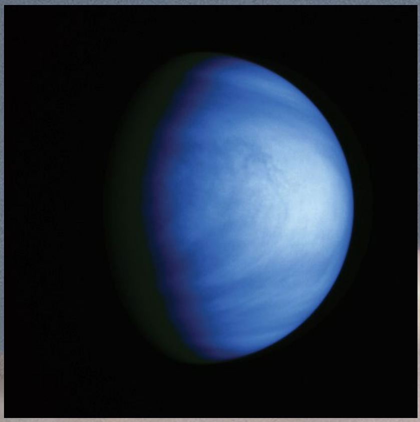
National Aeronautics and Space Administration



NASA
Sounding Rockets
Annual Report 2014

Phil Eberspeaker
Chief, Sounding Rockets Program Office

Message from the Chief

I am proud to report that the NASA Sounding Rockets Program had another very successful year. While our flight rate ended up being a little lighter than usual due to manifest dynamics, we continued to work on a significant number of flight projects in order to prepare for numerous field campaigns and 33 flights currently on tap for FY2015. It is very exciting to point out that the journal Science published an article in November 2014 by Cosmic Infrared Background ExpeRiment (CIBER) Principal Investigator Dr. James Bock/JPL and his team. The article reported that Dr. Bock and his team made a breakthrough discovery using data from the CIBER payload flown on sounding rockets from White Sands Missile Range and Wallops Flight Facility. The team's discovery shows that stars are stripped from their galaxies more frequently than previously thought. These rogue stars emit radiation in the infrared, which are the wavelengths CIBER was designed to capture. This new information may lead to new theories about galaxy formation. The CIBER mission exemplifies the crucial role played by sounding rockets in NASA's overall science goals - specifically that significant scientific discoveries can be made with a relatively low-cost 12-minute flight above the Earth's atmosphere. Just as exciting is the fact that recent data analysis from the Hi-C sounding rocket mission flown in 2012 has revealed new information about substructures in the solar corona and their impact on coronal heating (Dr. Cirtain et al.). Again, proving that a few minutes of suborbital flight can enable world class scientific discovery.

The missions flown in 2014 were spread over five disciplines, ranging from truly unique opportunities for scientific discovery to technology and education flights to support the sounding rocket development efforts and educate the next generation of scientists and engineers. A unique opportunity for sounding rockets was presented in late 2013 when Comet ISON made its appearance in the night sky. Johns Hopkins University scientist Dr. McCandliss and his team readied their Far-Ultraviolet Off-Rowland Telescope for Imaging and Spectroscopy (FORTIS) instrument on fairly short notice in hopes of gathering important spectral data on the comet before it passed behind the Sun. The mission was a great success, and the ability to turn around a mission like this on short notice (approximately six months) is one of the hallmarks of the program. Other notable missions in 2014 included the study of water on Venus, a flight to study the aurora, and several solar and astrophysics missions.

In preparations for FY2015 mission, several technologically and scientifically complex missions were developed over the past year. These efforts included significant ground tests and flight tests. The Cusp-Region Experiment (C-REX) mission will deploy 24 ampules of a barium mixture using small rocket motors to increase the deployment distance. The Auroral Spatial Structures Probe (ASSP) will deploy six spinning subpayloads using a newly developed high speed air-spring system. Both of these complex systems required significant development effort and the NSROC and NASA engineering teams worked diligently to meet the science deadlines while thoroughly evaluating test results and altering the design when required. Without such dedication and team work, complex missions like these would not be possible.

One of the core objectives of the sounding rockets program is to provide opportunities for students at all levels to engage in the fundamentals of engineering and science required for space flight. This year the program flew one dedicated student mission with RockOn! kit experiments and RockSat-C custom-built experiments. Over 150 students from around the nation participated in this opportunity which culminated in the launch of a Terrier-Orion sounding rocket carrying the experiments into space. Additionally, the Wallops Rocket Academy for Teachers and Students (WRATS) workshop was held for the fourth time. High school teachers from around the country attended the one week workshop and participated in lectures about rocket flight, engineering, and flight testing. WRATS challenged the teachers and provided them with knowledge and tools they could take back to their classrooms to enhance their STEM education. And, as usual, most of the large science missions involved undergraduate and graduate students, thereby ensuring the readiness of the next generation of scientists when the time comes.

The many successes achieved in the past year can be attributed to the truly outstanding workforce, consisting of both contractor (NSROC) and Civil Service team members. Their dedication and willingness to extend every effort to ensure the realization of the missions is what makes the program the success that it is.

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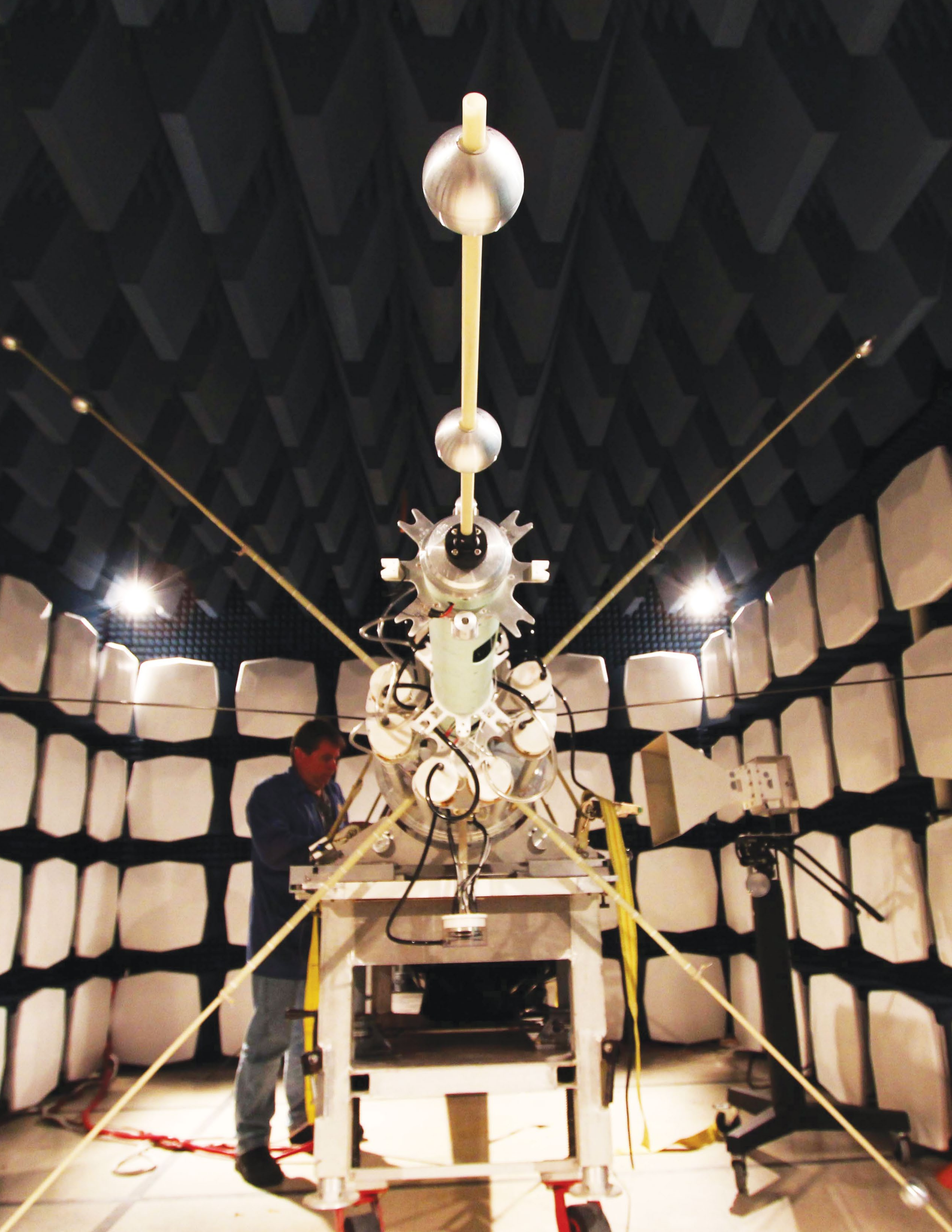
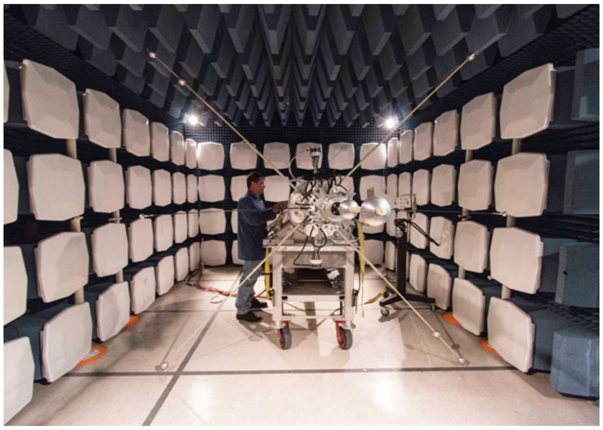
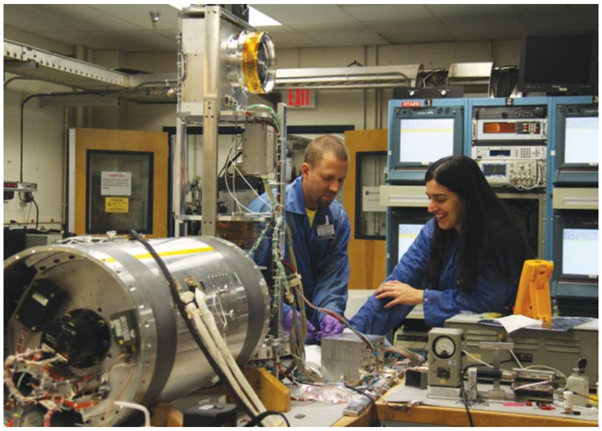
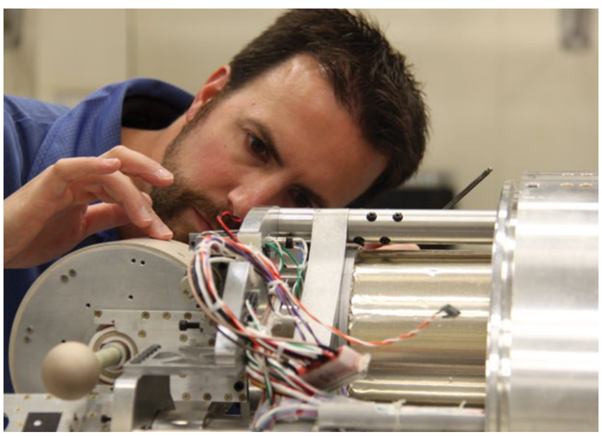
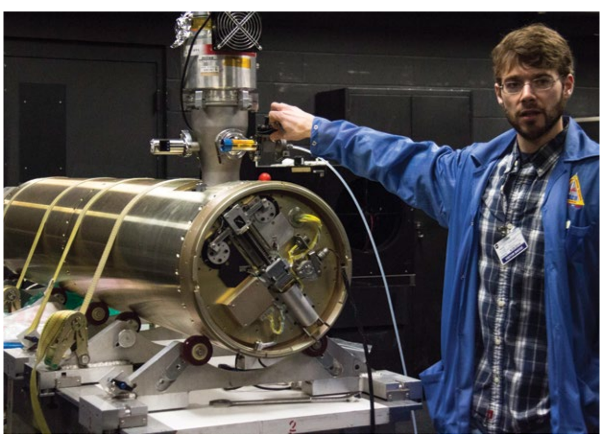


introduction





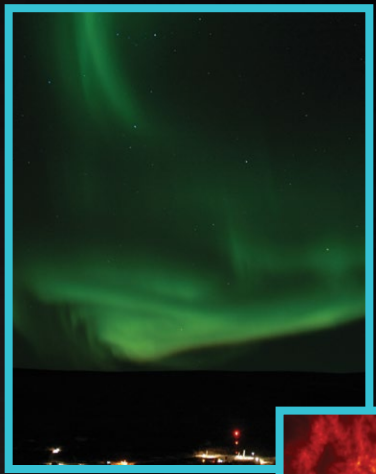


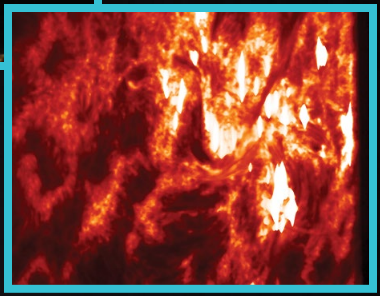


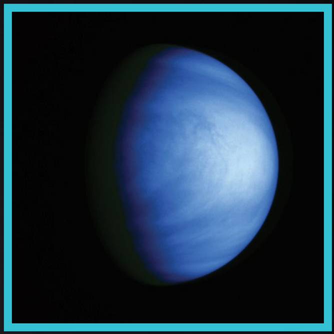
The Sounding Rockets Program Office (SRPO), at NASA Goddard Space Flight Center's Wallops Flight Facility, provides suborbital launch vehicles, payload development, and field operations support to NASA and other government agencies. SRPO works closely with the Sounding Rocket User Community to provide launch opportunities facilitating a broad spectrum of science and technology applications.

The Sounding Rockets Program supports the NASA Science Mission Directorate's strategic vision and goals for Earth Science, Geospace sience, 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. Operations are conducted from fixed launch sites such as Wallops Test Range (Virginia), Poker Flat Research Range (Alaska), and White Sands Missile Range (New Mexico) as well as sites such as Andoya Rocket Range (Norway), Esrange (Sweden) and Kwajalein Atoll, Marshall Islands. Launch operations are also conducted from mobile sites set up by the Wallops Test Range. Mobile "campaigns" have been conducted from Australia, Puerto Rico, and Brazil. The mobile capability offered by the Wallops Test Range allows scientists to conduct their science "where it occurs". 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.







Eleven missions, in five disciplines, were launched in 2014. Studying Comet ISON, measuring water on Venus, launching into an active Aurora, studying the Sun in several wavelengths and exploring the interstellar medium were all accomplished in Fiscal Year 2014. Additionally, two test flights, to advance sounding rocket technologies, and one education mission were conducted.

missions 2014

The Ground-to-Rocket Electrodynamics Electrons Correlative Experiment (GREECE) was flown from Poker Flat Research Range, AK in early 2014. This mission set out to investigate the electrodynamics associated with fluid-like auroral structures in an attempt to determine the driving forces behind them. GREECE used a combination of onboard instrumentation to measure the plasma environment as well as an array of ground-based optical auroral imagers positioned at a downrange site—located under the payload trajectory—in order to image the fluid motions of the aurora with high temporal and spatial resolution.

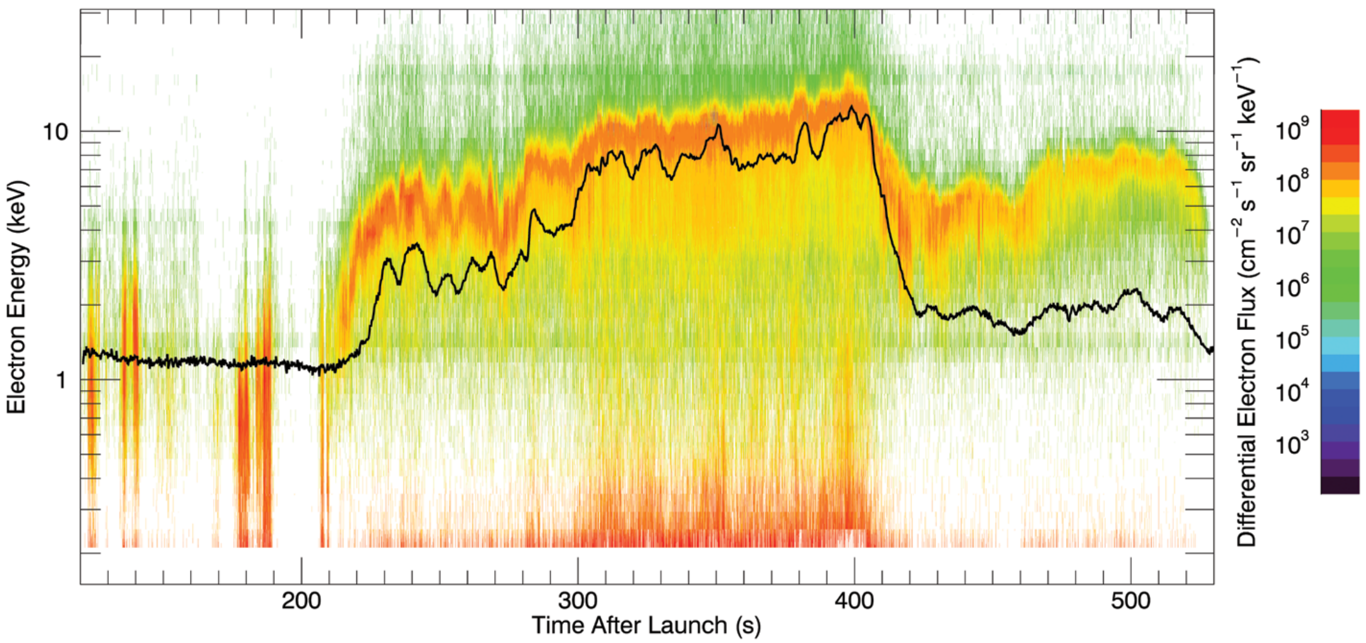
geospace science

GREECE

Principal Investigator:
Dr. Marilia Samara
Southwest Research Institute (SwRI) &
NASA Goddard Space Flight Center
Mission Number(s):
36.287UE
Launch site:
Poker Flat Research Range, AK
Launch date:
March 3, 2014

During the most dynamic displays, the aurora exhibits strong fluid-like motions in the direction perpendicular to the magnetic field. While these apparent flows have been observed and explored since the start of aurora studies, it is not yet understood what drives them and where in the near-Earth space environment those forces are acting.

The GREECE mission set out to investigate the electrodynamics associated with these fluid-like auroral structures in an attempt to determine the driving forces behind them. GREECE used a combination of onboard instrumentation to measure the plasma environment as well as an array of ground-based



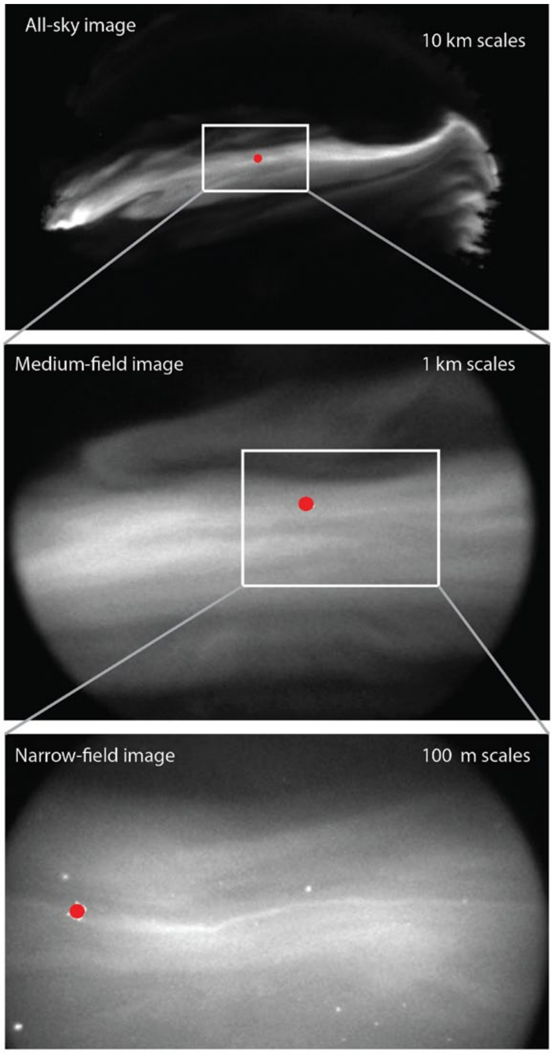
APES instrument electron spectra closely matching ground based auroral signature at the magnetic footprint of the rocket (black line).

Payload integration at NASA GSFC Wallops Flight Facility.

optical auroral imagers positioned at a downrange site—located under the payload trajectory—in order to image the fluid motions of the aurora with high temporal and spatial resolution.

The GREECE rocket launched on March 3, 2014 into an active auroral display that occurred directly over the downrange imaging site of Venetie, AK. The onboard electron detectors measured the precipitating electrons, which were then compared to the optical auroral structures that they were responsible for. The ground-based auroral imaging consisted of six different imagers with a total of three separate fields of view, providing information about the aurora on both the large-scale (>10 km) and the small scale (~100 m). Specifically, a correlation of emission line brightness data, corresponding to the rocket magnetic footpoint, with electron characteristics taken by the Acute Precipitating Electron Spectrometer (APES), was made. The ultimate goal is to characterize the auroral emissions produced from a known precipitating electron distribution, such that more accurate ground-based imaging and photometry to infer the characteristics of the precipitating electrons can be used. These techniques can then be applied over larger scales and longer times, when only multi-spectral imaging data are available with no corresponding in situ data.

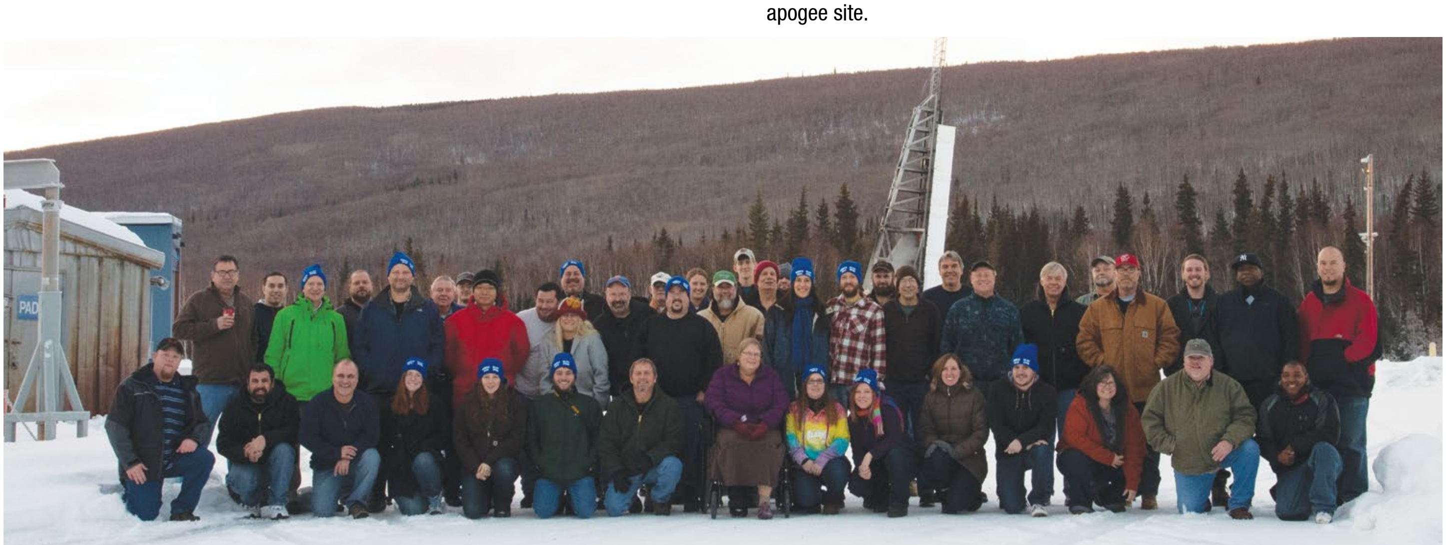
Moreover, using the electron detectors developed at Southwest Research Institute and the electric field instrument developed at the University of California, Berkeley, GREECE was able to determine that the auroral flows are not caused by large-amplitude electric fields in the low altitude (<400 km) ionosphere. The nature of the electron precipitation reveals that the flow structure is caused by motions of the electron source region, occurring much farther out in the near-Earth space environment.



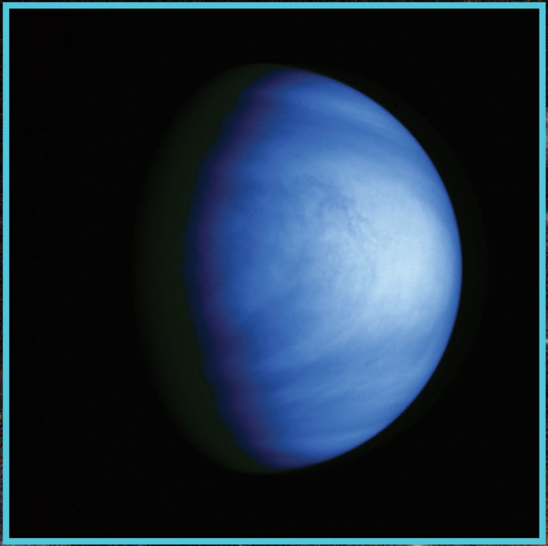
Images of the auroral event with 3 different fields of view, revealing the small–scale nature of the auroral structures.

Ground based imager set up at the Native Athabascan village of Venetie, AK, the GREECE apogee site.

PI Dr. Marilia Samara assisting with final assembly prior to launch.



GREECE mission team at Poker Flat Research Range, AK prior to launch.



Four Astrophysics missions were flown in 2014 and included rare opportunities such as a flight to study Comet Ison with the Far-Ultraviolet Off-Rowland Telescope for Imaging and Spectroscopy before it passed behind the Sun, The scientific objective of the Venus Spectral Rocket (VeSpR) mission was to study water on planet Venus. Additional astrophysics missions included the Colorado High-resolution Echelle Stellar Spectrograph (CHESS) and the X-ray Quantum Calorimeter (XQC).

astrophysics

Far-Ultraviolet Off-Rowland Telescope for Imaging and Spectroscopy

FORTIS

Principal Investigator:
Dr. Stephan McCandliss
Johns Hopkins University
Mission Number(s):
36.296 UG
Launch site:
White Sands Missile Range, NM
Launch date:
November 20, 2013

The FORTIS payload at White Sands Missile Range prior to flight.

The goal of this mission was to acquire imagery and spectra of the sungrazing Oort cloud comet C/2012 S1 (ISON), hereafter C/ISON, in the far-UV bandpass between 800 – 1950 Å over a 0.5 field-of-view (FOV), during its ingress towards perihelion. This bandpass and FOV provides access to a particularly rich set of spectral diagnostics for determining the volatile production rates of CO, H, C, C+, O and S, and allows us to search for previously undetected atomic and molecular species such as Ar, N, N+, N2, O+ and O5+. Of particular interest is addressing the question of whether Oort cloud comets carry a chemical composition similar to the proto-stellar molecular cloud from which the Solar System formed. Sounding rockets are uniquely suited to observing cometary emissions in the far-UV as they can point to within 25° of the sun, whereas the Hubble Space Telescope (HST) is limited to observations at angles greater than 50°.

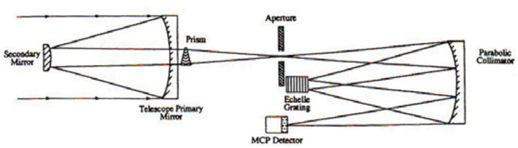
While the data from this flight will take some time to process completely, initial real-time reports from the rocket were able to give scientists some initial information on the comet's make up. "We received good measurement of the hydrogen coming off the comet which comes from the disassociation of water, and that provides a baseline for all other measurements," said Dr. McCandliss, Principal Investigator for the FORTIS missions.

FORTIS uses a prototype version of the microshutter array (MSA), which NASA's Goddard Space Flight Center developed for use on NIRSpec on James Webb Space Telescope (JWST). It 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 followup in the 900 -- 1800 Angstrom bandpass. In all, there are four different technological innovations that are in the process of maturation on this experiment. In addition to the MSA, a holographically ruled grating with a triaxial elliptical surface figure is flown as the telescopes secondary optic, along with a large microchannel plate detector featuring an on-axis imaging channel and two "outrigger" spectroscopic channels. Additionally an on-the-fly targeting system that processes the imaging data during flight to determine which microshutters to leave open for spectral acquisitions, was developed specifically for FORTIS.

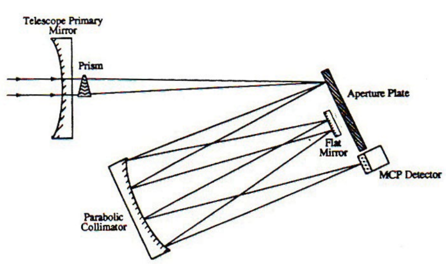
This was the second flight of the FORTIS instrument.

VeSpR

Principal Investigator:
Dr. John Clarke
Boston University
Mission Number(s):
36.261 UG
Launch site:
White Sands Missile Range,
New Mesico
Launch date:
November 26, 2013



Geometry of the VeSpR telescope and spectrograph.

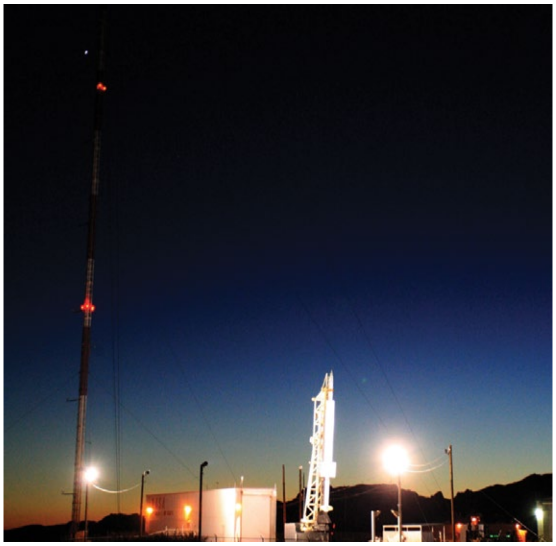


Layout of the reimaging system on VeSpR.

The Venus Spectral Rocket experiment (VeSpR) launched successfully on November 26, 2013 from the White Sands Missile Range. The scientific goals of the VeSpR mission were to obtain a high resolution spectrum of the hydrogen (H) and deuterium (D) Lyman-alpha emissions from the atmosphere of Venus, and thereby determine the D/H ratio at the top of Venus' atmosphere, and to obtain an H Lyman-alpha image of the extended emissions from the Venus corona. Both the present D/H ratio and the extent of the emission from the coronal atmosphere are related to the present day escape of water from the atmosphere of Venus into space. As water molecules diffuse upward through the atmosphere of Venus, they are photodissociated by UV sunlight, and the resulting H and O atoms with sufficient velocity can escape into space. D atoms escape more slowly than H atoms due to the mass difference, and over time the ratio of D/H in the atmosphere will increase as more water escapes. In this scenario, the present D/H ratio indicates the total amount of water that has escaped from Venus, giving important information about the history of water on Venus. Earlier estimates, made from data collected by NASA's 1978 Pioneer Venus spacecraft and other observations, indicated Venus could have had enough ancient water to cover the whole globe with 23 feet (7 meters) of liquid. However, data from the Venus Express mission have shown a different ratio in the middle atmosphere of Venus and variations with altitude. The goal is to understand the physical processes leading to the escape of H and D today, so that we may accurately extrapolate back in time and learn the history of water on Venus.

VeSpR was part of a three mission collaboration of coordinated observations of Venus to study the D/H ratio in the upper atmosphere. Observations of Venus were also obtained with the Hubble Space Telescope in October 2014, using the Space Telescope Imaging Spectrograph, also to detect the D and H Ly-alpha emissions with a long aperture extending across the disc of Venus. Other observations, beginning in December 2013, were conducted with Venus Express and the SPICAV instrument, using a near-IR solar occultation channel to measure the column densities of H2O and HDO in the middle atmosphere of Venus. Since this can only be done during the seasons of solar occultations seen from the spacecraft, these observations could not be simultaneous with HST and VeSpR.

The VeSpR scientific instrument consists of a 35 cm telescope feeding a 70 cm long echelle spectrograph with a microchannel plate detector with a crossed de-



VeSpR on the pad prior to launch.

VeSpR launch on November 26, 2013.

Science team preparing instrument during payload integration at NASA GSFC Wallops Flight Facility.

lay line detector. The use of a pre-dispersing prism to prevent long wavelengths from entering the spectrograph permits a long-aperture approach to echelle spectroscopy, and the chosen combination of imaging and dispersion scales provides high spectral resolution of emission line profiles with a several arc sec wide aperture for good sensitivity. In addition, light reflected from a mirrored aperture plate is re-imaged onto a second microchannel plate detector for an image of the field of view not entering the aperture. For the VeSpR mission, there were a number of launch window constraints. Venus must be observed near elongation, when it appears farthest from the Sun on the sky. While it can be seen in the dark sky either after sunset or before sunrise at different points in its orbit, for the purposes of this experiment only the elongations after sunset met the requirements of the spectral data. This relates to the line of sight Doppler shift of the Venus emission lines, Venus emissions must be blue-shifted with respect to the Earth geocoronal emission to observe the Venus D line clear of other backgrounds, including scattered light from the geocoronal H line from the echelle grating.

In the VeSpR flight mission, all mechanical and electrical systems functioned with nominal performance, however the UV photon count rate was not as high as expected. In post-flight calibration, the experiment showed a nominal response, similar to the pre-flight efficiency. The leading explanation for the low count rate is absorption of the UV photons by water ice that condensed on the optics while the payload was exposed to the elements on the rail. This ice was sublimating during the flight, and would sublimate off the optics in any vacuum system leading to a progressively higher count rate. Due to the short duration of the flight, however, the full response of VeSpR was not achieved. While UV emissions were recorded, the data collected were not comparable to the high quality spectrum obtained with HST. Overall, the combined three spacecraft mission to study Venus has been a success.

In other benefits of the VeSpR mission, experience gained with the design and testing of the VeSpR echelle spectrograph has led to the implementation of the first echelle spectrograph flown to another planet, in the IUVS instrument on the MAVEN mission to Mars. This channel of the MAVEN IUVS was modeled after the optical layout of the VeSpR spectrograph, and lessons learned in the testing of VeSpR were applied to its development. MAVEN is now returning high quality echelle spectra from Mars. In addition, VeSpR flight engineer Nathan Darling is now working on the NASA GOLD mission at UC Berkeley, having gained valuable experience and training on the VeSpR mission at BU. The development and testing of new technology, and training of young scientists and engineers, are among the most valuable attributes of NASA's sounding rocket program.

Colorado High-resolution Echelle Stellar Spectrograph

CHESS

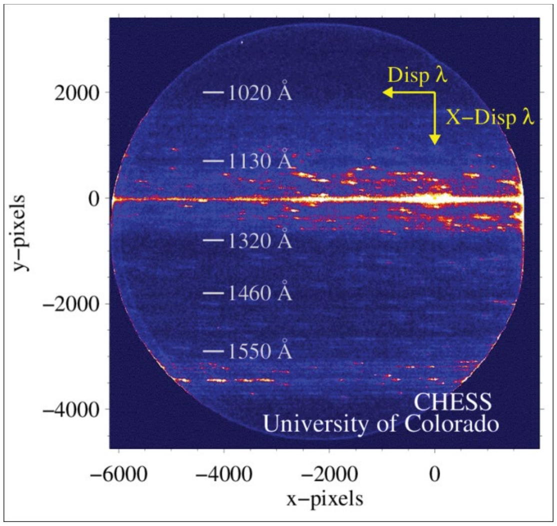
Principal Investigator:
Dr. Kevin France
University of Colorado
Mission Number(s):
36.285 UG
Launch site:
White Sands Missile Range,
New Mesico
Launch date:
May 24, 2014

The CHESS 36.285 Experiment and Wallops Flight Facility systems at White Sands Missile Range.

A stormy night at LC–36, about T– 3hrs before launch of 36.285.

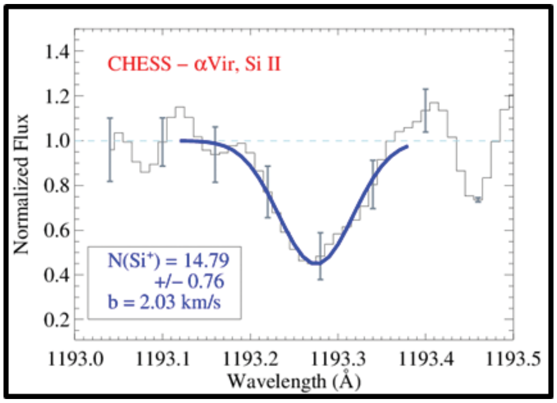
NASA and the University of Colorado at Boulder collaborated to launch an astrophysics experiment into Earth's near-space environment in order to study the life-cycle of stars in our Milky Way galaxy. The NASA/CU 36.285 UG – France mission launched successfully at 01:35am MDT on May 24th, 2014 from Launch 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, a postdoctoral fellow, and two 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 target into alignment with the payload. The payload achieved an apogee of approximately 200 miles, and landed approximately 55 miles uprange 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 Colorado High-resolution Echelle Stellar Spectrograph (CHESS). CHESS is an astrophysics payload carrying an objective echelle spectrograph covering the far-ultraviolet wavelength range from 102 – 160 nm. CHESS observed a hot star in the constellations of Virginis during the 2014 flight. This massive star is used as a background source 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 the team to measure the various phases of the interstellar medium. The CHESS instrument's combination of high spectral resolution ($\Delta v \leq 3$ km s-1) and broad wavelength coverage is unique to NASA astrophysics missions and provides the means to separate the signal from physical structures in 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. With the first flight of CHESS, the Colorado team was mainly focused on the low-density, intermediate temperature (~ 104 K) gas that pervades our local interstellar environment.



The first scientific results, calibration, and flight performance details from the 36.285 CHESS mission have been published in the proceedings of the SPIE by the team's lead graduate student researcher (Hoadley et al., SPIE, v8859, 2014). CHESS flight data reveal broad atomic and ionic absorption line features that arise in the photosphere (surface layers) of the target star, α Vir, and the targeted narrower absorption lines arising from the singly and doubly ionized gas in the local interstellar medium. The CHESS flight data are currently being analyzed in conjunction with supporting space and ground-based observations to derive new constraints on the chemical composition and physical state of the Sun's local Galactic environment. These data will be submitted to the Astrophysical Journal in 2015.

36.285 CHESS laboratory calibration (above) and flight data (below). The pre–flight data are created with an H/Ar discharge lamp. The flight data show an example of the low–density warm gas (Si+ ions) in the Sun's Galactic neighborhood detected by CHESS.



36.285 Recovery. Left to right: Kevin France (PI – Colorado), Keri Hoadley (Colorado), Robert Kane (Colorado), Brian Brittingham (NASA/WFF)

XQC

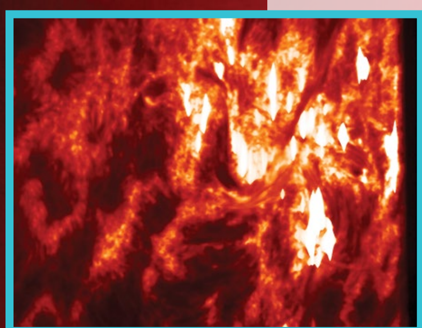
Principal Investigator:
Dr. Dan McCammon
University of Wiscnsin
Mission Number(s):
36.294 UH
Launch site:
White Sands Missile Range, New Mesico
Launch date:
November 3, 2013

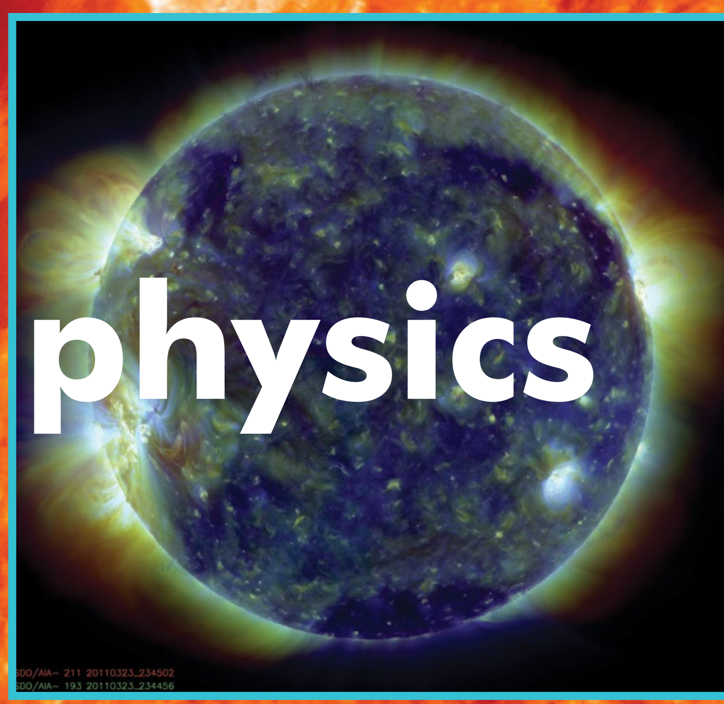
XQC being prepared for flight at White Sands Missile Range, NM.

The study of the Soft X-ray Background (SXRB) provides insight into the hot components of the interstellar medium, which can have important implications for our understanding of topics ranging from star formation to galaxy evolution. Historically, the primary contribution to the SXRB at ~¼ keV has been modeled as thermal emission from a region of diffuse interstellar plasma (T~10^6 K) extending about 100 pc in the vicinity of our Sun (a.k.a."The Local Hot Bubble" or LHB). More recent models and observations, however, suggest that around 40% of the SXRB in this energy range is produced by another mechanism known as Solar Wind Charge Exchange (SWCX) — the same mechanism responsible for Xray emission from comets and planetary atmospheres (Galeazzi, et al., Nature 512, 171-173, 2014). Utilizing a large-area microcalorimeter array operating near 0.05K, the aim of this experiment is to capture spectra with sufficient resolution and statistics to study the different emission models. Previous XQC missions have observed at high galactic latitude (l,b = 90°, +60°) where emission from the Galactic halo is important. The current flight observed toward the galactic anti-center (l,b = 165°, -5°) where nearby absorbing gas blocks distant components, so the LHB and SWCX should dominate. Comparison of the two spectra will help reveal the nature of contributions from the different sources. This mission was a re-flight of 36.264, which suffered from ice build-up on what was, at that time, the outer-most infrared-blocking filter over the detector. This problem has been successfully addressed by the installation of an additional outer filter held at 300K. Instabilities in the Black Brant burn caused higher-than-expected vibrations during the launch of the current mission, resulting in high and unstable detector temperatures during the observation. While this has added considerable complications to the analysis of the data, the eventual results are not thought to be compromised.

solar physics

Solar physics research in 2014 involved missions to study the Sun in high detail with the Very high Angular Resolution Ultraviolet Telescope (VAULT2.0), calibrate the Solar Dynamics Observatory with the SDO-EVE sounding rocket instrument, measure the nature of the inteplanetary medium with the Hydrogen Polarimetric Explorer (HYPE) and test a new Degradation Free Spectrometer for solar studies. Four missions were successfully flown from White Sands Missile Range, NM in 2014 and all instruments were recovered for possible re-flight in the future.

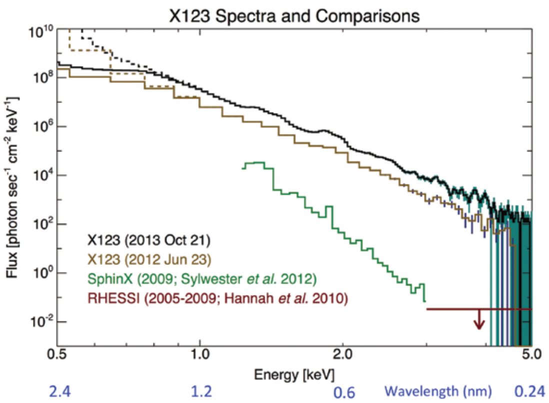




SDO-EVE

Principal Investigator:
Dr. Tom Woods
University of Colorado
Mission Number(s):
36.290 US
Launch site:
White Sands Missile Range, New Mesico
Launch date:
October 21, 2013

Twenty visitors from Colorado drove down and are shown here with the rocket science team in front of the 36.290 rocket before its successful launch on October 21, 2014.



The solar soft x–ray spectrum from the NASA 36.286 (2012) and NASA 36.290 (2013) flights is shown here in comparison to solar cycle minimum measurement from the Russian SphinX measurement in 2009 and solar cycle minimum upper limit from RHESSI. This figure is from Capsi and Woods (Astrophys. J., submitted, 2014).

NASA successfully launched a Black Brant IX sounding rocket at 2 p.m. EDT on October 21, 2013 from the White Sands Missile Range, N.M., carrying instrumentation to support the calibration of the EUV Variability Experiment, or EVE, aboard the Solar Dynamics Observatory, or SDO, satellite. EVE measures the total extreme ultraviolet output of the sun, called its irradiance.

As part of the planned SDO/EVE program, the rocket calibration flight occurs about once a year to accurately determine the long-term variations of the solar extreme ultraviolet irradiance. This kind of calibration is known as an under-flight. It uses a near-replica of the SDO/EVE instrument to gather a calibrated sounding rocket observation in coordination with the satellite's observations from its GEO location above White Sands. Comparison of the two data sets then validates the accuracy of the SDO/EVE data, providing crucial calibration of any long-term changes in the orbital instrumentation. This was the fourth under-flight calibration for the EVE instrument. The previous flight was successfully conducted on June 23, 2012. The next under-flight calibration for the EVE instrument is planned for May 2015 (NASA 36.300).

The mission principal investigator Tom Woods, from the University of Colorado at Boulder, reports that the under-flight data are excellent and that there was no damage to the instruments during the flight or landing. In addition to the calibration data for the SDO/EVE orbital instrument, this rocket flight also provided new soft x-ray spectral measurements to help address a gap in the satellite measurements. The SDO/EVE observes the solar spectrum from 6 nm to 106 nm with 0.1 nm spectral resolution but just observes the soft x-ray (1-7 nm) over a single broad band. The soft x-ray radiation is highly variable and is expected to have peak emissions near 2 nm. This rocket flight provided technology demonstration for two new soft x-ray spectrometers, one being a commercial Amptek X123 spectrometer and another being a pin-hole camera with a transmission grating and CCD detector. Both of these new instruments and measurement techniques worked very well and provided new soft x-ray spectra for the 0.03 nm to 6 nm range. Scientists from University of Colorado and University of Southern California are working now on applying these rocket calibration data in the SDO/EVE data processing algorithms and also on preparing publications of these new soft x-ray solar spectra results.

Hydrogen Polarimetric Explorer

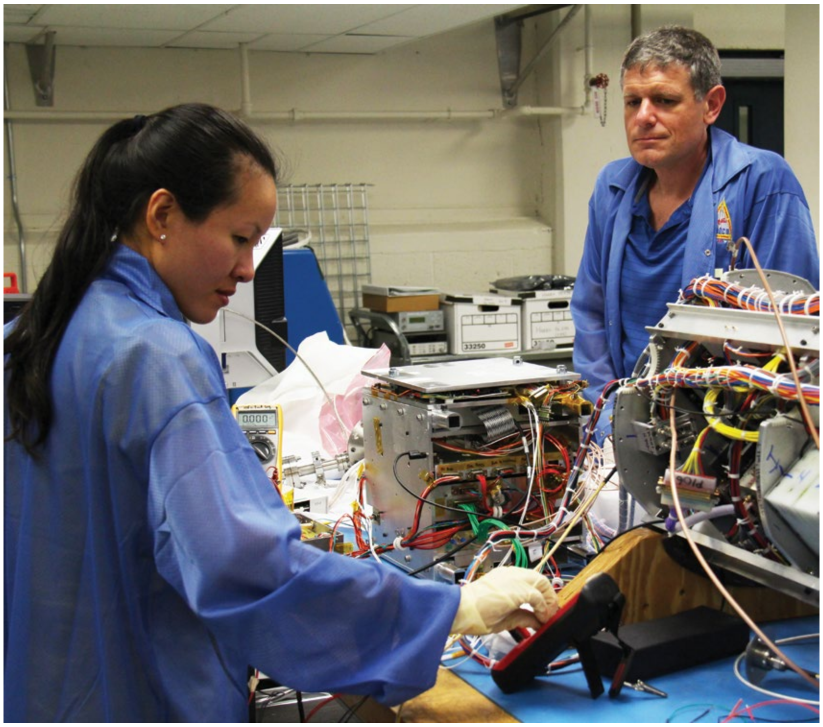
HYPE

Principal Investigator:
Dr. Harris
University of California-Davis
Mission Number(s):
36.235 US
Launch site:
White Sands Missile Range, New Mesico
Launch date:
May 3, 2014

The Hydrogen Polarimetric Explorer (HYPE) mission is designed to measure the nature of the interplanetary medium, characterizing the particles that fill our solar system. HYPE measures light reflected by interplanetary hydrogen that originally flows in from outside the galaxy. Along its travels, the hydrogen crosses the boundaries of our heliosphere, the local bubble surrounding the sun and planets that is inflated by the solar wind. Thus it can provide not only information about the nature of near space, but also of the galactic environment and how it interacts with the sun and heliosphere.

The HYPE sounding rocket measurements provide important information on the size and shape of the heliosphere as well as information on the interstellar magnetic field at the boundary. These results will be combined with NASA's Interstellar Boundary Explorer, Voyager, and Hubble Space Telescope interplanetary hydrogen measurements to improve models of the heliospheric boundary and its interactions with the local interstellar medium.

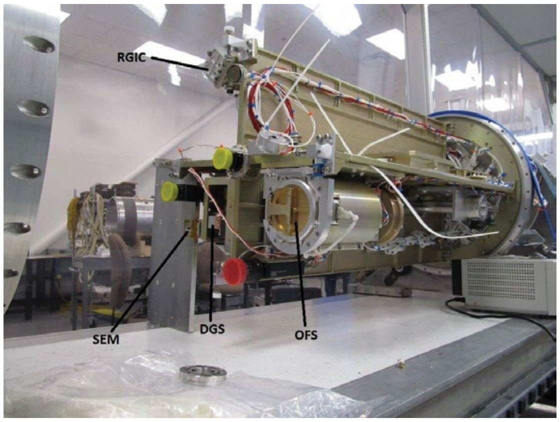
HYPE payload on balancing table at Wallops.



HYPE science team completing instrument checks during payload integration at Wallops.

DFS

Principal Investigator:
Dr. Leonid Didkovsky
University of Southern California
Mission Number(s):
36.289 US
Launch site:
White Sands Missile Range,
New Mesico
Launch date:
July 22, 2014
PI website:
www.usc.edu/dept/space_science/whatsnew.html



Degradation Free Spectrometers science payload

The July 22, 2014 Degradation Free Spectrometers (DFS) 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 behavior of our dynamic sun and its effects on planetary atmospheres and the heliosphere. 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. The instruments proven on this flight include the degradation free Optics Free Spectrometer (OFS), which obtains solar EUV spectra through energy analysis of photoelectrons from ionization of a neon target gas by incoming EUV photons, and the Dual Grating Spectrometer (DGS), which rejects visible light and isolates EUV bands by diffracting incoming photons twice through in-series, free-standing transmission gratings. Both instruments operate without reflective optics or thin film filters. Elimination of these degradation-prone optical elements represents a highly desirable advance in degradation free spectrometer technology. The mission also provides an under-flight calibration for the SOHO/CELIAS Solar EUV Monitor (SEM) instrument which has been in operation since December of 1995.

The 36.289 mission was the second flight of the OFS and the DGS, and both instruments performed extremely well and provided high quality science data. The instruments featured several performance and reliability enhancements added since their first flight (36.263 US) in 2012. A power supply issue which prevented the OFS from returning any science data on the 2012 flight was eliminated by including a redundant power supply on the 36.289 flight. The OFS also included new control electronics to improve its spectral resolution and signal to noise ratio. The DGS performed successfully on the 2012 flight, but for 36.289 included upgraded detectors that increased sensitivity and further improved visible light rejection.

Valuable irradiance data was also obtained from the DFS payload's other two solar instruments, the Rare Gas Ionization Cell (RGIC), and a clone of the SOHO/CELIAS/SEM instrument. The RGIC is an absolute detector which integrates the solar flux over much of the EUV spectral range. The SEM clone sensitivity has been well characterized based on calibrations at the National

Institute of Standards and Technology's Synchrotron Ultraviolet Radiation Facility. Both instruments have significant flight heritage and provide valuable absolute EUV irradiance measurements for maintaining the long-term calibration of the SOHO/SEM and other on-orbit EUV instrumentation. spectral range. The SEM clone sensitivity has been well characterized based on calibrations at the National Institute of Standards and Technology's Synchrotron Ultraviolet Radiation Facility. Both instruments have significant flight heritage and provide valuable absolute EUV irradiance measurements for maintaining the long-term calibration of the SOHO/SEM and other on-orbit EUV instrumentation.

VAULT 2.0

Principal Investigator:
Dr. Angelos Vourlidas
Naval Research Laboratory
Mission Number(s):
36.288 DS
Launch site:
White Sands Missile Range,
New Mesico
Launch date:
September 30, 2014

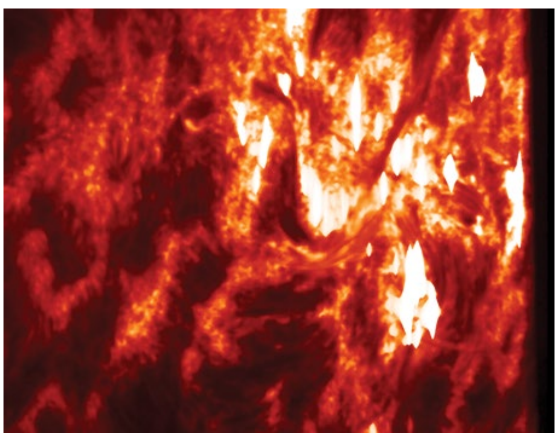


Figure 1. A snapshot of the Lya atmosphere over active region 12172 as observed by VAULT2.0. In this 3–sec exposure, several areas are bright enough to cause saturation in the imaging detector. The field of view is 384 by 256 arcseconds or 0.4 x 0.3 of the solar radius.

The Very high Angular resolution ULtraviolet Telescope (VAULT) is a high resolution imaging spectroheliograph designed in the Naval Research Laboratory's (NRL) Space Science Division and sponsored by NASA. It images the solar atmosphere at the Lyman-alpha line (Lyα, 1216 Å) with ultra-high spatial resolution and spectral purity. In two successful flights (1999 and 2002), VAULT obtained the highest resolution images of the solar atmosphere ever from a space-based platform. The flights proved that sub-arcsecond (~0.45 arc-second) imaging is possible with a modest aperture telescope from a solar physics sounding rocket.

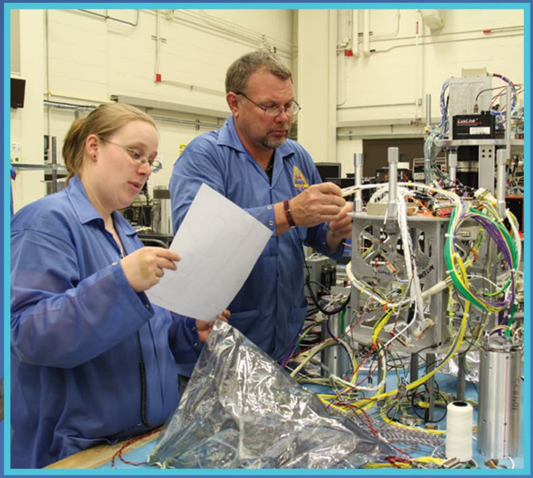
The VAULT2.0 project, under NASA sponsorship, refurbished and upgraded the VAULT payload with new control and camera electronics and a new CCD detector. The instrument maintains the f/24.6, 30-cm diameter Cassegrain telescope followed by a zero-dispersion spectroheliograph, which provides a modest bandpass (150 Å at Lyα). A filter with 70 Å FWHM further restricts the instrument bandpass. VAULT2.0 can obtain images at twice the cadence of the VAULT payload with the same spatial resolution. VAULT2.0 was successfully launched on September 30, 2014 from the White Sands Missile Range. It obtained 33 images, 8 secs apart, of the Lyα atmosphere over active region 12172, as it was approaching the solar limb. The images captured light emitted from hydrogen atoms at temperatures of 8,000 to 100,000 degrees Kelvin. "That's the temperature range where the action is," said Angelos Vourlidas, the principal investigator for VAULT2.0 at the Naval Research Laboratory in Washington, D.C. "These are the temperatures where the heating of the sun's atmosphere – the corona -- really takes place." Understanding how the corona heats remains one of the great, unanswered questions on the sun. The solar surface itself is only about 5000 degrees, but further up in the atmosphere, the temperatures rise to million of degrees Kelvin – the opposite of what one typically expects when moving away from a heat source. Something heats up that corona, and the VAULT2.0 images, in connection with supporting data from other observatories may help in uncovering the mystery.

The NRL VAULT2.0 launch team consisted of Angelos Vourlidas, Samuel Tun, Kevin Eisenhower, and Clarence Korendyke from the Space Science Division's Solar and Heliospheric Physics Branch, and a PhD student, George Chintzoglou, from George Mason University. In addition, the VAULT2.0 refurbishment project included Mary Johnson-Rambert, Don McMullin, Ed Shepler, Dave Roberts, Damien Chua, and Bob Moye. The flight is dedicated to the memory of Dave Eugene Roberts, an exceptional rocketeer and human being. He will be sorely missed.

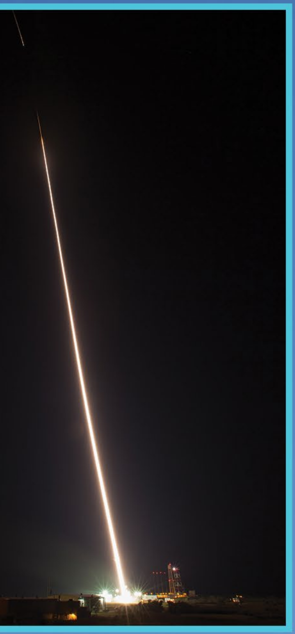
Several solar observatories undertook special observing programs in support of the VAULT2.0 launch. Thus, the science analysis of the VAULT2.0 observations will be augmented by observations from the joint NASA- Japanese Aerospace Exploration Agency's Hinode and NASA's Interface Region Imaging Spectrograph, and from ground-based observations from the Dunn Solar Telescope and the Big Bear Solar Observatory.VAULT2.0 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, the recently launched VERIS spectrometer, and 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/.



Two technology development missions were flown in 2014. Both flights involved testing of a new deployment system for ampules scheduled to fly on the Cusp-Region Experiment (C-REX) mission. Additionally, the Sub-TEC 6 mission included other new technologies under development to further enhance program offerings to the science community.



technology

Principal Investigator:
Mr. Giovanni Rosanova
NASA Wallops Flight Facility
Mission Number(s):
46.007 GP
Launch site:
Wallops Island, Virgina
Launch date:
July 2, 2014

The Sub–TEC 6 payload during deployment testing at Wallops.

The Sub-TEC 6 mission was launched on July 2, 2014 and tested several new technologies.

The primary objective was to develop the next generation standard carrier for technology demonstration missions, with secondary objectives including flight test of NSROC developed technologies. Sub-TEC 6 also served as a test round for the ampule deployment system on the upcoming C-REX mission from Norway. The PI for C-REX is Dr. Mark Conde/University of Alaska-Fairbanks.

NSROC developed technologies included:
mJAGR (miniature Javad Antivibration GPS Receiver)
High Temp Wrap Around Antenna
HD Camera
High Data Rate Encoder
Low Cost Attitude Experiment (LCAE)
40 Mbit telemetry encoder
Several new telemetry transmitters
New uplink command system components
Vacuum monitor system
New electronic timers

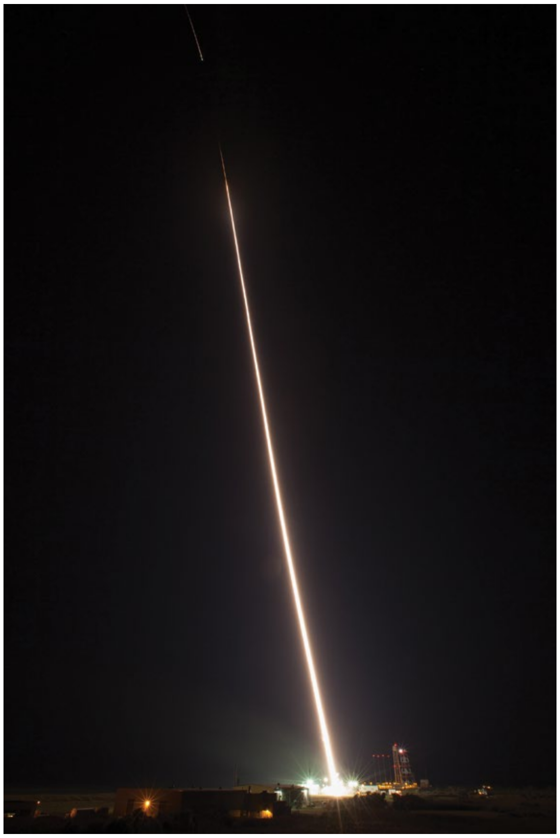
Other technology experiments included:
CubeSat Deployer, developed via Internal Research and Development (IRAD) funding by Code 548

Primary data was not recorded due to the second stage anomaly but good performance data was received pertaining to the functionality of the Ampule Control Modules (ACMs). Onboard logic identified the second stage anomaly and programed the ACM electronics to ignite the chemicals at a predetermined flight time prior to reaching the ground. The functionality demonstrated is critical to ensure the concept of using multiple ampule chemical releases can be safely implemented. The survival of the ACM hardware during the anomaly is a testimony to its robust design.

Principal Investigator:
Mr. Brian Hall
NASA Wallops Flight Facility
Mission Number(s):
36.308 GT
Launch site:
Wallops Island, Virgina
Launch date:
August 28, 2014

The primary objective of this mission was to evaluate the ampule deployment system for the upcoming Cusp-Region Experiment (C-REX) mission. C-REX will be launched from Norway in late 2014 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. The payload is designed to deploy 24 vapor trails of Barium mixtures over an altitude range of 150 - 400 km at 50 km intervals.

The test round mission achieved partial success and deployed one ampule from the payload that ignited as designed. The flight provided additional flight verification of the autonomous in flight programing of the ACMs. The flight identified an inadequate configuration of the small rocket motors that propel the ampules. Identification of the design issues led to extensive testing and modifications that will enhance probability of success on future flights.



Test round mission launches from Wallops Island, VA.

Vapor tracers released from the payload.

education

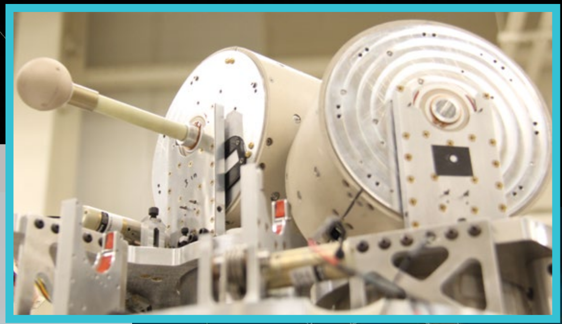
One education mission was flown in 2014. The RockOn! flight included 21 standardized experiments built by 70 participants and 7 custom-built RockSat-C experiments developed by 7 universities and colleges and 1 foundation. This was the seventh RockOn! mission since 2008.

Principal Investigator:
Mr. Christopher Koehler
Colorado Space Grant
Mission Number(s):
41.110 UO
Launch site:
Wallops Island, Virgnia
Launch date:
June 26, 2014

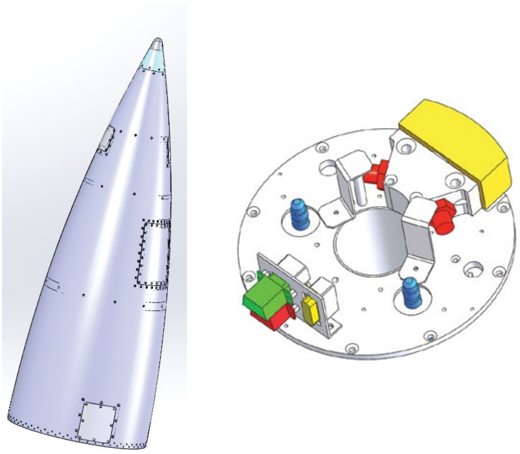
Images of RockOn! participants completing experiment assembly (top and bottom) during the workshop. RockSat–C students inspecting their payload after vibration (middle).

This mission was the seventh 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), Sounding Rockets Program Office and NASA Wallops Flight Facility. Since its beginning in 2008, over 300 people participated in the RockOn! from 38 states (plus Washington, DC and Puerto Rico) and over 125 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 2014 RockOn! mission included 21 standardized experiments built by 70 participants and 7 custom-built RockSat-C experiments developed by 7 universities and colleges and 1 foundation and by ~80 students and faculty. One of the payloads was developed by students at the University of Colorado at Boulder in support of a new program called Cubes In Space and contained 116, 40 mm cubes containing experiments from hundreds of middle school students from across the US. The workshop was conducted at Wallops Flight Facility during the students' summer break with the actual launch occurring on June 26, 2014. 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.

Several new sub-systems have been brounght online in the last year. The Radially Ejecting OGIVE System (REOS) was qualified as operational. Significant development work was undertaken for the C-REX and ASSP missions, both scheduled to fly in the next fiscal year.



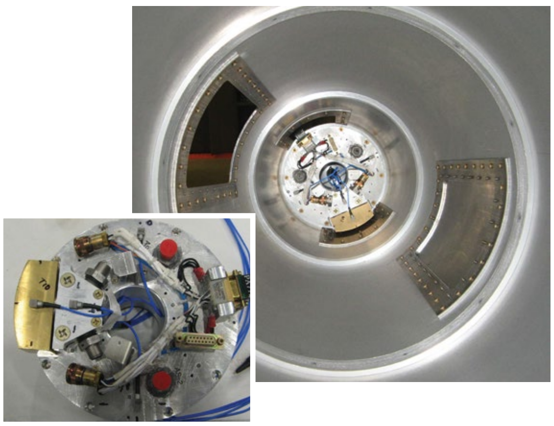
technology development & upgrades



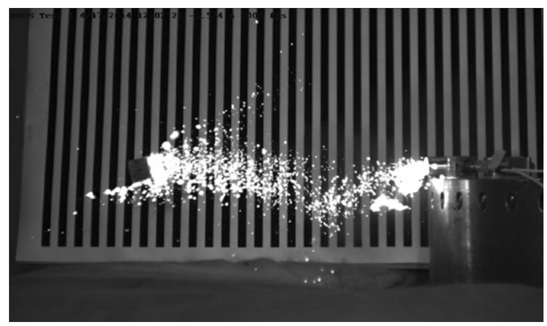
Engineering models of the REOS.

Radially Ejecting OGIVE System (REOS)

The development was completed for a NSROC design of a sub-system used to radially deploy an OGIVE nosecone in flight. The REOS system will be used for science flights that require the nosecone to be removed from the payload flight path as well as on vehicles using an exo-atmospheric rocket motor where the nosecone is removed prior to final stage burn in order to reduce weight and gain performance. The REOS replaces a legacy sounding rocket system and uses modernized surface mounted components, a rechargeable battery pack, and optional in-flight monitors. The system has been qualified and is now considered operational and standard for such missions.



REOS test unit (left) and REOS installed in the nose cone.

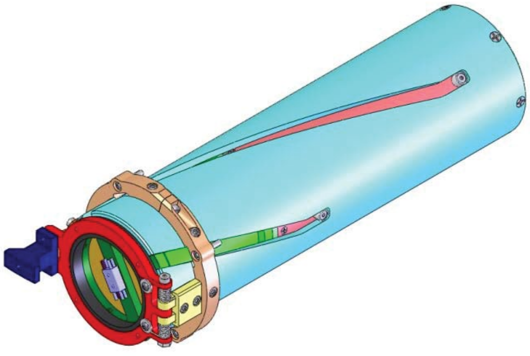


Video frame from a REOS deployment test.

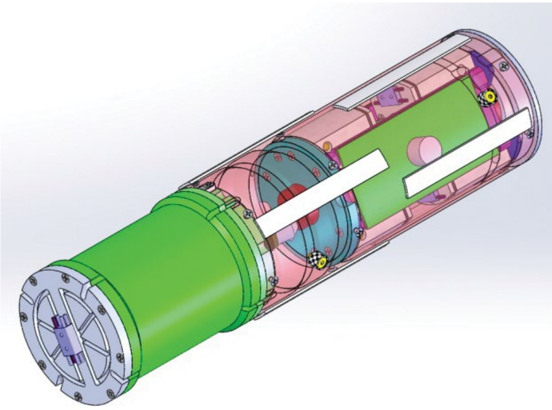
C–REX payload with doors deployed.

Real-Time Trajectory-Based Event Control - Ampoule Control Module - C-REX Ejectable Deployment

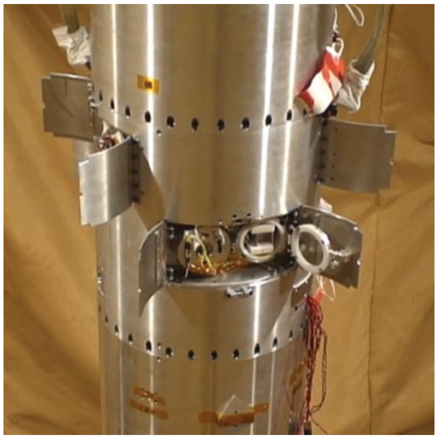
The development was completed for a NSROC design of a system that calculates event times real-time in flight based on actual trajectory and then uploads the updated event times into ejectable sub-payloads prior to release from the main payload. This system makes it possible to compensate for several different anomalous flight events and can adjust event times accordingly. The real-time trajectory-based event control system was designed for the 52.001 Conde C-REX mission but has already been incorporated into several other payloads. The system has been qualified, has flown and successfully operated on two test flight missions, and is now considered operational. The first use on an operational science mission will occur in November 2014 in Norway.



Ampoule exterior view.



Ampoule interior view.



Ampoules visible in payload after door deployment.

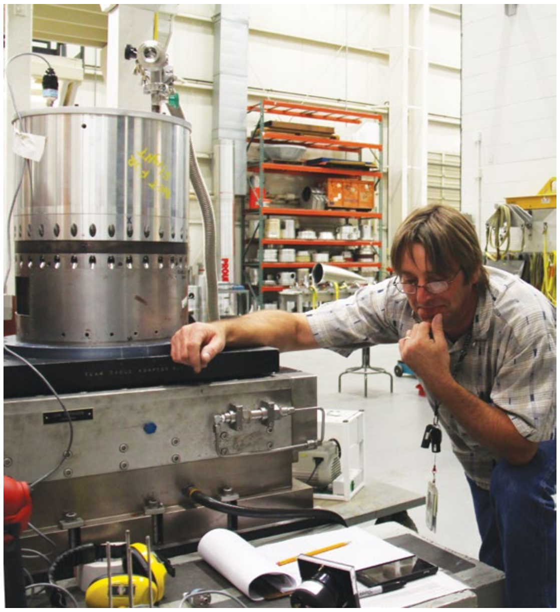
The C-REX mission required delivery of chemicals to specified altitudes as far as possible from the main payload. Given the normal trajectory dispersion, typical time based control of the chemical dispersion could not achieve the desired altitude specification (within 25 km of target). NSROC developed a solution that combined the technologies used by Electrical Engineering and GNC to provide a unique answer. The solution was to develop a single event CDI (the Ampule Control Module or ACM) to release the chemical that could accept the time in flight. The NIACS, using the new capabilities developed for the LDSD project, determined the trajectory state at the up-leg deployment. This state was transferred to an auxiliary computer, the SMAC Ampule Supervisor or SAS.

The SAS projected the trajectories of the ejectables out until all were at the minimum altitude. The associated times for the chemical dispersions were determined and sent to the CDI's on all of the ejectables. The Conde mission requires 24 ampules. Using conventional wired housekeeping telemetry would be impractical. The ACM's provided telemetry reports back to the SAS and SAS sends a single, aggregated telemetry stream back to the ground.

The chemicals are dispersed with a thermite charge. In addition to the technical challenge of chemical dispersion at the desired altitude, there were a number of challenges associated with this pyro control. First, the CDI needed to handle all of the typical safeties that are required for pyro systems. Second, the system needed to guarantee that none of the chemicals returned to the ground undispersed.

In order to accomplish this, new failure detection methods were developed and implemented. These methods were implemented by the SAS working in concert with each of the ACM's. Although not the desired outcome, the Rosanova / 46.007 and Hall / 36.308 demonstrated the system's ability to handle failures. On Rosanova / 46.007, the second stage failed. The SAS identified this condition and changed the chemical dispersion event time to guarantee the chemical dispersed in flight. On Hall / 36.308, three of the ejectables did not leave the payload. Each of the ACM's detected the no-deploy event and set its event time to the predetermined time to disperse.

In addition to a new system and associated hardware, new test methods were also required. First there was a large number of events happening that needed to be monitored. In the case of Conde, there were 24 ejectables with 48 bridge wires for chemicals, 48 motor ignitors, and 48 bridge wires for door deployments. Two new data acquisition systems were developed that permitted simultaneous monitoring of all pyro events. The failure conditions and nominal conditions were tested on the ground in an extended sequence test. During this testing, GPS spoofing was required to create the flight conditions. The data acquisition system also needed to control lift and deployment signals at precise times to simulate flight conditions.



Rocket motor going through vibration testing inside a vacuum chamber.

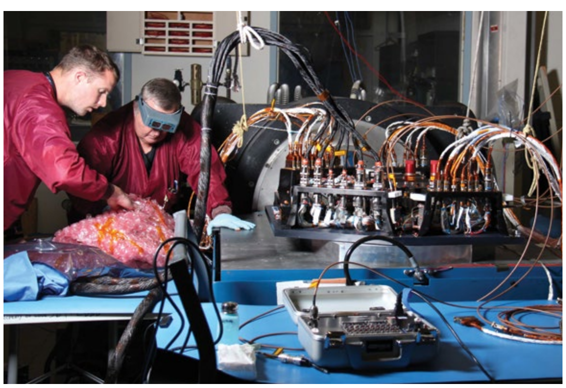
One ejectable was deployed on Hall / 36.308 using the in flight dispersion time update. Its chemical was deployed within 70 meters of the desired altitude based on ground observation of the chemical release. All preparations for the Conde flight went well and the payload is currently in the field undergoing final preparations for launch.

Rocket Propelled Subpayloads

In collaboration with the Principal Investigator Dr. Mark Conde/University of Alaska, Fairbanks, the NASA Sounding Rockets Program finalized the development of rocket propelled subpayloads. This novel system used an amateur rocket motor, available off-the-shelf, to eject small experiments from the main payload structure. Due to the non-standard use of these rocket motors (traditionally they are used to ignite amateur or model rockets on the ground) development efforts were focused on the reliability of motor ignition in the vacuum of space. Vibration testing was completed to ensure system integrity after exposure to the vibration loads of a sounding rocket flight. This type of vibration testing is standard for all sounding rocket systems. After a testflight on a sounding rocket in August 2014 showed some anomalies in the deployment system, further ignition tests were completed after minor changes were made to the design. The first operational flight of the system is scheduled for late 2014 with the launch of the C-REX mission from Norway.

Rocket motor for subpayload ejection test firing.

GLN-MAC Enhancement

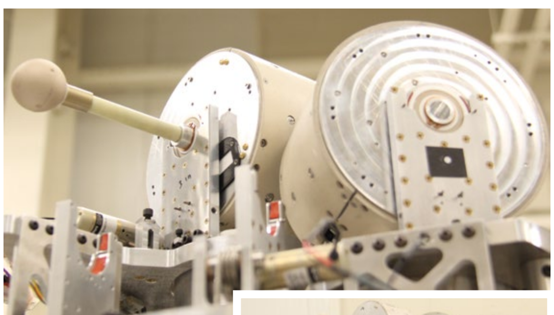


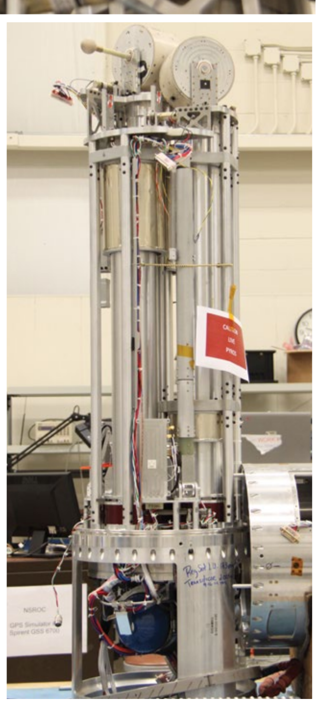
Vibration testing of the WFF Avionics Pallet for LDSD.

The Low-Density Supersonic Decelerator (LDSD) project was led by JPL to flight test Mars entry concepts. For these test vehicles (3 units), JPL selected the GLN-MAC to provide post-flight attitude. The test vehicle was lofted to approximately 36 km by a balloon and dropped. The test vehicle then ignited a STAR48 motor to achieve an apogee of about 61.5 km and then reached approximately Mach 4 on down-leg. As the project progressed, JPL found that they required an in-flight trajectory solution to trigger deployment events based on the magnitude of Earth-relative velocity. JPL also conclude that the GPS solution would likely fail during the powered phase.

In cooperation with JPL, NSROC developed a navigation solution within the GLN-MAC. The solution was required to be accurate to 30 m/s within the first

ASSP air–spring deployment testing at Wallops.





ASSP payload section with subpayloads installed (right). ASSP subpayloads (above).

200 seconds of flight without any GPS after being dropped from the balloon. To support the navigation solution, a real-time attitude solution was required. This demanded attitude initialization without use of an ACS engineer in the blockhouse. NSROC developed an attitude initialization method based on the GLN-MAC measurements, position from the GPS, and a magnetometer for azimuth (while swinging on a balloon).

Finally the system required performance enhancements. The existing flight software was restructured and made more efficient. The system is about 40% faster and now has the ability to support long auxiliary computations.

The first LDSD vehicle was launched on June 28, 2014. The upgraded system demonstrated excellent performance. The system initialized its attitude and navigation state with very modest drift. Early in the powered flight the GPS solution was lost, validating the design decision. The GLN-MAC did trigger all of the required events correctly. Post-flight analysis has shown that the GLN-MAC achieved a velocity solution with only a 5 to 6 m/s error.

This system has now been used adopted for both TM Gyro applications (flown on Pfaff / 21.141 and Samara / 36.287) and on the NIACS. The navigation solution without any GPS was used on Hall / 36.308 and determined the apogee to within 550 m. The ability to perform long, auxiliary calculations has been used on Hall / 36.308, Conde / 52.001, and Collins / 46.009 & 46.010.

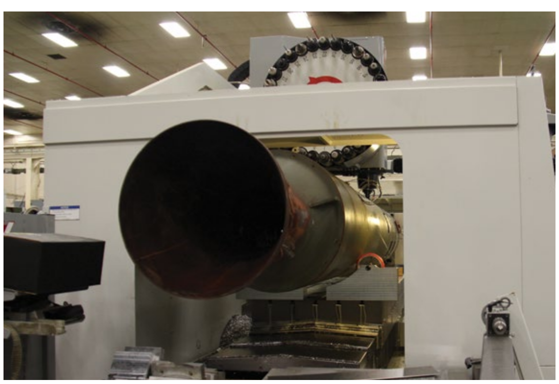
The attitude initialization has also been adopted for NSROC. This system has reduced the workload of the ACS Engineer - only azimuth and time to launch need be entered, improved accuracy, and reduced rail operations as there is no longer a need to measure roll alignment on the rail. This initialization method went into use over the summer of 2014.

Air-Spring Development and Testing for the Auroral Spatial Structures Probe (ASSP) mission

The development was completed for a NSROC design of a high velocity sub-payload ejection system that is capable of ejecting six sub-payloads from the main payload at over 80 miles per hour. The sub-payloads will be deployed spinning about their axis both along the payload flight path and perpendicular to the payload flight path and will reach a separation distance of 50 km from each other by the end of the flight. The system has undergone extensive ground testing and the first operational science mission will be flown in January 2015 from Poker Flat Research Range, Alaska.

Peregrine motor casing with two of four fins installed for load testing.

Open air Peregirne igniter test at Mashall Space Fligth Center.



Taurion motor casing being modified in the machine shop.

Peregrine Status

Good progress has been made on the prototype Peregrine project this year. All six metal cases have been completed and delivered. The hydro proof case was instrumented and successfully tested to 1.4 MEOP at MSFC and was shipped to WFF for fit checks with other new vehicle hardware. An open air igniter test was successfully completed at MSFC and all other igniter hardware is complete. All work on aft closures, exit cones, and insulation installation has been completed by the insulation vendor. All four live cast insulated cases are at the cast vendor waiting to be filled. All casting procedures have been successfully tested with the inert cast that was completed at the end of FY14. After live motor casting is complete the team is looking forward to the static test firing at MSFC and inaugural Peregrine flight in the first part of 2015. The second two flights are scheduled shortly after mid-year 2015. At the end of a successful test program the Peregrine motor will be an alternative motor that could be used to support all science missions.

Taurion

The Taurion is a new vehicle under development that is a mixture of Taurus and Orion hardware specifically designed to acquire certain flight conditions. The activity is a partnership between SRPO, NASA Engineering Safety Center (NESC), ATK and the Navy suborbital launch group. The concept is to use

Taurion motor casing modification.

the high weight and drag of the Taurus case to reduce the performance of the Orion motor installed inside the larger case to achieve the desired flight conditions. The vehicle flight trajectory is designed to burnout at apogee, at 0° elevation angle, at a slightly subsonic velocity, and just below 10,000 ft altitude. The concept repurposes the Taurus hardware that is in process of disposal and makes use of the existing tactical fins (first use by NASA), lugs, and standard rail interface configuration. NESC interest in the project is to install instrumentation to enable flight verification testing to refine state of the art CFD modeling techniques. A goal is to obtain high-speed, low altitude in-flight aerodynamic data. This data will be beneficial in calibrating wind tunnel data and computational fluid dynamic analysis at flight Reynolds numbers related to a variety of NASA technical programmatic activities. This effort will also provide a flight verified means of tailoring sounding rocket performance to meet specific flight test needs suitable to aerodynamic configurations.

Taurion launch vehicle.

New launch vehicle

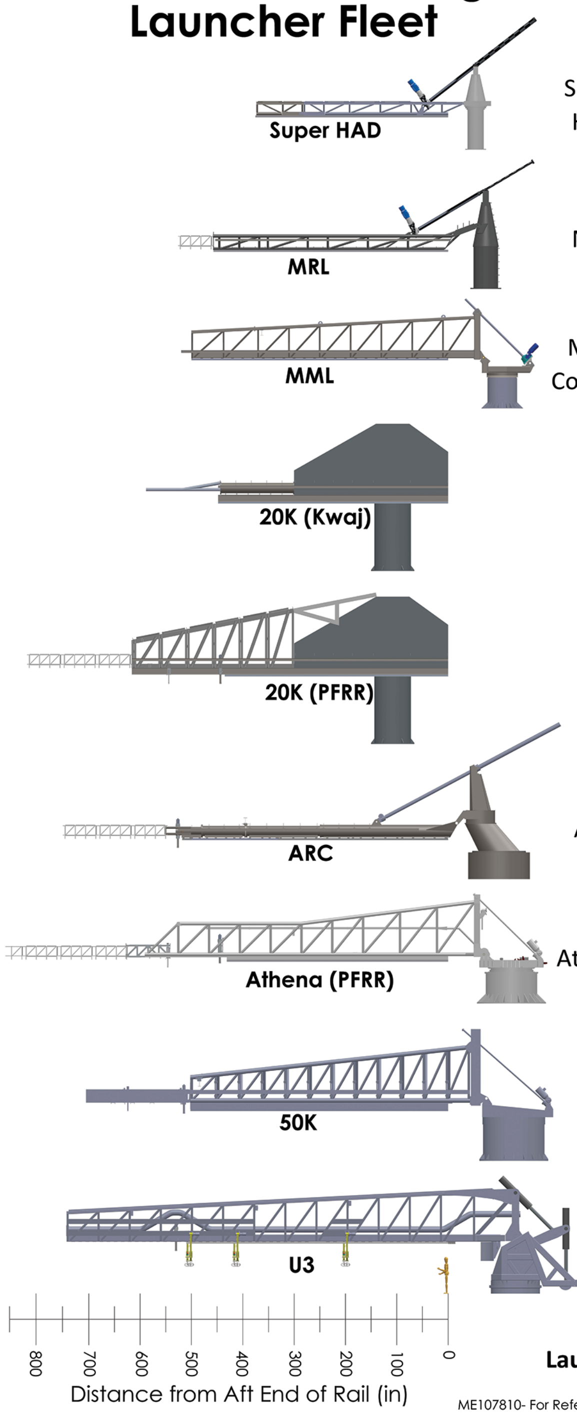
A new guided vehicle currently under development will be utilizing a DOD sustainer motor that has only recently become available as a surplus asset. This is one of the few large diameter sustainer motors that are suitable for use in the SRP. The guidance system hardware will be repurposed and used to offer a new guided vehicle capability. This is a partnership between NASA, DOD and OSC. Involvement in this project may yield SRPO with new vehicle configurations to add to the stable as well as a new guidance capability all at a minimal investment. The initial flight configurations to be tested are a single stage and a two stage vehicle boosted by a Terrier first stage. Orbital is reaching back to Launch Services Group (LSG) in Chandler, Az for assistance with the vehicle development. This reach back is an excellent example of how OSC can gain access to additional expertise not well established locally. This also enables a more dynamic and responsive workforce as personnel resource requirements change. Distribution A: Approved for public release.

New launch vehicle configuration.

Other Development efforts

The NSRP has long had a "Vehicle Stable" Drawing that shows the wide variety of launch vehicles used to expose payloads to space, but what has not always been clearly illustrated is the vast array of sounding rocket rail launchers used by the program throughout the world. This image was made possible by the recent entry of geometry for all launchers into NSROC's SolidWorks 3D modelling software. The scale, locations, and lifting capacities of each launcher are listed for the program's mobile and fixed assets. Of special note is the Medium Mobile Launcher (MML), which is currently under development for program use in 2016.

NASA's Sounding Rocket Program Launcher Fleet



Launcher	Sites	Rated Capacity Moment about Pivot Point (mil. in-lb)	Max Rail Length (in)
Super HAD	WFF, PFRR, Kwaj	.96	375
MRL	WFF, WSMR, PFRR, Kwaj	1.76	457
MML Concept	WFF	3.00	500
20K	Kwaj, PFRR	2.10	449, 616
ARC	WFF	3.37	518
Athena	WSMR, PFRR, ASC	4.13	587
50K	WFF	4.80	502
U3	ASC	5.00	743

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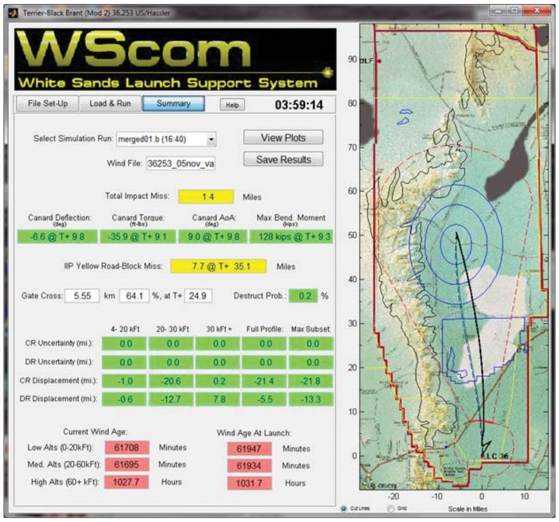


White Sands Wind Weighting software

The new White Sands Wind Weighting (WSWW) software performs wind-weighting analysis of one or two-stage guided or unguided Sounding Rockets at WSMR. It assists the user in evaluation of criteria related to S19 limits (canard deflection, torque and angle of attack), flexible vehicle bending moments, wind-weighted miss from the nominal aim-point, road-block miss, IIP display and gate-crossing. User can interactively determine wind displacements, displacement uncertainty, and wind-age at various altitudes and subset altitudes. Graphs of the simulation results are displayed for current wind data and old wind data. Summary of results is displayed both numerically and color-coded for easy comparison against criteria. The gate criteria is also evaluated from this software. The time for real time decision making has been reduced and the program is more dynamic than the heritage version.

Equipment Upgrades

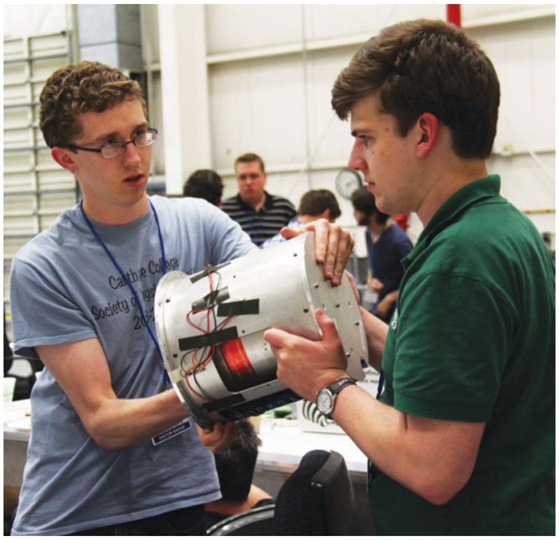
HAAS ST20 CNC lathe.

HAAS VF11 vertical machining center.

HAAS VF 3 YT vertical machining center.

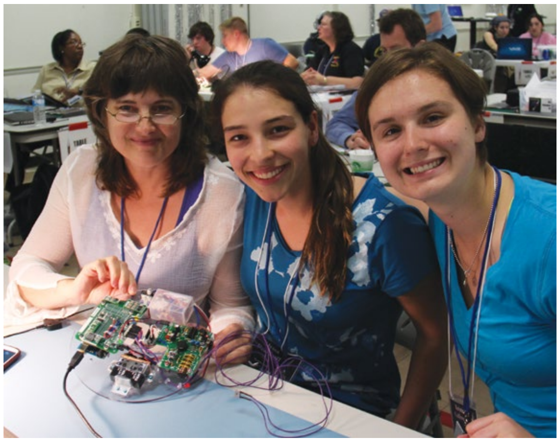
NSROC has installed three new machines in the machine shop. This includes the replacement of two older machines and an additional small lathe. This new machinery allows for larger work envelopes and added production efficiencies. The new machines also bring newer technology in terms of speeds and feeds which removes waste material faster. These machines use the same HAAS controllers as other machines in the shop making it easier for a machinist to move from one machine to another with a minimal controller learning curve. These improvements will reduce the bottle necks currently experienced with milling of large skin sections. NSROC will be introducing several Lean Manufacturing Processes over the next year, such as progressive machining, multiple part machining and machining work cells. The new machines and processes will increase the production output and allows for the machine shop to produce historically purchased parts in house, which results in manufacturing control and cost savings to the program.

education & workforce development



RockSat–C experiment post–vibe check out.

RockOn experiment work.



RockOn! team with finished payload.

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.Faculty members attending RockOn! are given the tools to continue participation in either the workshop level missions or the more advance RockSat-C and RockSat-X flights.

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 Island to launch their payloads. into space.

RockSat–X team members preparing their instrument for flight.

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. A Magnetic NSROC Inertial Attitude Control System is flown on the RockSat-X missions to allow 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/.** This partnership opptimizes NASA's investment by reaching the maximum number of participants at the national level.

NASA Pathways intern Victoria Danna assisting a WRATS teacher.

Internships

Over 170 students have participated in the internship program managed for the Sounding Rockets Program Office by NSROC. The program, now in its 16th year, provides internships and co-op opportunities for students studying engineering, computer science, electrical or mechanical technology as well as business disciplines. Students work side-by-side with experienced engineers and managers to perform significant, valuable tasks, leading to a better understanding of the work in a highly technical 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.

NSROC Testing and Evaluation group intern, Seth Austin, conducting a fin bend test.

In 2014 NSROC provided oppotunities for 14 internships involving all engineering disciplines and one business internship. Interns returning for the second time were rotated into new departments to gain experience in a different engineering discipline thereby providing a broader understanding of the sounding rockets program as a whole. SRPO also provided a NASA Pathways internship opportunity for a student majoring in Education.

K-12 Programs

WRATS are instructed on rocket construction by Tammy Sheppard/NASA intern.

Phil Eberspeaker/SRPO Office Chief giving launch preparation presentation.

WRATS rocket stability swing test.

Wallops Rocket Academy for Teachers and Students (WRATS)

For the fourth year the Sounding Rockets Program Office arranged the Wallops Rocket Academy for Teachers and Students (WRATS) workshop for High School educators. Twenty high school teachers 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 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.

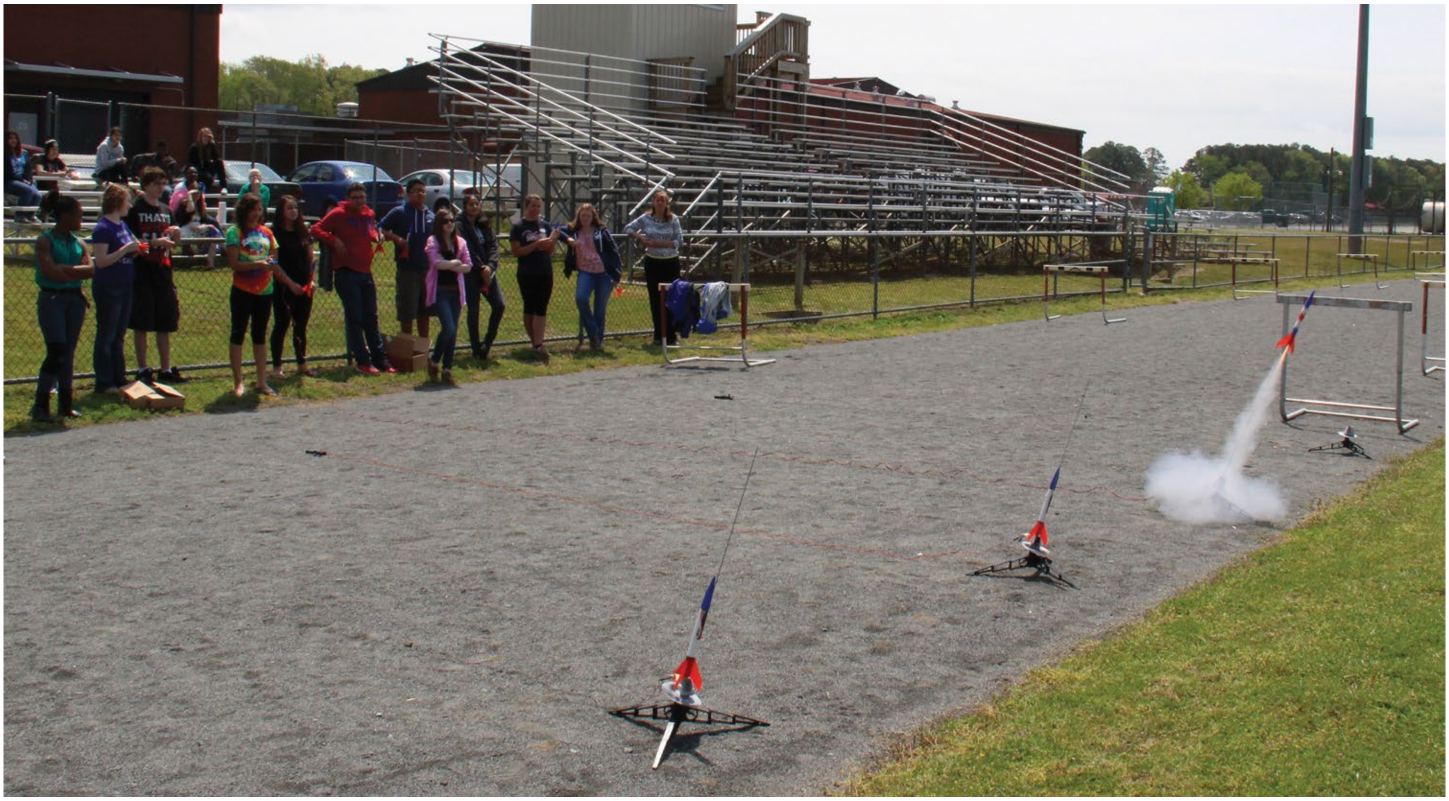
Recovery system (parachute) design, construction and testing familiarized the educators with the geometry of parachute shapes, size estimation and drag calculations. The shock cords were tested for elasticity to maximize the probablity of a good parachute deployment and rocket recovery. The rockets were tested for stability. 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 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 2014 approximately 20 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.

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.



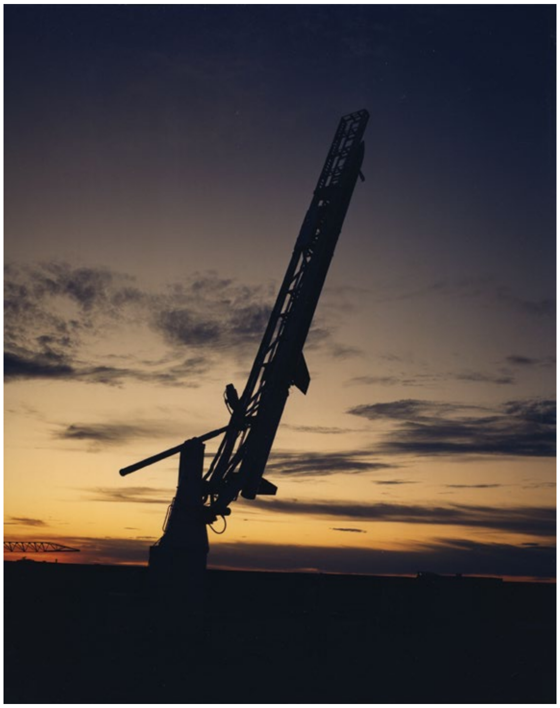
Arcadia High School students launching rockets in 2014.

on the horizon

Australia Campaign

After a nearly 20 years hiatus, the SRPO is once again poised to undertake Sounding Rocket Campaign in the real "Outback" of Australia. While it has been several years in the planning the International Agreement is in final stages of approval. John Hickman of the SRPO and Jack Vieira (on detail to the SRPO) recently traveled to HQ to stress the urgency of releasing the agreement and to work with Wilt Sanders, Astrophysics Division Discipline Scientist, on requirements for missions that will be selected for this opportunity. "There is

much interest in the science community to study Southern Hemisphere targets and we have been trying to get this kick started for several years." said Phil Eberspeaker, Chief of the SRPO. "It appears the timing is right now from both a budget and an operations perspective to make the 2016 Australian Campaign a reality." Historically, SRPO has taken missions to the Southern Hemisphere approximately every 10 years. However, shrinking budgets and other operational considerations have made it harder and harder to execute a campaign of this magnitude. The last big campaign was conducted in 1987 and 1988 when



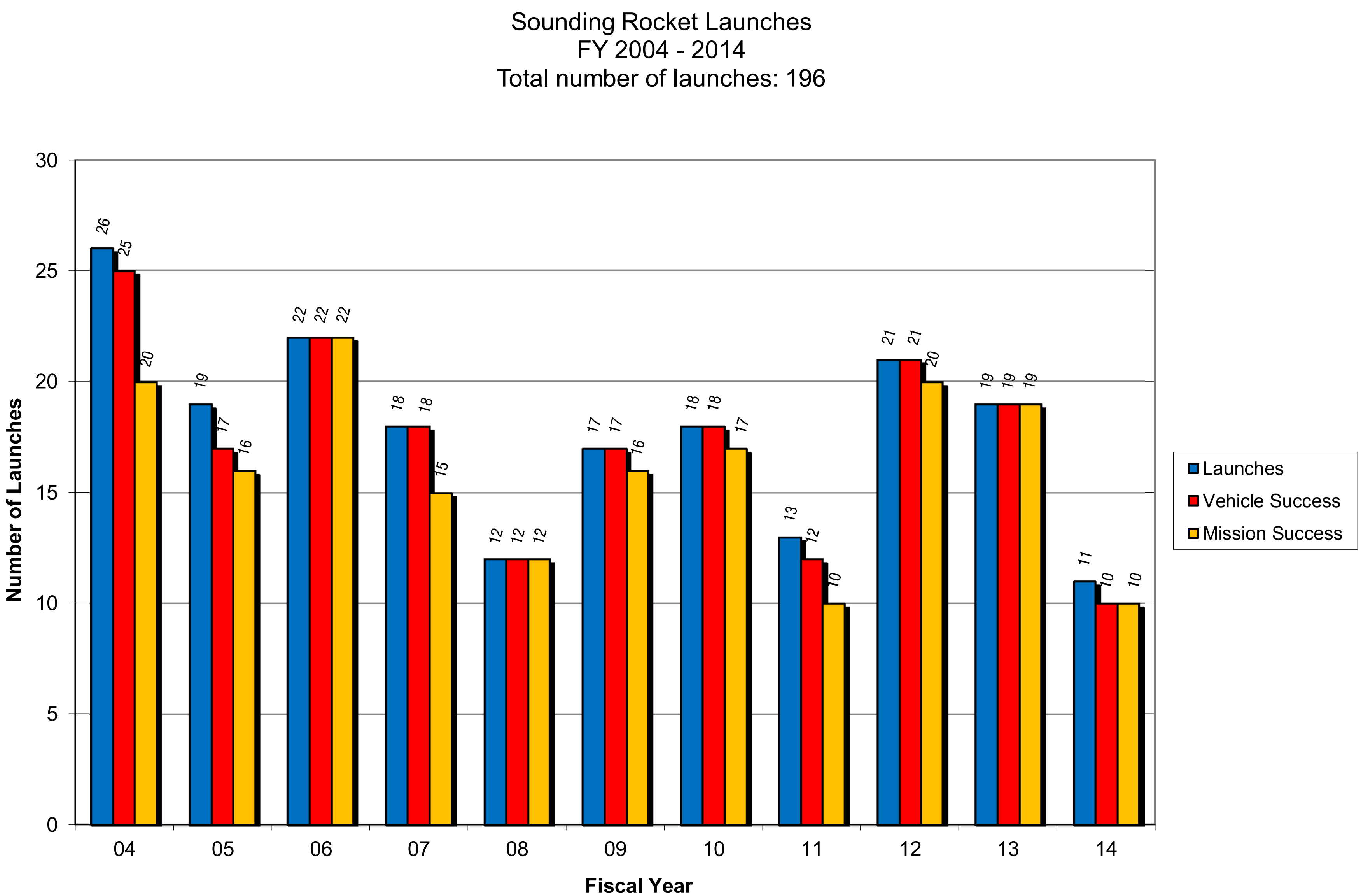
Sounding rocket range at Woomera, Australia in 1988.

Supernova 1987a was discovered while rocket teams were in Greenland on the COPE II Campaign. Within several months time, two separate Supernova 1987a mini-campaigns were mounted in late 1987 and early 1988. Another smaller expedition was mounted in 1996 which was our last trek into the Australian outback.

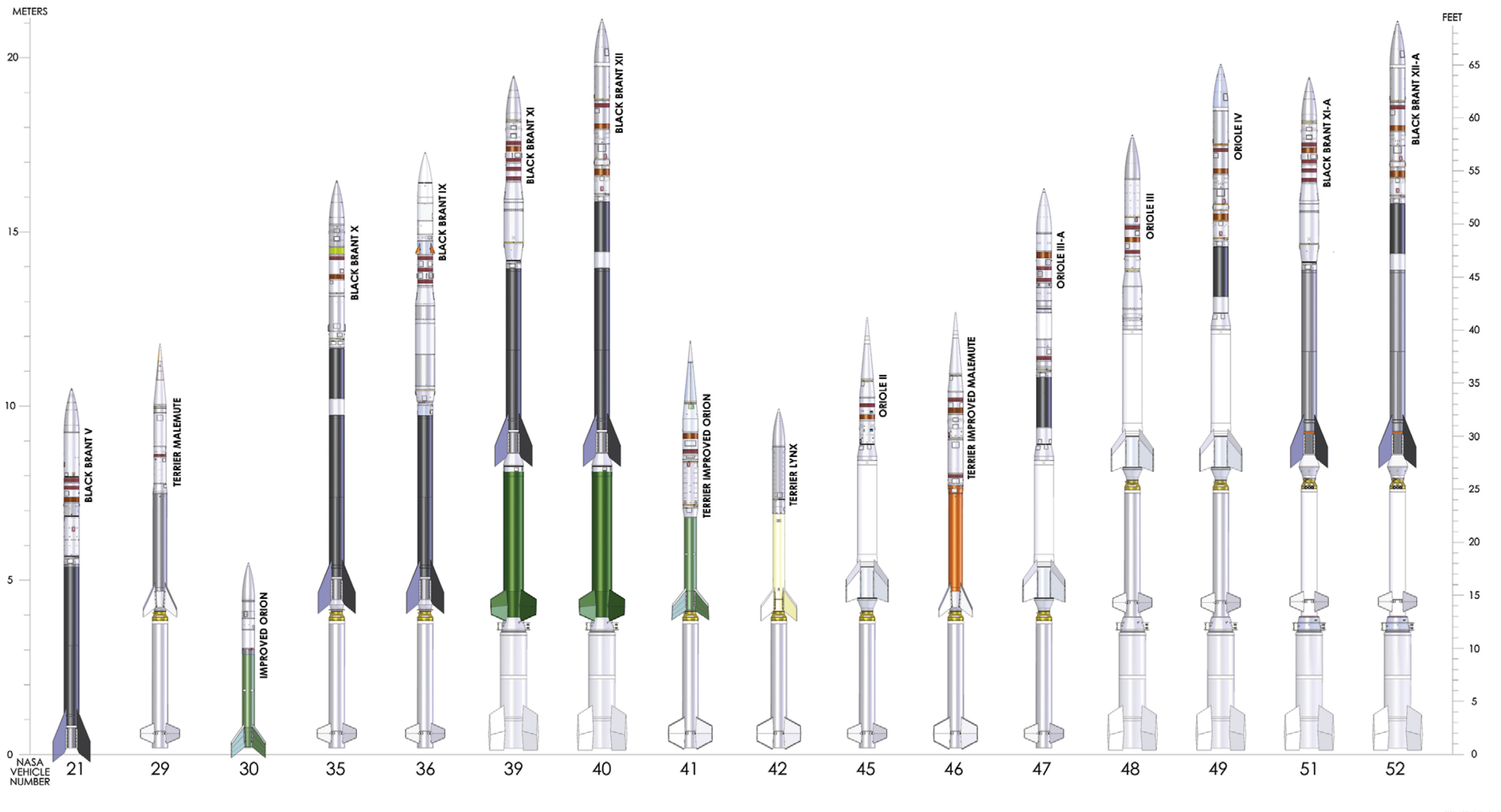
The Campaign, which will be conducted from Australia's Woomera Test Range, is currently scheduled for September/October 2016. The SRPO is currently baselining a 2 week launch window with 4-6 Sounding Rocket missions which may include field refurbishment and refly of selected missions. This will be a relatively large campaign with WFF providing power, telemetry, and command systems in addition to all of the other "rocket gear" necessary to launch sounding rockets in a mobile environment. Another unique aspect of this campaign will be the construction and first use of a NSROC designed and built Medium Mobile Launcher (MML). The MML is a homegrown design that grew from the need to have a larger launcher to accommodate the ever growing payloads length and mass. Mission selection and announcement will take place over the next few months and a Campaign "Kickoff" meeting is planned for March 2015.

charts

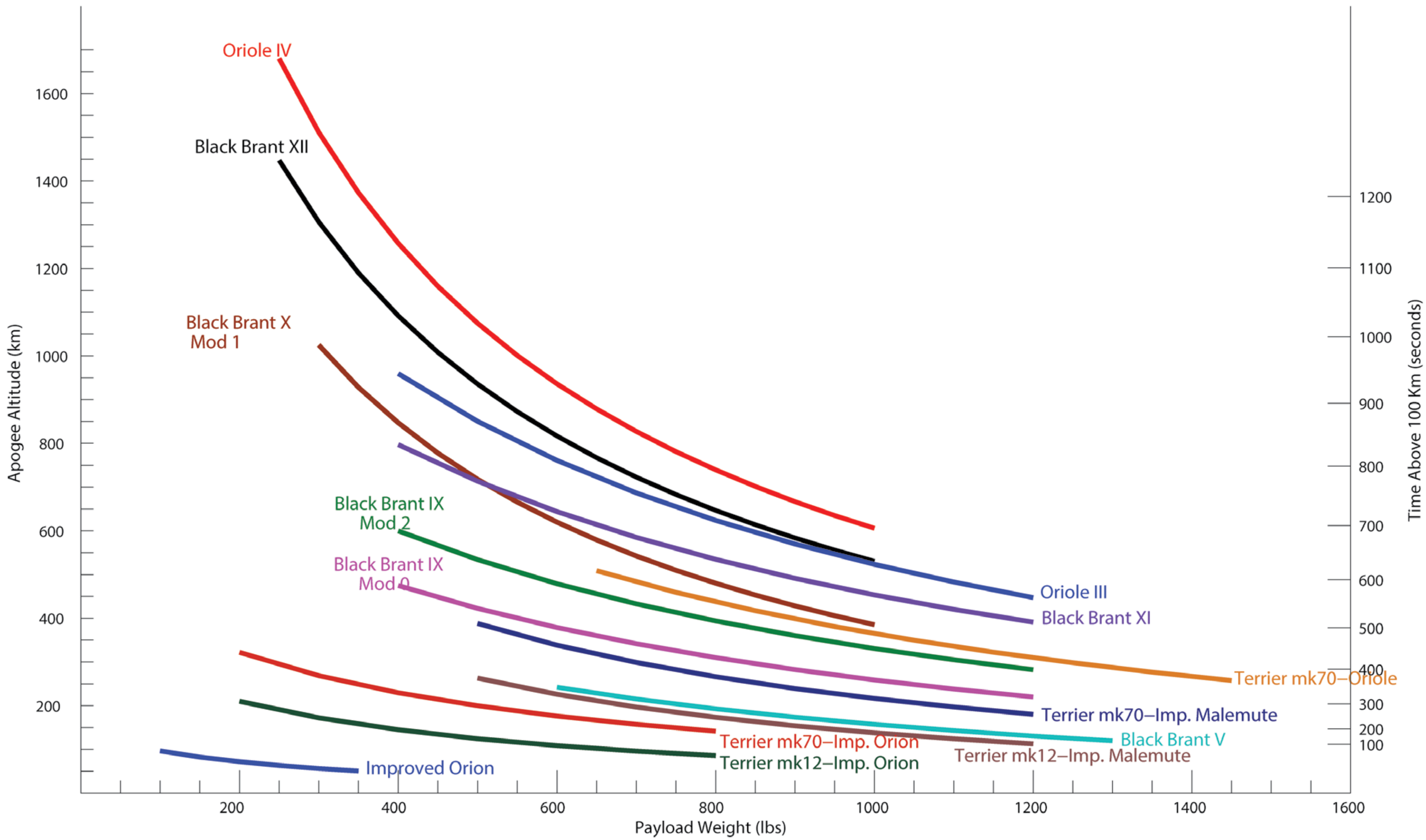
Mission Success History



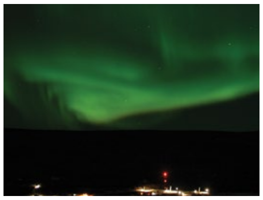
Sounding Rocket Vehicles 2014



Sounding Rocket Vehicle Performance



Sounding Rocket Launch Sites



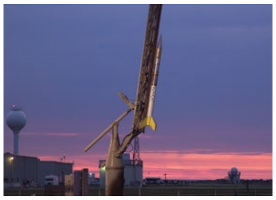
Poker Flat, Alaska

Esrange, Sweden

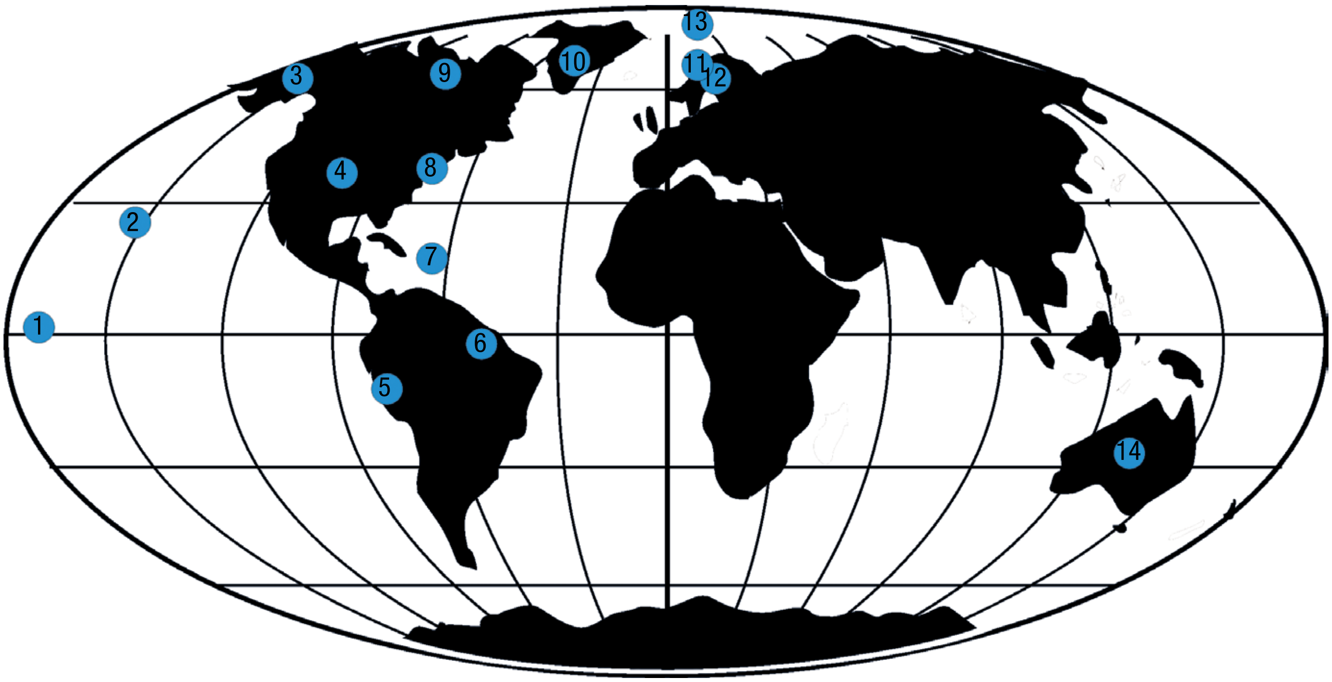
Kwajalein, Marshall Is.

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

* Inactive launch sites

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Chief

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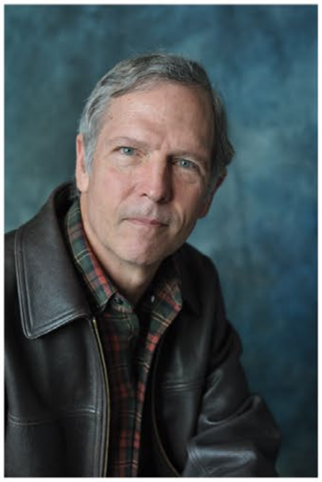
Secretary



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Science mission information submitted by Principal Investigators.

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