompanying this upwelling. The goal of C-REX is to measure the neutral and ion flow fields in the region of the density anomaly, to see if that flow is consistent with establishing the observed density enhancement. If possible the launch will be coordinate with overflights of one of the SWARM spacecraft, however this is not essential for mission success. Ground based instrumentation will support the mission. This includes the European Incoherent Scatter Scientific Association (EISCAT) Svalbard Radar, the University College London all-sky Fabry-Perot spectrometer at Longyearbyen, and various instruments run by University Center in Svalbard (UNIS).

A newly developed three stage launch vehicle, a Black Brant XII-A consisting of a Talos - Terrier - Black Brant V - Nihka, stack will be used for the C-REX mission. C-REX will launch from Andoya Rocket Range in Norway and deploy 24 sub-payloads with tracers consisting of mainly barium with small quantities of strontium (lithium may be used in lieu of strontium) over the Greenland Sea west of Svalbard, at altitudes between 150km and 400km. Part of the barium release ionizes quickly, has a red color, and can be used to track the motion of the charged particles in the ionosphere. The remainder is neutral, has a different red color, and can be used to track the motion of the neutral particles in the atmosphere. A small quantity of strontium is often added to the barium mixture because it remains neutral and has a brighter greenish emission that makes it easier to track the neutral cloud. Lithium also remains neutral but is brighter than strontium and therefor esier to track. The sub-payloads will separate 50 km from the parent rocket with a largely horizontal velocity vector.

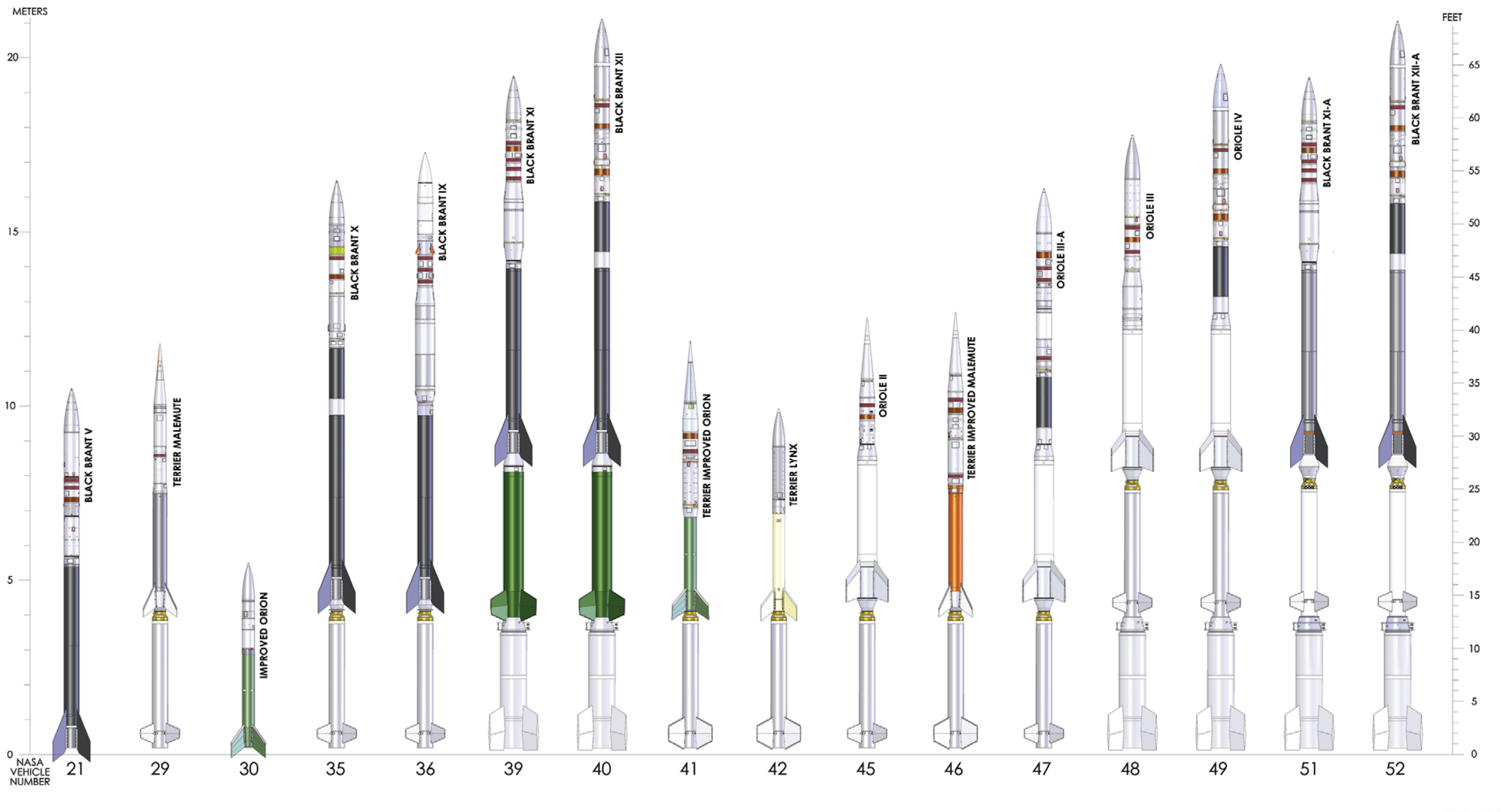
CHARTS

Mission Success History

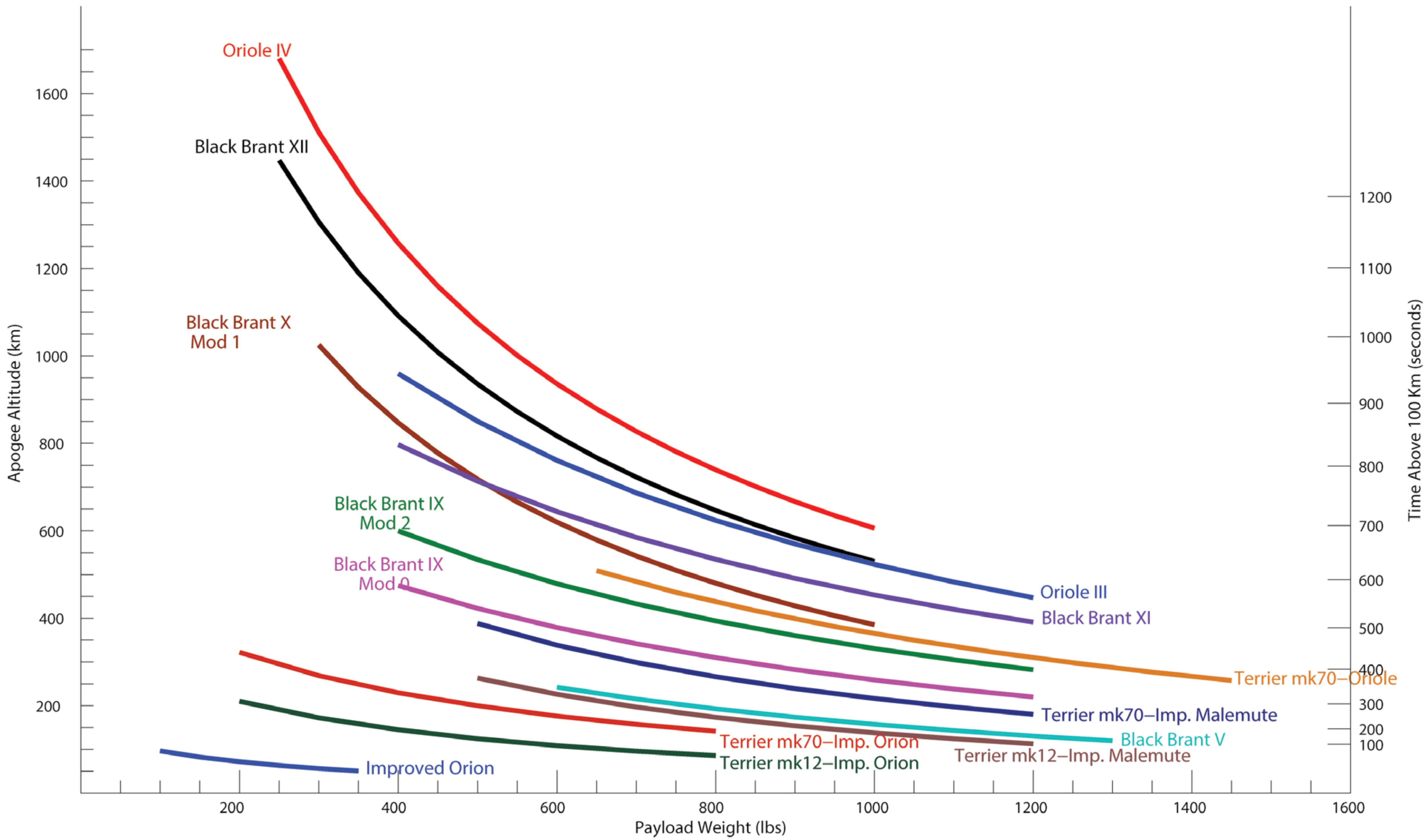
Sounding Rocket Launches
FY 2003 - 2013
Total number of launches: 212



Sounding Rocket Vehicles 2013



Sounding Rocket Vehicle Performance



Sounding Rocket Launch Sites

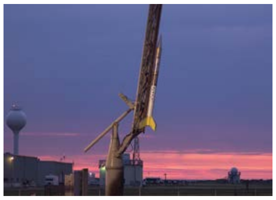
Poker Flat, Alaska

Esrange, Sweden

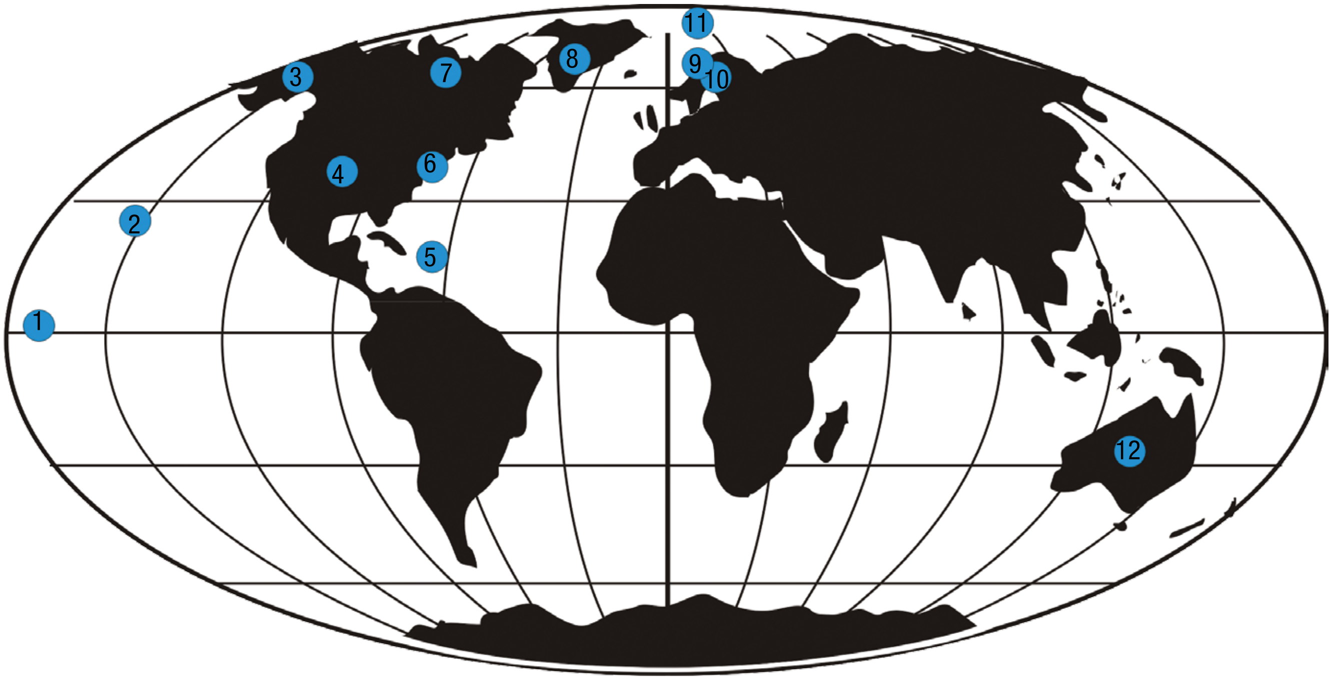
Kwajalein, Marshall Is.

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

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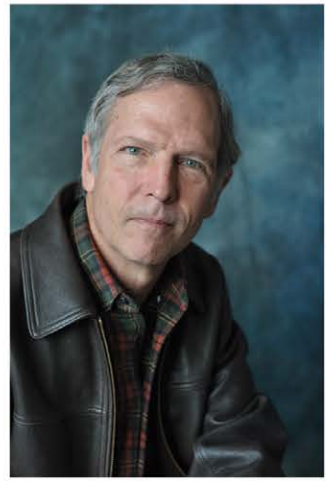

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12 Doug Rowland - MILENA image
13 Wallops Imaging Lab - Launch Photo
13 Rob Pfaff - currents and electric fields
13 Wallops Imaging Lab - Launch Photos
14 Miguel Larsen - Lithium Trail Images
14 Rob Pfaff - Zonal Current Density plot
15 Hubble Space Telescope/NASA/ESA
16 Jamie Bock,/Caltech, CIBER instrument
17 Timothy Cook/U Mass Lowell
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36 Mark Hylbert/NSROC - Vehicle rendering
43 White Sands Missile Range Optical Section
44 White Sands Missile Range Optical Section
45 International Space Station
46 Trond Abrahamsen/Andoya Rocket Range
47 Mark Hylbert/NSROC - Vehicle rendering
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