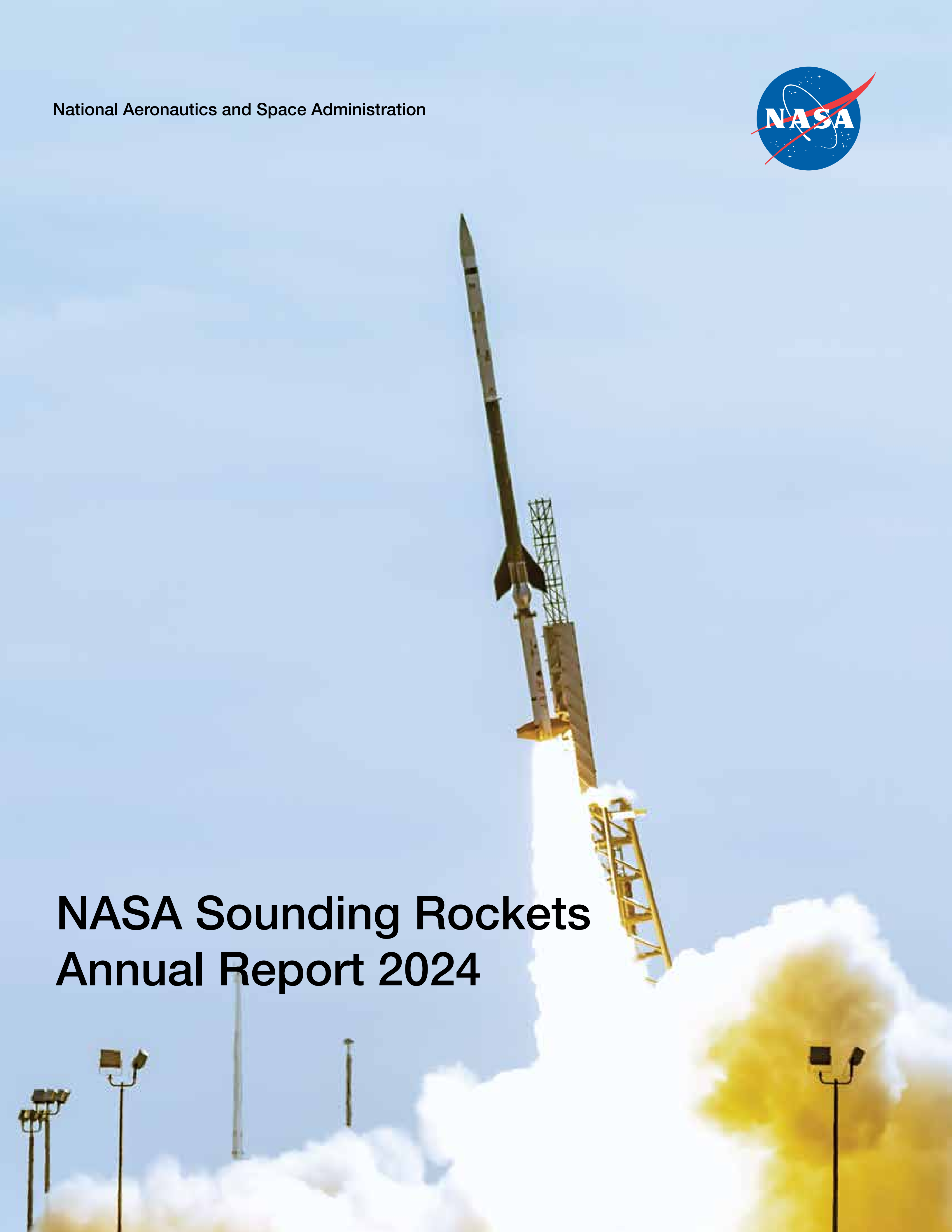
National Aeronautics and Space Administration



NASA Sounding Rockets Annual Report 2024

Message from the Chief

Giovanni Rosanova, Jr.
Chief, Sounding Rockets Program Office

Once again it is my pleasure to recap the Sounding Rockets Program achievements for the Fiscal Year and provide an overview of future activities.

In FY 2024 the program achieved a success rate of 94% which is well above the required 85%. Seventeen launches were completed with only one not meeting minimum success criteria. We supported four disciplines including: Geospace Science, Solar Physics, Astrophysics, and Student outreach.

The year was especially unique in that two solar eclipses were observable in the continental United States. On October 14, 2023, the White Sands Missile Range (WSMR), NM was very near the peak of an Annular eclipse path, and on Wallops Island, VA on April 8, 2024, a near 80% totality was observed. Six Terrier-Black Brant rockets were launched to study the ionosphere during the eclipses, three from each location. Dr. Barjatya from Embry-Riddle Aeronautical University was the Principal Investigator, and all vehicles and payloads performed nominally. To enable multi-point measurements the payloads utilized the recently developed and flight qualified ejectable sub-payloads.

A first for the Sounding Rockets Program was the Solar Flare campaign from Poker Flat Research Range (PFRR), AK in the spring of 2024. Two payloads, both previously flown for different research, Focusing Optics X-ray Solar Imager (FOXSI) 4, and High-resolution Coronal Imager Flare (Hi-C Flare) were staged and readied for a solar flare event. PFRR enabled a longer launch window with daily opportunities to launch. Scientists monitored solar activity, using GOES x-ray data, and were able to launch during an M-class flare. The goals of the campaign were to acquire multi-scale, multi-wavelength observations of a solar flare and open the possibility of validation of flare-optimized instruments.

Astrophysics missions included three successful flights. Dr. Fleming/University of Colorado, Dr. McCandliss/Johns Hopkins University, and Dr. Zemcov/Rochester Institute of Technology. All flights were from WSMR and met comprehensive success criteria.

Our longstanding commitment to education provided launch opportunities for college students and faculty through the highly successful RockSat program. The program is a collaborative effort between the Sounding Rockets Program Office and the Wallops Education Office. Funding is provided through the NASA Heliophysics program. RockOn is the first level of the student flight program and is offered as a workshop held at Wallops Flight Facility. As the first foray into space flight, students and faculty build, integrate and test an experiment from a kit. The workshop teaches fundamentals of sensors and data systems. RockSat-C is the follow-on program where students design their own experiments. The final step, RockSat-X, is the most advanced opportunity, and offers access to the space environment by deploying the payload skin. Standard payload support systems such as telemetry and attitude control are also included. Other education efforts included the Wallops Rocketry Academy for Teachers and Students (WRATS), where High School teachers attend a weeklong workshop to learn about rocketry through hands-on activities. The workshop includes building and flying model rockets, conducting software flight simulations, and designing parachutes. Additionally, the teachers attended the RockOn launch on Wallops Island.

Interns were again hosted both by SRPO and the NASA Sounding Rocket Operations Contract (NSROC). Facility tours are regularly arranged for both educational and civic groups, and hundreds of people get a firsthand look at the manufacturing and testing of sounding rocket payloads.

The flight manifest for FY 2025, currently at 18 launches, includes several remote campaigns. Launches will take place from Andoya Space in Norway, PFRR in Alaska, and the Kwajalein Atoll in Marshall Islands. Additionally, we continue operations from Wallops Island, VA and WSMR, NM. The year will be heavily focused Geospace Science with 14 missions. Additionally, three Solar Physics missions are on schedule, as well as, one Technology Demonstration mission, SubTEC-10. Two Student mission are also manifested, leading to a total of 20 missions for FY 2025.

For the longer term, a Geospace Science campaign from Punta Lobos, Peru is in the planning stages. SRPO personnel have conducted several site visits and are in discussions with the Peruvian space agency, CONIDA, Peruvian Air Force, Institute Geophysics Peru (IGP), and the Port of Callao. Infrastructure upgrades to the launch site will be necessary to accommodate the campaign. Punta Lobos' location near the magnetic equator, and the availability of the nearby Jicamarca Incoherent Scatter Radar, enables scientists to explore space physics phenomena found only at these latitudes. This is the hallmark of the Sounding Rockets Program – we go where the science is!

Looking back at the past year, I am pleased to report that the program continues to exceed all expectations. The technical challenges in our program, with each payload custom built to meet the science requirements, leads to innovative approaches and solutions. Our personnel; managers, engineers, technicians, machinists, and program support, meet the challenges exceptionally well while maintaining tight mission schedules. Every experimenter is treated with the same high level of professionalism, be it college students flying their first experiment or a returning Principal Investigator with years of experience. All are regarded with respect and no effort is spared to accomplish mission success. Sounding rocketeers can be relied on to get the job done in the field, in the office, in the shop, in the lab, and anywhere rockets are flown!

We Fly for Science!

Giovanni Rosanova, Jr.

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Cover photo: APEP launch from Wallops Island, VA on April 8, 2024
NASA Photo/Berit Bland

Sounding Rockets Overview

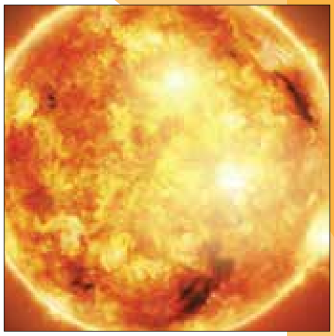
The Sounding Rockets Program supports the NASA Science Mission Directorate's strategic vision and goals for Earth Science, Heliophysics and Astrophysics. The 18+ suborbital missions flown annually by the program provide researchers with unparalleled opportunities to build, test, and fly new instrument and sensor design concepts while simultaneously conducting world-class scientific research. Coupled with a hands-on approach to instrument design, integration and flight, the short mission life-cycle helps ensure that the next generation of space scientists receive the training and experience necessary to move on to NASA's larger, more complex space science missions. The cost structure and risk posture under which the program is managed stimulates innovation and technology maturation and enables rapid response to scientific events.

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

Telescopes and spectrometers to study Solar and Astrophysics are flown on sounding rockets to collect unique science data and to test prototype instruments for future satellite missions. The program's rapid response capability enabled scientists to study the Supernova 1987A before it faded from view. Currently, new detectors, expected to revolutionize X-ray astronomy, are under development and have been successfully tested on sounding rocket flights. An important aspect of most satellite missions is calibration of the space based sensors.

Science with Sounding Rockets

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



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

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

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

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

In the high energy and the ultraviolet and visible parts of the spectrum, Astrophysics uses sounding rockets to test new instruments on unique scientific missions. Subsystems, developed by NASA, provide unprecedented pointing accuracy for stellar targeting, yielding high resolution spectra and potentially leading to new ground breaking discoveries about our own galaxy. Sounding rockets offer calibration and validation flights for many space missions, particularly solar observatories such as the Thermosphere-Ionosphere-Mesosphere-Energetics-Dynamics (TIMED) satellite, the Solar Heliospheric Observer and the future Solar Dynamics Observatory (SDO).

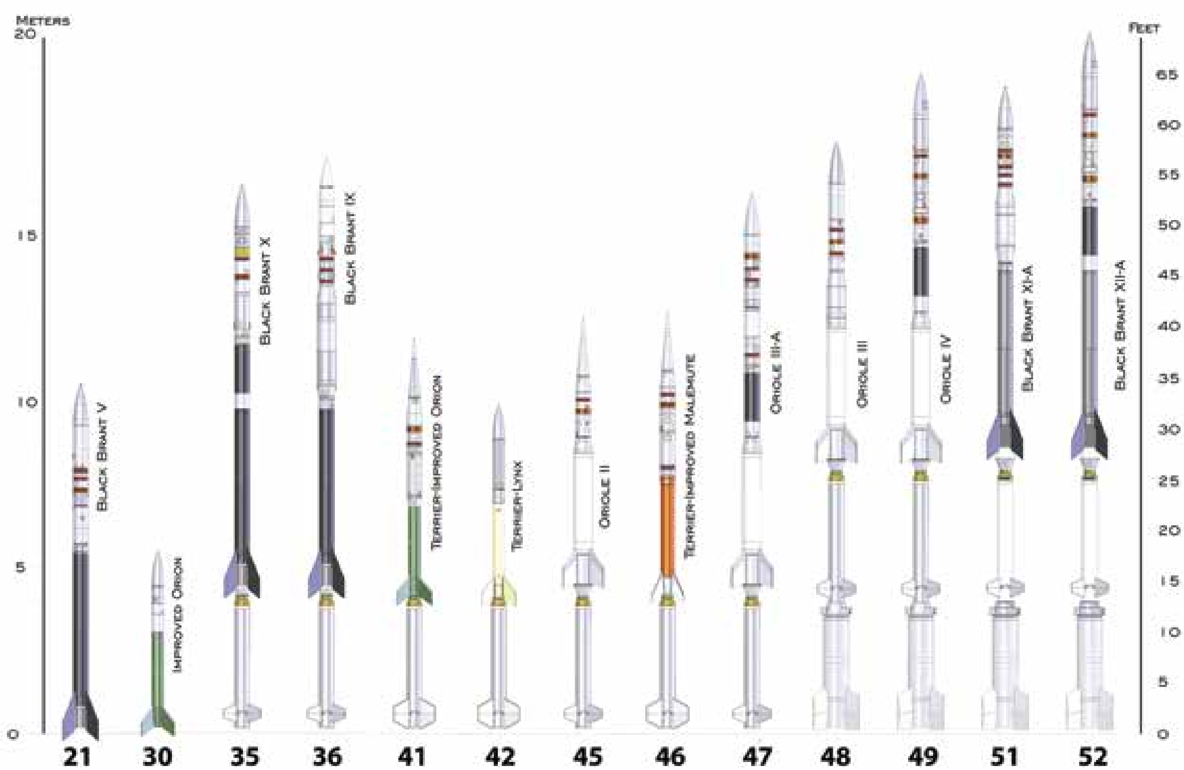
Additionally, sounding rockets are well suited for testing new technologies for future space missions. For example, parachute technologies for the Mars 2020 mission were tested on sounding rockets.

End-to-End Mission Support

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

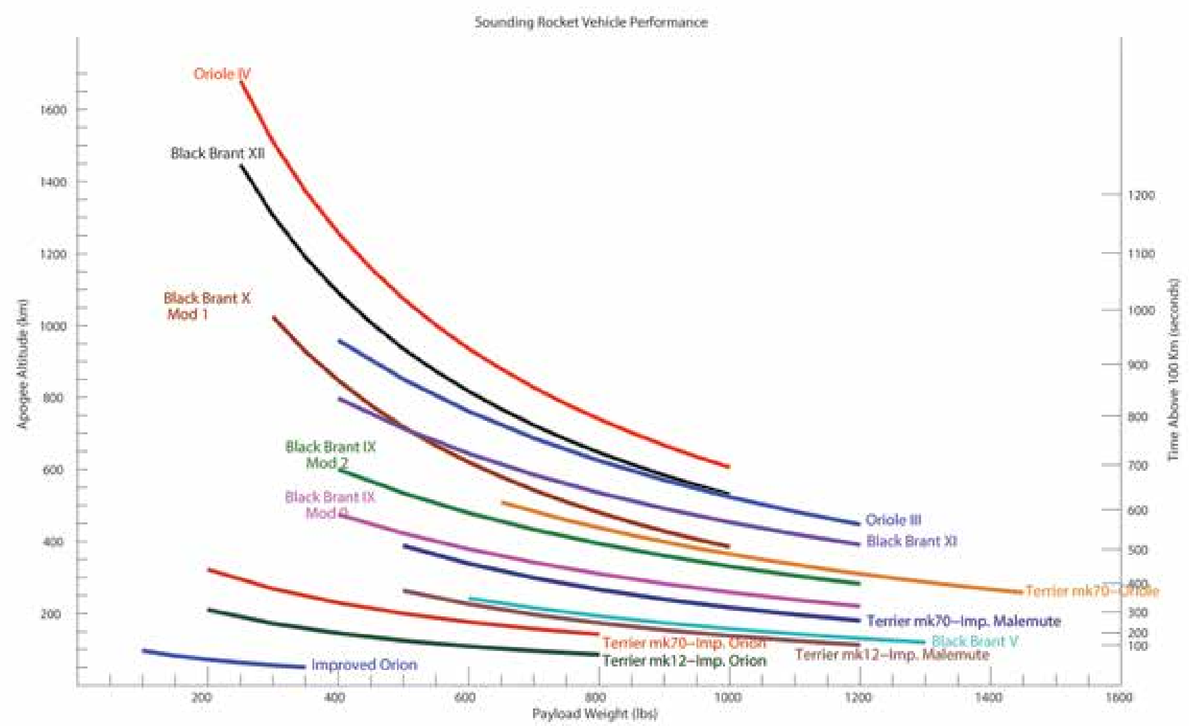
Extensive experience, over 2,500 missions flown, has lead to streamlined processes and efficient design, manufacturing and assembly techniques. Management and technical support is provided for all facets of a mission and includes engineering design, manufacturing, integration, and testing and evaluation.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

Launch Vehicles



Sounding Rocket Vehicles
By NSROC Mechanical Section

The Sounding Rocket Program offers multiple proven launch vehicles to meet the needs of most researchers. New vehicles are brought online periodically to meet customer requirements and enhance capability. Currently, 13 vehicles are provided "off-the-shelf" and range in performance from a single stage Orion to a four stage Black Brant XII-A and Oriole IV.

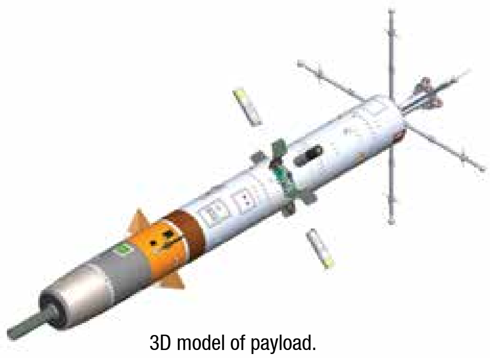


Sounding Rocket Vehicle Performance
By NSROC Flight Performance

Payload Design

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

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



3D model of payload.
Credit: Graham Taylor/NSROC
Mechanical Engineering

Manufacturing

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



Machine shop in Building F–10 at Wallops Flight Facility.
NASA Photo/Berit Bland

Assembly

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

Payload assemblies during integration.
NASA Photo/Berit Bland

Sub-systems

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

The boost guidance system controls the path of the rocket during the initial 20 seconds of flight where air density is adequate to permit course correction by means of movable fins. The vehicle pitch and yaw angles are detected by a gyro platform which produces corresponding output signals; the signals are processed in an autopilot and, after roll resolution, are used as servo command signals.

Magnetic Attitude Control Systems testing.
NASA Photo/Berit Bland

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

Electrically operated vacuum doors are available for most telescope payloads.

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

Open shutter door with instrument visible during testing at Wallops.
NASA Photo/Berit Bland

In instances where missions require measurements from multiple widely spaced platforms a special payload is created to permit separation into several sub-payloads. Each sub-payload has it's own Telemetry link to transmit all science and housekeeping data for that section.

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

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

Payload recovery at White Sands Missile Range, NM.
WSMR Photo

Testing and Evaluation

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

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

Vibration Testing

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

Payload on vibration table.
NASA Photo/Berit Bland

Bend Testing

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

Bend testing of payload.
NASA Photo/Berit Bland

Spin Testing - Operational and Deployment

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

Payload with deployed booms and instruments.
NASA Photo/Berit Bland

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

Mass Properties Measurements

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

Payload place on mass properties measurement table.
NASA Photo/Berit Bland

Static And Dynamic Balancing

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

Payload being prepared for balancing.
NASA Photo/Berit Bland

Thermal Testing

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

Vacuum Testing

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

Payload ready to enter the thermal–vacuum chamber.
NASA Photo/Berit Bland

Launch operations support

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

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

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

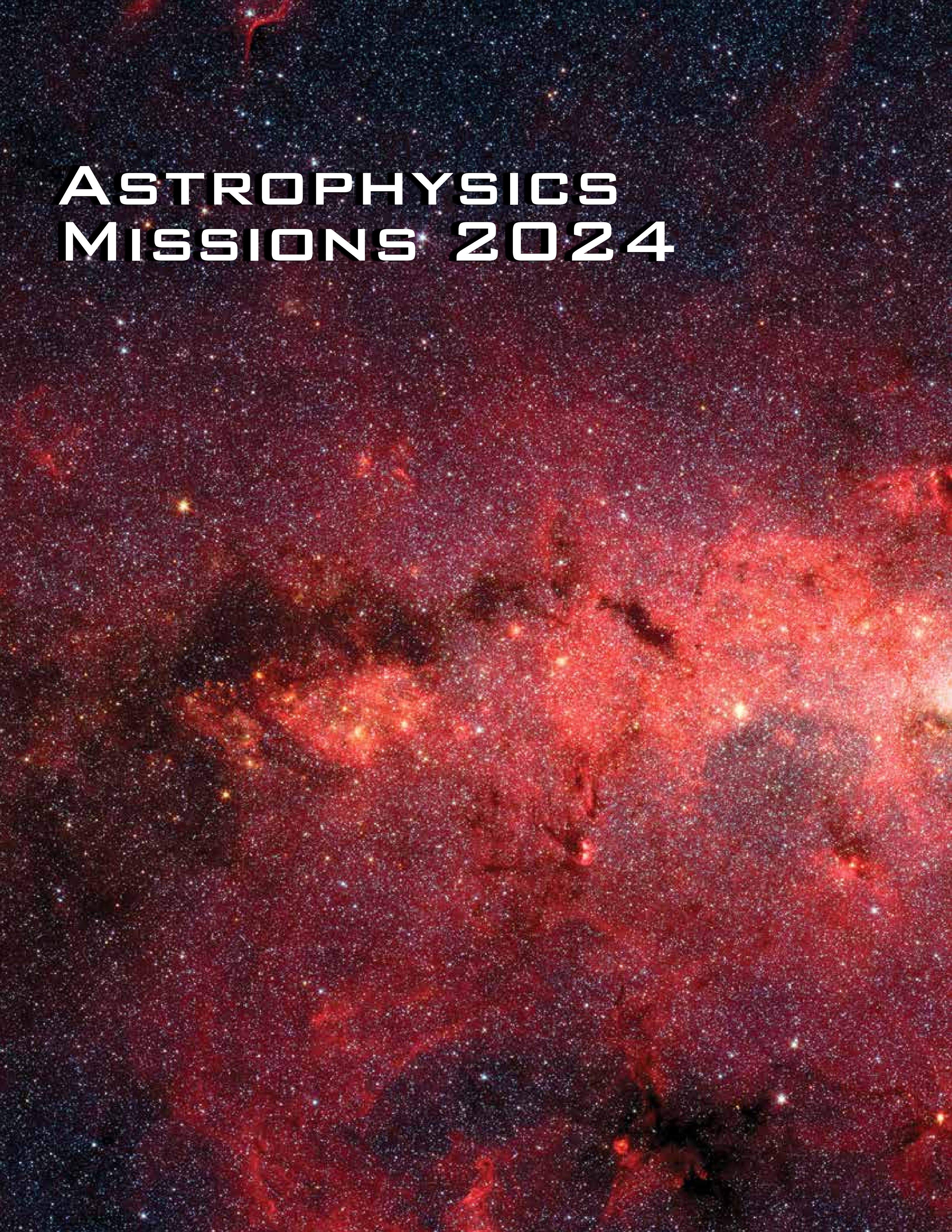
Past and present world wide launch sites used by the Sounding Rockets Program to conduct scientific research:

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. Andøya, Norway
12. Esrange, Sweden
13. Svalbard, Norway
14. Australia (Equatorial Launch Australia (ELA) & Woomera)

* Inactive launch sites

52.009 AE Beam - Plasma Interactions Experiment (Beam-PIE)
NASA Photo/Berit Bland

Astrophysics Missions 2024



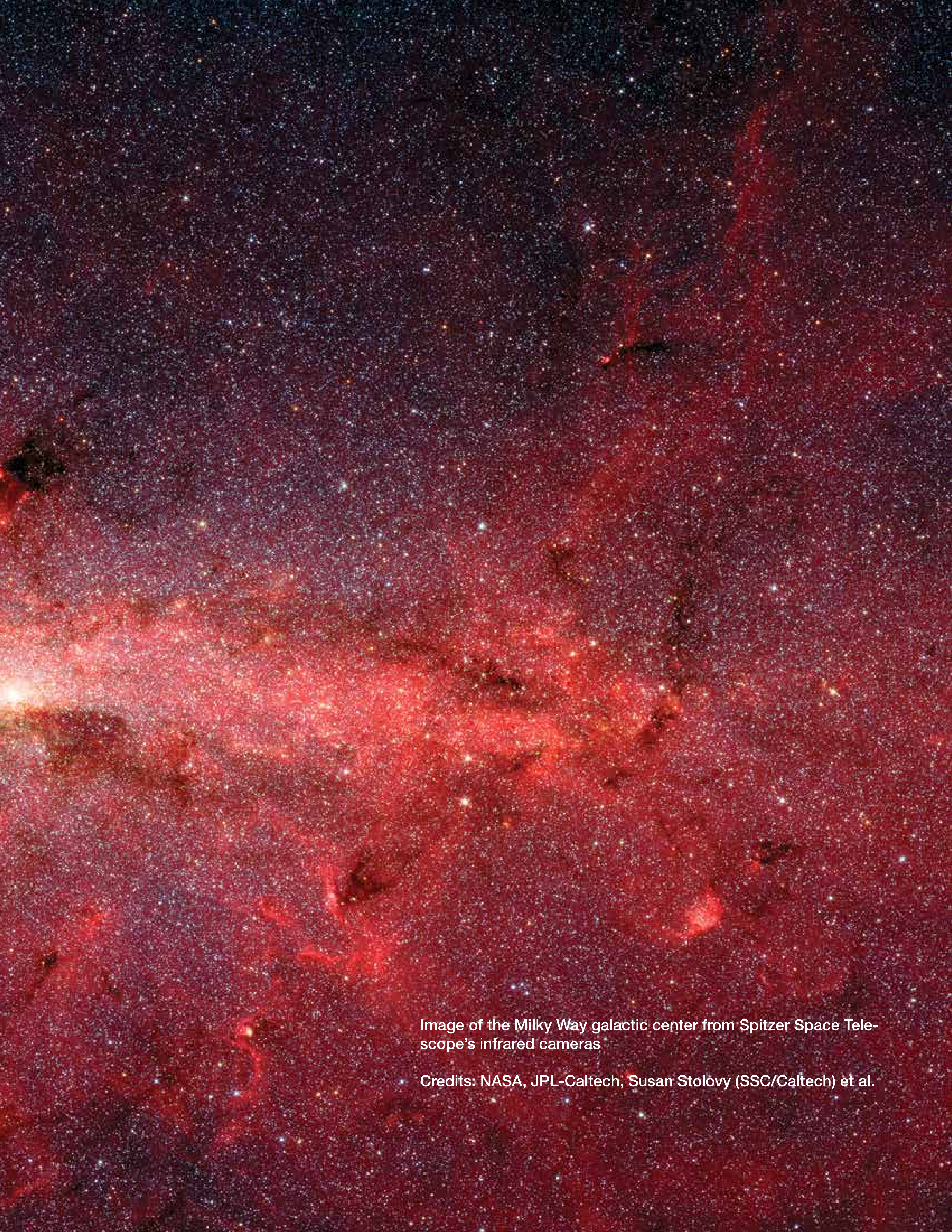


Image of the Milky Way galactic center from Spitzer Space Telescope's infrared cameras

Credits: NASA, JPL-Caltech, Susan Stolovy (SSC/Caltech) et al.

INtegral Field far-Ultraviolet Spectroscopic Experiment (INFUSE)

INFUSE, an integral field spectrograph (IFS) operating from 1000 - 2000 Å, was successfully launched on October 30, 2023 at 05:45:00 UTC from White Sands Missile Range, NM.

INFUSE payload team at WSMR.
Credit: Ryan Harty/WSMR

The fundamental objective of INFUSE is to understand how material from supernovae (SNe) reshapes the interstellar medium (ISM) by observing shock fronts in supernova remnants (SNR). Emission lines in the far-ultraviolet (FUV) trace the point at which the ISM and the supernova begin interacting with each other.

INFUSE is the first far ultraviolet integral field spectrometer. It features an f /16, 0.49 m Cassegrain telescope and a 26-element image slicer feeding 26 holographic gratings, with spectra imaged by the largest cross-strip microchannel plate detector flown in space.

This, the first launch of INFUSE demonstrated spectral multiplexing, successfully detecting ionized gas emission in the XA region of the Cygnus loop.

The second launch of INFUSE is projected for fall 2025 to observe the star-forming galaxy NGC 2366 alongside companion NGC 2363. Housed within NGC 2366 is the Mrk 71 region, a prototype for studying highly ionized starburst regions, making NGC 2366 a local analog to Green Pea type galaxies. Several enhancements are planned for INFUSE before this second science flight, including adding an improved baffle to reduce contamination by second order light, improving grating alignment to reduce overlap between different spectrograms, and iriditing several surfaces to reduce scattered geocoronal Ly-α. An additional grating coated with xenon diflouride-enhanced lithium fluoride will also be added to flight qualify a new coating that may support ultraviolet capability on the Habitable Worlds Observatory. The second flight will also feature a ride along mission, the Spectroscopic Ultraviolet Multi-Object Observatory.

Principal Investigator: *Dr. Fleming/University of Colorado* • ***Mission Number(s):*** *36.375 UG*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *October 30, 2023 (UT)*

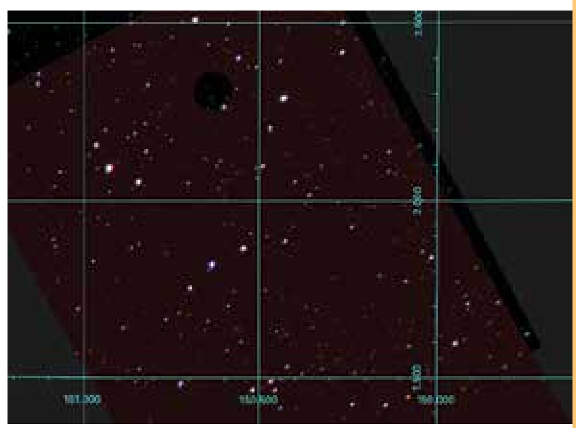
Cosmic Infrared Background Experiment (CIBER) 2

The Cosmic Infrared Background ExpeRiment 2 (CIBER-2) is a rocket-borne instrument designed to conduct comprehensive multi-band infrared (IR) measurements of spatial fluctuations in the extra-galactic background light (EBL) on a wide range of angular scales. CIBER-2 was successfully flown from White Sands Missile Range, NM for the second time on May 6, 2024. A previous successful flight occurred on June 7th of 2021.

CIBER–2 team at WSMR.
Credit: Ryan Harty/WSMR

The EBL is the summed light produced by all emission over the Universe's history, and it encodes a great deal of information about the history of stars and the assembly of cosmic structure over time. At near-IR wavelengths, the EBL teaches us about the first objects that formed during the earliest phases of galaxy assembly all the way up to the most faint and diffuse objects in the nearby Universe. Broad-band intensity mapping is a technique in which spatial fluctuations are used to unambiguously disentangle the faint EBL from brighter foreground emission from our solar system and Milky Way galaxy. Multiple intensity mapping studies, including those by CIBER-2's predecessor rocket experiment, have found that fluctuations in the EBL significantly exceed predictions from galaxy models. What could be causing the discrepancy is unclear, and better measurements are required.

CIBER-2 is designed to isolate the sources of near-IR fluctuations, and test technologies to be used in the Spectro-Photometer for the History of the Universe, Epoch of Reionization, and ices Explorer (SPHEREx) Medium Explorer (MIDEX) mission. CIBER-2 comprises a 28.5-cm telescope cooled to 80 K that images to three HAWAII-2RG detectors with dual-band filters to simultaneously obtain degree-scale data over the range 0.5-2.0 μm in six bands.



CIBER–2 three–band image of a ~1 square degree image of the sky from a preliminary analysis. The total flight has approximately 20x more data than shown here, and will be used to characterize the spec–trum of fluctuations in the near–infrared background light
Credit: Dr. Zemcov/Rochester Institute of Technology

CIBER-2 is led by the Rochester Institute of Technology in collaboration with the California Institute of Technology, the University of California Irvine, Kwansei Gakuin Univiersity and the Kyushu Institute of Technology in Japan, and the Korea Astronomy and Space Science Institute.

Principal Investigator: *Dr. Zemcov/Rochester Institute of Technology* • ***Mission Number(s):*** *36.396 UG*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *May 6, 2024*

Off Axis Far-ultraviolet Off Rowland-circle Telescope for Imaging and Spectroscopy (OAxFORTIS)

The Johns Hopkins University (JHU)/NASA sounding rocket 36.384 UG, carrying the Off-Axis FORTIS (OAxFORTIS) experiment, was successfully launched from White Sands Missile Range, NM on August 26, 2024 at 04:00:00 UTC on a mission to probe the mysterious population of hot UV emitting stars in the Globular Cluster (GC) M10.

OAxFORTIS payload team at WSMR.
WSMR Photo

FORTIS is an innovative multi-object spectro/telescope (MOS), operating in the far-UV, featuring several new technologies that were developed under the support of the NASA's Astrophysics Research and Analysis (APRA) and Strategic Astrophysics Technology (SAT) programs with Co-Investigators from Goddard Space Flight Center (GSFC). (OAxFORTIS) is a new version of the largely matured FORTIS instrument evolved into an Off-Axis telescope configuration. The new design eliminates a problem with scattered geo-coronal radiation that prevented FORTIS from making detector background limited observations on previous missions. The new design incorporated a new set of 3-d printed baffles to restrict direct illumination of the detector by the geo-corona.

The multi-object spectroscopic capability is provided by a Next Generation Micro-Shutter Array (NGMSA) fabricated by the team at GSFC that developed the 1st Generation MSAs for the Near Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope (JWST) programs. NGMSAs feature a simple pure electrostatic actuated shutter, in contrast to the hybrid magnetic/electrostatic actuation technique used on NIRSpec that required a complicated magnet scanning mechanism. MSAs are programmable slit masks that allow simultaneous acquisition of several widely spaced objects within the field-of-view of the spectrograph.

In this first flight of OAxFORTIS, far-UV spectra were acquired of the Hot Horizontal Branch (HHB) stars in M10. The HHB of GC is populated by far-UV luminous stars at the end stage of evolution. They lie along a roughly horizontal line in the Hertzsprung-Russell diagram. By the time stars reach the zero-age-horizontal-branch (ZAHB), nucleosynthetic energy generation has for the most part ceased. The temperature, mass, radius, and chemical abundance of the atmospheres of stars on the ZAHB offer clues as to their progenitor mass and initial chemical abundance.

Principal Investigator: *Dr. McCandliss/Johns Hopkins University* • ***Mission Number(s):*** *36.384 UG*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *August 26, 2024*

The goal is to identify the progenitor populations of the ZAHB in three GCs starting with M10 (this flight). They all have similar ages and [Fe/H] abundances - as determined from near-UV and visible photometry - but exhibiting significant differences in the distribution of ZAHB temperatures. The objective is to determine the spread of temperature, mass, radius, and abundances of stars on the ZAHB sequence in a region extending from the cluster core out to ~ half the tidal radius and provide critical constraints to evolutionary models of stars in globular clusters. The multiple spectra of hot stars in M10 were acquired autonomously using our Zero Order Monitor Interface (ZOMI) to the NGMSA. This flight produced the first ever autonomous MOS acquisition in the far-UV.

Other technologies flown on OAxFORTIS include: an aspheric diffraction grating; a large three element (borosilicate) microchannel plate detector (fabricated Sensor Sciences); and LiF/Al optical coatings deposited by the mirror coating team at GSFC. All these system components are prototypes of technologies that have been proposed for the MOS instrument on NASA's next flagship mission the Habitable Worlds Observatory, which is currently undergoing formulation. Analysis of the data will be incorporated into the PhD thesis of JHU Graduate Student Mackenzie Carlson.

OAxFORTIS recovery operations at WSMR.
WSMR Photo

Geospace Missions 2024

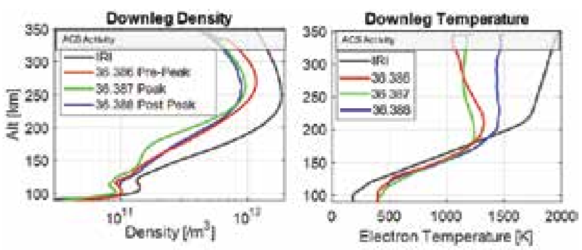
Aurora over Andoya Space, Norway with the Aurora Current and Electrodynamics Structure (ACES) 2 rockets on the pad November 2022.
Credit: NASA Photo/Lee Wingfield

Atmospheric Perturbations around Eclipse Path (APEP) - Annular Eclipse

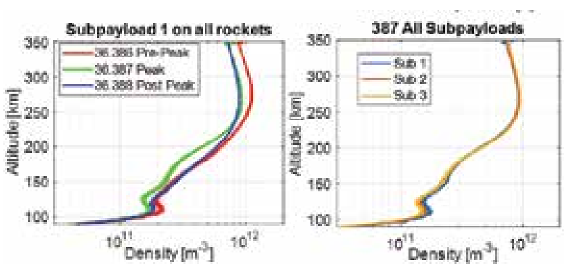
Solar eclipses present a unique opportunity to study the effects of a supersonic cooling shadow and its modulation of the structure and energetics of the ionosphere-thermosphere system. APEP was an eclipse rocket campaign that launched three rockets from White Sands Missile Range (WSMR), NM during the October 14, 2023 annular eclipse. The recovered rockets were relaunched from Wallops Island, VA during the April 8, 2024 total solar eclipse. This campaign was the first simultaneous multipoint spatio-temporal in-situ observations of electrodynamics and neutral dynamics associated with solar eclipses.

APEP Science Team at WSMR.
Credit: WSMR/Judy Hawkins

For the Annular Eclipse the first rocket, 36.392, was launched at 16:00 UTC, the second, 36.393 at 16:35 UTC, and the third, 36.388, at 17:10 UTC. This enabled data to be gathered before, during, and after the local peak eclipse.The launches were be supported by ground-based observations from Air Force Research Laboratory (AFRL) Digisondes and meteor wind radar.



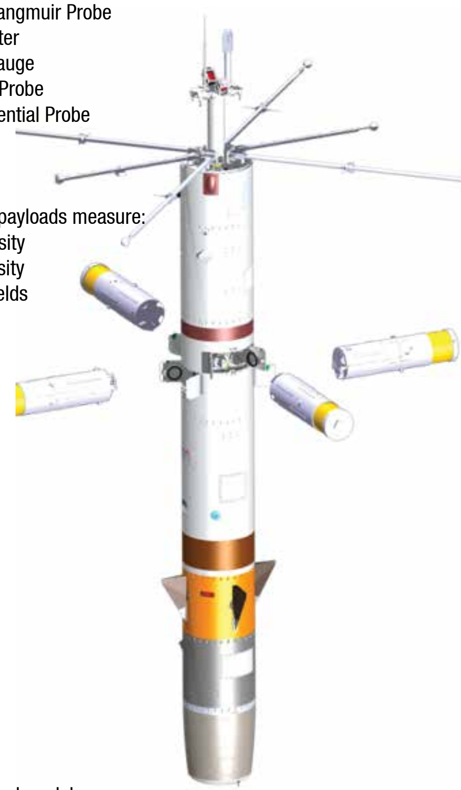
Sweeping Langmuir probe derived absolute plasma densities and electron temperature.



Plasma density profiles from ejected Subpayloads.

Instrumented booms include:
Sweeping Langmuir Probe
Magnetometer
Ionization Gauge
Positive Ion Probe
Floating Potential Probe

Ejected Subpayloads measure:
Plasma Density
Neutral Density
Magnetic Fields



Payload model.
Credit: Graham Taylor/NSROC Mechanical Engineering

Four subpayloads were ejected from each rocket. Three provided by Embry-Riddle Aeronautical University (ERAU) and one from Dartmouth College. Each ERAU subpayload carried a fixed bias Langmuir probe. All three ERAU ejected payloads from the same rocket saw relatively similar density, where as subpayloads ejected from different rockets matched the profiles as seen by the Sweeping Langmuir Probe (SLP) on the main payload.

Principal Investigator: *Dr. Barjatya/Embry-Riddle Aeronautical University*
Mission Number(s): *36.386, 387, 388 UE*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *October 14, 2023*

Atmospheric Perturbations around Eclipse Path (APEP) 2 - Total Eclipse

The second APEP mission, also including three payloads, was launched from Wallops Island, VA during the Total Eclipse on April 8, 2024. The payloads carried the same instrumentation as the WSMR mission, and were launched in a similar sequence, before, during, and after the local peak eclipse.

All three payloads were successfully launched. All ejectables deployed and all booms deployed and all instruments worked.

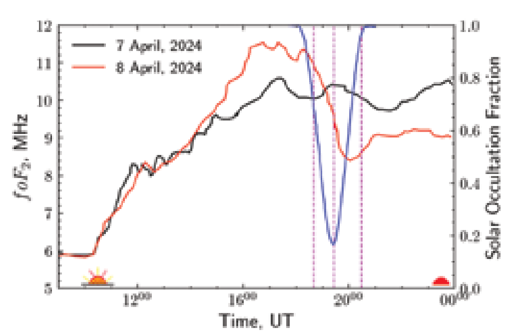
The launch times were 18:40, 19:25, 20:28 UTC. The second and third launches were delayed from the originally planned launch times. This eclipse was different and unexpected. At first glance, the onset was slower and the recovery phase was much slower than during the Annular Eclipse in October 2023, as well as, during the 2017 eclipse. The use of the Vertical Incidence Pulsed Inospheric Radar (VIPIR) for displaying real-time data enabled visualization of the ionospheric response. The first launch was approximately 10 minutes after the eclipse start. See the eclipse occultation fraction in the data plot. The F region ionosphere had barely started to respond and thus this may be considered an almost pre-eclipse background measurement. The second launch was at peak local eclipse but not the deepest density depletion in the F region ionosphere, which continued to decline in density for an additional 30 minutes. Based on the live data plots from VIPIR, the third launch was delayed to make sure the F-region was in recovery phase, while the eclipse had almost entirely passed.

Data is currently being analyzed in preparation for publication.

36.394 APEP–2 launching from Wallops Island, VA.
Credit: NASA Photo/Chris Pirner

APEP payload team with the three payloads at WSMR.
Credit: NASA /Ted Gacek

2023 and 2024 Solar Eclipse Paths
Credit: NASA/Scientific Visualization Studio/Michala Garrison; Eclipse Calculations By Ernie Wright, NASA Goddard Space Flight Cente



VIPIR data on the day of eclipse (red) and the prior day (black).
Also overlaid is the eclipse occultation fraction (blue).
Credit: Dr. Chakraborty /ERAU and Dr. Bullett/Front Range Radio

Principal Investigator: *Dr. Barjatya/Embry-Riddle Aeronautical University*
Mission Number(s): *36.392, 393, 394 UE*
Launch site: *Wallops Island, VA* • ***Launch date:*** *April 8, 2024*

DISSIPATION

The DISSIPATION experiment was launched on November 8, 2023 and provided, for the first time, comprehensive and concurrent in situ measurements of the response of the thermosphere to Joule heating in the auroral transition region.

45.007 GE Benna launches from Poker Flat Research Range, AK.
Credit: NASA photo/Danielle Johnson

Joule heating results from friction between the ion and neutral gases when the gases are not flowing at the same speed and direction. Energy dissipation within the transition region via particle precipitation and Joule heating can cause profound horizontal and vertical redistributions of thermospheric mass density, composition, temperature, and winds.

Most of the knowledge of this dissipative process is based on remote and/or limited observations of neutral gas and plasma parameters. DISSIPATION was designed to provide a more direct observations.

DISSIPATION, is aimed at gathering data on how charged solar wind particles dissipate their energy in the high-latitude ionosphere-thermosphere. That region is about 62 to 186 miles above the surface and at latitudes above 65 degrees. DISSIPATION will enable NASA to better understand how the energy imparted by solar winds into the atmosphere is dispersed. This process is part of what creates the auroras and has large implications in space weather predictions.

DISSIPATION payload team at Poker.
Credit: NASA photo/Danielle Johnson

Understanding the energy dissipation mechanism will help explain processes that create high-latitude wind in Earth's upper atmosphere near the edge of space. That wind has a significant role in space weather because it influences the regulation and redistribution of mass, momentum, and energy in the ionosphere-thermosphere around the planet. Improved space weather forecasting has become increasingly important to operators of satellites, communication and navigation systems, and power grids, all of which can be damaged or disrupted by space weather.

The Modular Spectrometer for Atmosphere and Ionosphere Characterization (MoSAIC), a prototype instrument for NASA Goddard Space Flight Center's Geospace Dynamics Constellation, flew on DISSIPATION. The Geospace Dynamics Constellationa is a set of six satellites that will orbit Earth in the early 2030s to conduct similar studies of the upper atmosphere.

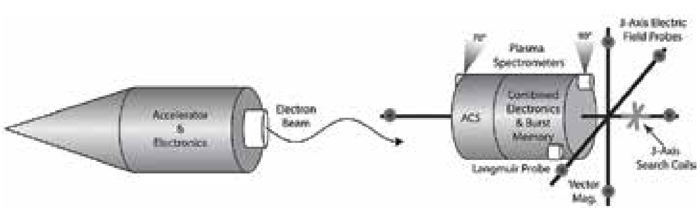
Principal Investigator: *Dr. Benna/NASA GSFC* • ***Mission Number(s):*** *45.007 GE*
Launch site: *Poker Flat Research Range, AK* • ***Launch date:*** *November 8, 2023*

Beam - Plasma Interactions Experiment (Beam-PIE)

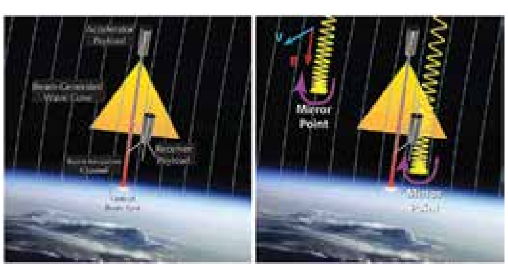
The Beam-PIE payload was launched from Poker Flat Research Range, AK on November 9, 2023. The objective of the Beam Plasma Interactions Experiment was to discover and characterize fundamental wave-particle interactions by generating waves using a modulated energetic electron beam, characterizing the wave properties to test theoretical and model predictions. As a secondary objective was to determine if the beam-generated wave fields are strong enough to produce measurable scattering of ambient ionospheric electron populations.

Beam PIE utilized a “mother-daughter” rocket configuration in which one rocket segment, the “accelerator” housed the electron beam and power systems and the other section, the “receiver” housed the fields, waves, and particle detectors.

After achieving operational altitude and immediately after engine cutoff an attitude control system (ACS) oriented the payloads such that they were aligned ±2° to the magnetic field at apogee which achieves ±5° for all altitudes above 300 km. The accelerator and receiver segments were spring-separated to place the accelerator segment on a higher altitude trajectory (apogee ~500 km) and the receiver segment on a lower-altitude trajectory with ~1 km peak separation as achievable by the spring system. With the rocket body oriented along B the separation creates a V primarily in the B direction. Thus, separation of the accelerator and receiver payloads is roughly field-aligned with minimal separation in the perpendicular to B direction. GPS receivers on both payloads will provide knowledge of the payload separations both along and perpendicular to B.



Schematic of the Beam PIE payload and instrument locations. The Accelerator Payload contains only the accelerator and associated electronics. After payload separation it will be aligned roughly along the magnetic field and boosted to a higher altitude. The Receiver Payload consists of 3–axis electric and magnetic field probes, a wave digitizer/receiver, a plasma spectrometer, a Langmuir probe, a vector magnetometer and associated electronics [see sections DC and Wave Electric Field Detectors–Energetic Electron Spectrometer (APES)]. An attitude control system (ACS) will be used to achieve a spin rate for the receiver payload of 1Hz. The same ACS will orient the payloads such that they will be aligned ±2 to the magnetic field at apogee which achieves ±5 for all altitudes above 300 km.



Schematic of the Beam PIE concept of operations. The Accelerator Payload directs the electron beam down the magnetic field line. The beam–generated waves spread out in a cone of wave power. The waves are detected and characterized by the Receiver Payload flying at a somewhat lower altitude. In the region where waves are present, they resonantly pitch angle scatter ambient ionospheric electrons which lowers their magnetic mirror points and increases the flux of upward going electrons detected at the Receiver Payload.

Results from the flight are being analyzed.

Principal Investigator: *Dr. Reeves/Los Alamos National Laboratory* • ***Mission Number(s):*** *52.009 AE*
Launch site: *Poker Flat Research Range, AK* • ***Launch date:*** *November 9, 2023*

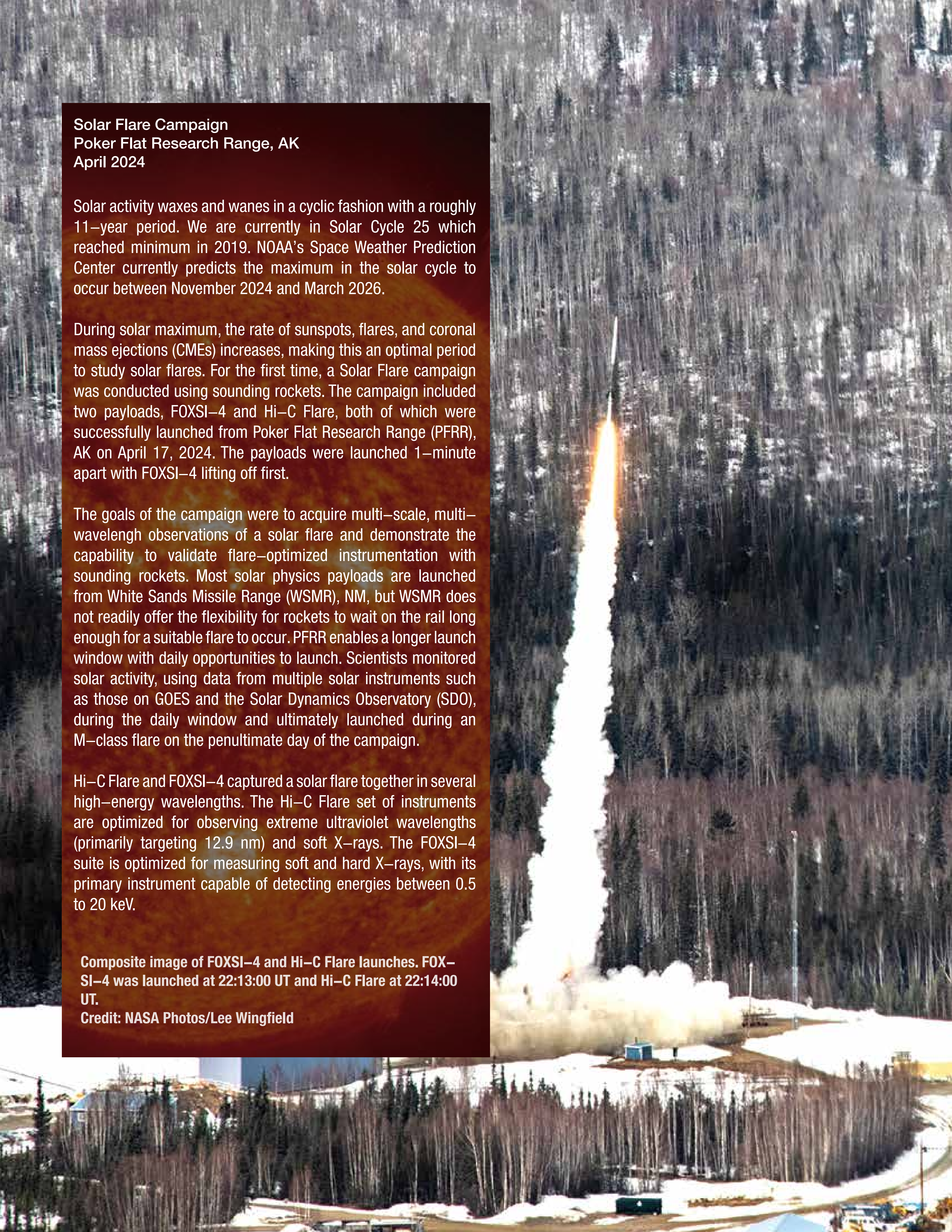
Solar Flare Campaign
Poker Flat Research Range, AK
April 2024

Solar activity waxes and wanes in a cyclic fashion with a roughly 11–year period. We are currently in Solar Cycle 25 which reached minimum in 2019. NOAA's Space Weather Prediction Center currently predicts the maximum in the solar cycle to occur between November 2024 and March 2026.

During solar maximum, the rate of sunspots, flares, and coronal mass ejections (CMEs) increases, making this an optimal period to study solar flares. For the first time, a Solar Flare campaign was conducted using sounding rockets. The campaign included two payloads, FOXSI–4 and Hi–C Flare, both of which were successfully launched from Poker Flat Research Range (PFRR), AK on April 17, 2024. The payloads were launched 1–minute apart with FOXSI–4 lifting off first.

The goals of the campaign were to acquire multi–scale, multi–wavelengh observations of a solar flare and demonstrate the capability to validate flare–optimized instrumentation with sounding rockets. Most solar physics payloads are launched from White Sands Missile Range (WSMR), NM, but WSMR does not readily offer the flexibility for rockets to wait on the rail long enough for a suitable flare to occur. PFRR enables a longer launch window with daily opportunities to launch. Scientists monitored solar activity, using data from multiple solar instruments such as those on GOES and the Solar Dynamics Observatory (SDO), during the daily window and ultimately launched during an M–class flare on the penultimate day of the campaign.

Hi–C Flare and FOXSI–4 captured a solar flare together in several high–energy wavelengths. The Hi–C Flare set of instruments are optimized for observing extreme ultraviolet wavelengths (primarily targeting 12.9 nm) and soft X–rays. The FOXSI–4 suite is optimized for measuring soft and hard X–rays, with its primary instrument capable of detecting energies between 0.5 to 20 keV.



Composite image of FOXSI–4 and Hi–C Flare launches. FOXSI–4 was launched at 22:13:00 UT and Hi–C Flare at 22:14:00 UT.
Credit: NASA Photos/Lee Wingfield

Solar Physics Missions 2024

Focusing Optics X-ray Solar Imager (FOXSI) 4

FOXSI-4 was launched from Poker Flat Reasearch Range, AK on April 17, 2024.

Pre–flight instrument testing of FOXSI–4.
Credit: NASA Photo/Lee Wingfield

The purpose of the FOXSI-4 experiment was to develop an instrument that studied hard and soft X-rays using direct focusing optics, and to advance toward understanding the high-energy aspects of solar flares.

FOXSI-4 uses direct imaging and single photon counting to obtain locations, timing, and energy information for every X-ray hitting the telescopes. This allows us to study particle acceleration and plasma heating on the Sun in unprecedented detail.

FOXSI-4 aimed to:

- Study the amounts and locations of energy release throughout flares
- Determine how flares accelerate particles and how those energetic particles propagate
- Determine how superhot plasma arises during flares
- Study coronal heating

Hard X-rays (HXRs, emitted via bremsstrahlung) offer a useful diagnostic tool.

Data was successfully gathered during the flight and is currently being analyzed. Initial assessment indicates that the instruments worked as predicted and data is of high quality.

Principal Investigator: *Dr. Glesener/University of Minnesota* • ***Mission Number(s):*** *36.370 US*
Launch site: *Poker Flat Research Range, AK* • ***Launch date:*** *April 17, 2024*

High-resolution Coronal Imager (Hi-C) Flare

Hi-C Flare was launched from Poker Flat Research Range, AK on April 17, 2024.


Pre–flight instrument testing of Hi–C Flare
Credit: NASA Photo/Lee Wingfield

This flight was the fourth for the Hi-resolution Coronal Imager instrument, improved for capturing high-speed, high-temperature solar flare dynamics. In addition to the Hi-C instrument, the Hi-C Flare payload included three new experiments: COOL-AID, CAPRI-SUN, and SSAXI.

The purpose of the Hi-C Flare experiment suite is to determine:

- the mechanisms that drive continual heating of flares into the decay phase,
- how energy is transferred from the corona to the chromosphere during flares,
- the morphology of the source regions associated with particles that are accelerated into the heliosphere.

Initial assessments indicate that the primary instrument worked as predicted, capturing high resolution images of hot, flaring plasma.


Solar Flare Campaign Team
Credit: NASA Photo/Lee Wingfield

Principal Investigator: *Dr. Savage/NASA MSFC* • ***Mission Number(s):*** *36.371 NS*
Launch site: *Poker Flat Research Range, AK* • ***Launch date:*** *April 17, 2024*

Marshall Grazing Incidence X-ray Spectrometer (MaGIXS) 2

MaGIXS-2 was flown from White Sands Missile Range, NM on July 16, 2024. This was a new instrument with heritage from past experiments. The scientific goal is to determine the frequency of heating in active region cores by making four critical observations in the soft X-ray wavelength range:

1. Derive the relative amount of high temperature plasma in different solar structures
2. Measure the elemental abundances in different solar structures
3. Compare the temporal variability at high temperatures in different solar structures
4. Identify the likelihood of Maxwellian or non-Maxwellian distributions

MaGIXS–2 ready for launch.
Credit: White Sands Missile Range

The sun's surface temperature is around 10,000 degrees Fahrenheit—but the corona routinely measures more than 1.8 million degrees, with active regions measuring up to 5 million degrees. Studying the X-rays from the sun sheds light on what's happening in the solar atmosphere—which, in turn, directly impacts Earth and the entire solar system.

X-ray spectroscopy provides unique capabilities for answering fundamental questions in solar physics and for potentially predicting the onset of energetic eruptions on the sun like solar flares or coronal mass ejections. These violent outbursts can interfere with communications satellites and electronic systems, even causing physical drag on satellites as Earth's atmosphere expands to absorb the added solar energy.

For this, the second flight, MaGIXS-2, the instrument was reconfigured to a more simplified optical layout that reuses the Wolter-I telescope and blazed varied-line space reflective grating. The field stop at the telescope focal plane and the finite conjugate spectrometer mirror pair have been removed – the telescope now directly feeds the grating. Additionally, an identical but new 2k x 1k CCD camera was built for this flight. The MaGIXS-2 data product will again be overlapping spectroheliograms of at least one solar active region, but with improved resolution, a larger field of view and increased effective area.

Principal Investigator: *Dr. WinebargerNASA MSFC* • ***Mission Number(s):*** *36.385 NS*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *July 16, 2024*

Full-sun Ultraviolet SpecTrograph

FURST was flown from White Sands Missile Range, NM on September 3, 2024. The goal of this mission was to study and better understand spectra of the "Sun as a Star". FURST was designed to obtain the first high resolution (R > 20, 000), radiometrically calibrated FUV spectra of the Sun as a star, from 121-185 nm. FURST spectra will have applications to solar and stellar physics, climate science, and the interaction of solar UV radiation with comets, moons, and planets.

Testing of FURST at White Sands Missile Range, NM.
Credit: NASA Photo/Daniel Bowden

The immediate science goal is to understand better the processes of chromospheric and coronal heating. The solar spectrum obtained will enable a better understanding of the interaction of solar UV radiation with solar system bodies, the nature of magnetic energy dissipation as a Sun-like star evolves, and the dependence of magnetic activity on stellar mass and metallicity.

FURST science is cross disciplinary and includes:

Sun as a star:

- Comparison of solar and stellar spectra
- Heating of solar and stellar atmospheres
- Waves and reconnection
- Solar cycle variation

Atmospheric, solar system, and heliospheric science:

- Earth, planets, moons, comets
- Resonant absorption in atmospheres

Post-flight assessment confirms that images taken during flight are not scientifically usable due to saturation by stray light. An investigation into possible sources of the stray light is ongoing and a proposal for a re-flight will be submitted.

Principal Investigator: *Dr. Kankelborg/Montana State University* • ***Mission Number(s):*** *36.366 US*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *September 3, 2024*

Education Missions 2024

RockSat-X group on Wallops Island, VA
NASA Photo/Berit Bland

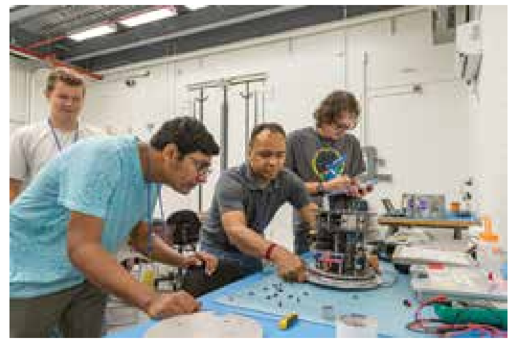
Level 1
RockOn!

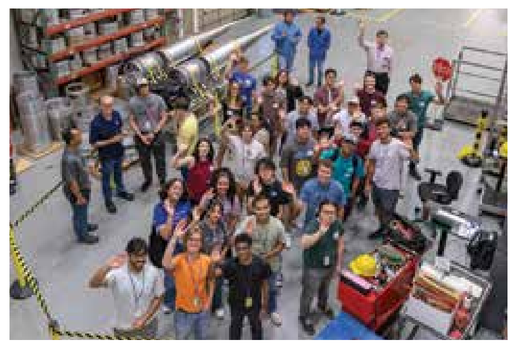
Level 2
RockSat-C

Level 3
RockSat-X

RockOn & RockSat-C

The RockOn! workshop was conducted at NASA Wallops Flight Facility in June 2024. This was the 16th RockOn workshop since the inception of the program in 2008. RockSat-C experiments are flown in the same rocket as the workshop experiments but are more advanced and completely designed and fabricated by the students.





NASA Photos/Berit Bland

The goal of the ***RockOn*** missions is to teach university faculty and students the basics of rocket payload construction and integration. RockOn also acts as the first step in the RockSat series of flight opportunities, and workshop participants are encouraged to return the following year to design, build, test, and fly their own experiment. The RockOn experiments are designed to capture and record 3-axis accelerations, humidity, pressure, temperature, radiation counts, and rotation rates over the course of the mission. All items and instruction necessary to complete the experiment are provided for the participants during the workshop, and teams of students and faculty work together to build their experiment. The workshop culminates with the launch of the experiments on a Terrier-Improved Orion sounding rocket. This year, 26 teams from 5 states and Washington D.C. participated.

This year, faculty from Minority Serving Institutions (MSI) attended a dedicated workshop in late May and flew their RockOn experiments on this flight.

RockSat-C offers students an opportunity to fly more complex experiments of their own design and construction. The intent is to provide hands-on experiences to students and faculty advisors to better equip them for supporting the future technical workforce needs of the United States and/or helping those students and faculty advisors become principal investigators on future NASA science missions. Teaming between educational institutions and industry or other interests is encouraged.

Participating schools for 2024 included:

Temple University

Southeastern Louisiana University

Old Dominion University

University of Delaware

Stevens Institute of Technology

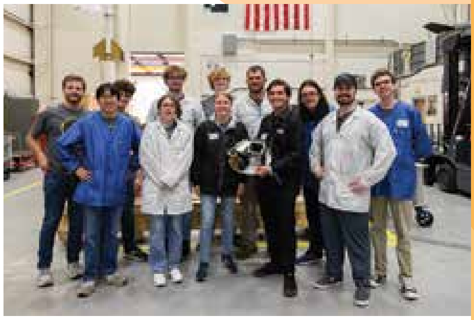
Nosecone: Cubes-in-Space. Cubes in Space, part of the RockSat-C program, is aimed at middle school students and allows them to design an experiment that fits in a 40 x 40 x 40 mm cube.

Student flight opportunities website: https://www.nasa.gov/nasa-rocksat-program/

Principal Investigator: *Mr. Koehler/NASA Wallops Flight Facility* • ***Mission Number(s):*** *41.133 WO*
Launch site: *Wallops Island, VA* • ***Launch date:*** *June 20, 2024*

RockSat-X

RockSat-X was launched from Wallops Island, VA on August 13, 2024. RockSat-X carried student developed experiments and is the third, and most advanced, student flight opportunity. RockSat-X experiments are fully exposed to the space environment above the atmosphere. Power and telemetry were provided to each experiment deck. Additionally, this payload included an Attitude Control System (ACS) for alignment of the payload. These amenities allow experimenters to spend more time on experiment design and less on power and data storage systems.


University of Alabama Huntsville

The following experiments were flown on RockSat-X in 2024:
The ***University of Alabama Huntsville*** flew two primary experiments:
1. Joint Union of Payload Information and Technology between Experiments and Rockets (JUPITER), a custom spacecraft bus-like system that connects experiment hardware with existing launch vehicle electronics.
2. SwingSat will increase the technology readiness level of momentum exchangetether technology in the context of satellite constellation deployments.


University of Alberta

The ***University of Alberta*** demonstrated instruments for characterizing plasma wave activity and electron microburst precipitation, specifically by resolving precipitating relativistic and sub-relativistic electrons. The project aimed to measure magnetic plasma wave oscillations, including chorus waves and ground-based Very LowFrequency transmitters. The outcome of this mission will improve the Technology Readiness Level (TRL).


Clemson University

Clemson University's experiment measured electron density and temperature of the E-region ionosphere, between 56 - 93 miles (90-150 kilometers).


College of the Canyons

The ***College of the Canyons*** experiment deployed three capsules to gather data on greenhouse gases in the upper atmosphere to aid in the fight against climate change.

The ***Community Colleges of Colorado***, a collaboration of ***Arapahoe and Red Rocks Community Colleges***, aimed to evaluate how microgravity affects the mechanical properties of lunar regolith simulants sintered during suborbital flight. The mission also created a cost-efficient star tracker using off-the-shelf materials and open-source software.


Community Colleges of Colorado

Principal Investigator: *Mr. Koehler/NASA Wallops Flight Facility* • ***Mission Number(s):*** *46.042 WO*
Launch site: *Wallops Island, VA* • ***Launch date:*** *August 13, 2024*

Northwest Nazarene University tested a space-rated robotic arm capable of tracking and capturing objects. The arm was designed to catch three balls, then stow itself for reentry, and also capture video footage of all the catch attempts.

The ***University of Puerto Rico*** collected environmental data of the atmosphere using humidity, temperature, and pressure sensors. Using an Ultra High Frequency antenna, telecommunications used open-source protocols to beam down data to groundstations at Wallops. Uninterrupted Virtual Reality footage of flight will be used for STEM engagement.

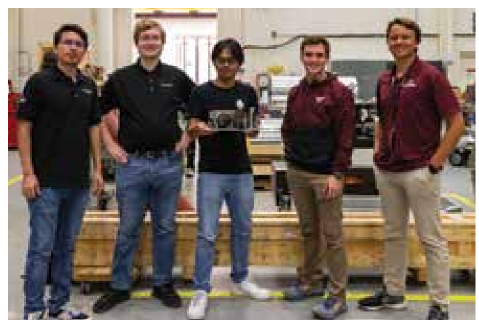
Virginia Tech's experiment tested a space tether that was designed to provide a small CubeSat with power and a mechanical connection.

West Virginia Space Collaboration, a collaboration of five West Virginia universities, conducted nine independent experiments on the 2024 RockSat-X mission. Included were:

- Lower Ionosphere Electric Field Double Probes (LIEF), which studied plasma and electric field densities throughout the flight.
- A mycelium properties experiment that studied the mechanical properties of mycelium under space flight conditions.
- A flight dynamics module that recorded data on rocket and space flight conditions.
- A Geiger counter to detect radiation density during flight.
- A heat study that analyzed heat dissipation during flight and reentry.
- A study on the effect of spaceflight on microbes in soil during flight and reentry.
- Power generation using type K thermocouples.
- Spectrometric and photographic data of the Sun.
- Creation of a 3D model of flight using LiDAR tracking and flight data.

Northwest Nazarene University

University of Puerto Rico



Virginia Tech

West Virginia Space Collaboration

Credit: NASA Photos/Berit Bland

For more information and application process, visit: **https://www.nasa.gov/nasa-rocksat-program/**

41.133 WO Koehler RockOn launches on June 20, 2024.
NASA Photo/Berit Bland

STEM Engagement

The Sounding Rockets Program Office (SRPO) and NASA Sounding Rocket Operations Contract (NSROC) offer opportunities for teachers and students to participate in rocketry related activities.

The Wallops Rocketry Academy for Teachers and Students (WRATS) workshop is offered annually to High School teachers interested in incorporating rocketry activities in their teaching.

WRATS Teachers with model rockets.
Credit: NASA Photo/Berit Bland

NSROC and SRPO staff visit schools to give lectures, arrange rocketry activities, and judge science fairs. Additionally, tours are given to groups of all ages of the payload manufacturing and testing areas.

NSROC manages the internship program and recruits about 10 - 15 interns annually from Universities and Colleges. The interns work with technicians and engineers on rocket missions and gain invaluable work experience.

Twenty High School teachers from eleven states participated in the WRATS workshop June 17 - 21, 2024. The workshop is held the same week with the RockOn flight and the teachers attend the launch of the RockOn mission on Wallops Island - a highlight of the week.

During the workshop particpants learn about model rocketry and how models relate to sounding rockets. Three models were constructed and flown during the week. The first experiment demonstrates mass vs. altitude by varying the "payload" mass carried by a small rocket. Parachutes are designed and constructed for the second small rocket to demonstrate and evaluate shape and size parameters and their trade-offs in rocket recovery. Advancing to the final rocket for the week, both mass and parachute experiments are incorporate and an altimeter is added to gather data altitude reached.

Additional components of the workshop include tours of Wallops Flight Facility, presentations by Subject Matter Experts on parachutes and internship opportunities.

The WRATS workshop is a collaboration between the Wallops Education Office, Sounding Rockets Program Office (SRPO), and the NASA Sounding Rockets Operations Contract (NSROC).

Some of the feedback received from the teachers:
"I did not master the science of rockets before, now I'm confident in my ability to teach the concepts."

"Rocketry is more exciting than I thought."

NASA Photos/Berit Bland

Internships

Over 200 students have participated in the internship program managed for the Sounding Rockets Program Office by NSROC. The program, now in its 23rd 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. Many of the 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 Electrical Engineering intern in the Ground Station. Credit: NASA Photo/Berit Bland

In addition to the NSROC internship program, the SRPO also offers opportunities for interns through the NASA Internship Program.

Outreach

Throughout the year, SRPO and NSROC personnel supported local schools by providing speakers, judging science fairs, and conducting special programs. Additionally, speakers were provided upon request to local civic organizations through the NASA Office of Communications. Tours of sounding rocket facilities were conducted for both school and civic groups throughout the year.

Sounding Rockets display at Junior Achievement event. Credit: Phil Cathell/NSROC

NSROC and SRPO staff supported the NASA Community College Aerospace Scholars (NCAS) with mentors, presentations and facility tours. NCAS is a national STEM focused program where community college students interested in NASA related careers participate in a five-week online learning experience.

Technology Development

SPARCS-8 Development Team at WSMR.
Credit: Ryan Harty/WSMR

This has been a great year for the NASA Sounding Rocket Program (NSRP) technology development. The program has been gearing up for the next technology demonstration flight, SubTEC-10, currently scheduled for September of 2025. That flight will provide an opportunity to test many new and important technology developments for our program as well as to further demonstrate several technologies first flown on SubTEC-9 in April of 2024. Additionally, this year several science missions enabled our program to test vital technologies in a flight environment.

The program's three major initiatives for technology:

- Increasing Science Data: enabling our research teams to collect more science data during each sounding rocket flight.
- High Cadence Mesospheric Capability: leveraging current sub-payload technologies to develop a small diameter, high cadence platform for mesospheric science instruments.
- Capability improvements: improving the programs current capabilities to support science payloads and preventing component obsolescence.

36.386, 387, 388 Barjatya (APEP I), 36.396 Zemcov (CIBER-2) and 36.382 Gilchrist (B-SPICE):

Universal Telemetry Analysis Suite (UTAS)	Capability Improvement

UTAS is an in-house developed software package that serves as a telemetry decom display tool, interfacing with multiple types of decom hardware Ground Support Equipment (GSE), providing a uniform look for displayed telemetry data. UTAS was first successfully demonstrated during the three launches from the White Sands Missile Range (WSMR), as part of the APEP I campaign, as well as being the primary decom display for CIBER-2. Further testing will occur as part of the B-SPICE mission, with future developments expanding the ability to interface with additional decom hardware.

36.385 Winebarger (MaGIXS-2) and 36.366 Kankelborg (FURST):

Solar Pointing Attitude Rocket Control System (SPARCS-8)	Capability Improvement

The upgraded solar pointing system, called SPARCS-8, has an integrated Tern Inertial Navigation System (INS) and replaces the currently operational SPARCS VII. The first SPARCS-8 flight occurred as part of the MaGIXS flight in July, followed shortly by the second flight, on FURST, in September. The SPARCS-8 system performed well and both missions accomplished their comprehensive success criteria for attitude control. Development work continues, with the goal of 0.2 to 0.3 peak-to-peak performance with future flight demonstrations already planned.

SPARCS–8 Sees the Real Sun!
Credit: Valerie Gsell/NSROC

Additional Work in FY 2024

Launch Site Vacuum System (LSVS)	Capability Improvement
Versatile Linear Shape Charge (VLSC)	Capability Improvement

In July the LSVS team traveled to the WSMR to conduct their third site visit, a pre-integration test that including both function tests and fit checks of the vacuum system with launch site infrastructure. Data flow to and from the system was verified through a full handshaking test, electrical isolation from the launcher was verified, and a pull-away test was successfully accomplished.

The VLSC team assembled their mechanical prototype, which underwent shock and vibration testing successfully in July. The team was also able to develop their qualification test plan (QTP) for VLSC ordnance and are working on procuring the ordnance required for the QTP.

12.091 Yacobucci (SubTEC-10):

300 Mbps C-band Telemetry System	Increasing Science Data
Store-and-forward capability as part of WFFCM4	Increasing Science Data
Wallops Integrated Star Tracker (WaIST)	Capability Improvement
Celestial Attitude Control System Gips Tern (CACS-GT)	Capability Improvement
NSROC Common Ignition System (NCIS)	Capability Improvement

C-Band telemetry allows for higher data rates and/or more downlinks and it complements our current S-band capabilities. Our program has been building on the demonstration of the 40 Mbps C-band links for SubTEC-9, with the development of a 300 Mbps C-band system that will be first flown on SubTEC-10. This year, a prototype of the 300 Mbps system was built, and ground testing began. An end-to-end closed loop test was completed, bringing the Technology Readiness Level to TRL 4. Later this year, an end-to-end open loop test will be conducted, followed by a gain variation test in the Wallops Anechoic Chamber.

The development of the WFFCM4 flight computer has continued through 2024, working towards an objective to demonstrate both a buffered telemetry downlink as well as a data storage capability on the upcoming SubTEC-10 flight. A prototype was built and flown on a balloon test flight in the fall of this year, providing an early test of some of the planned functionality of the WFFCM4.

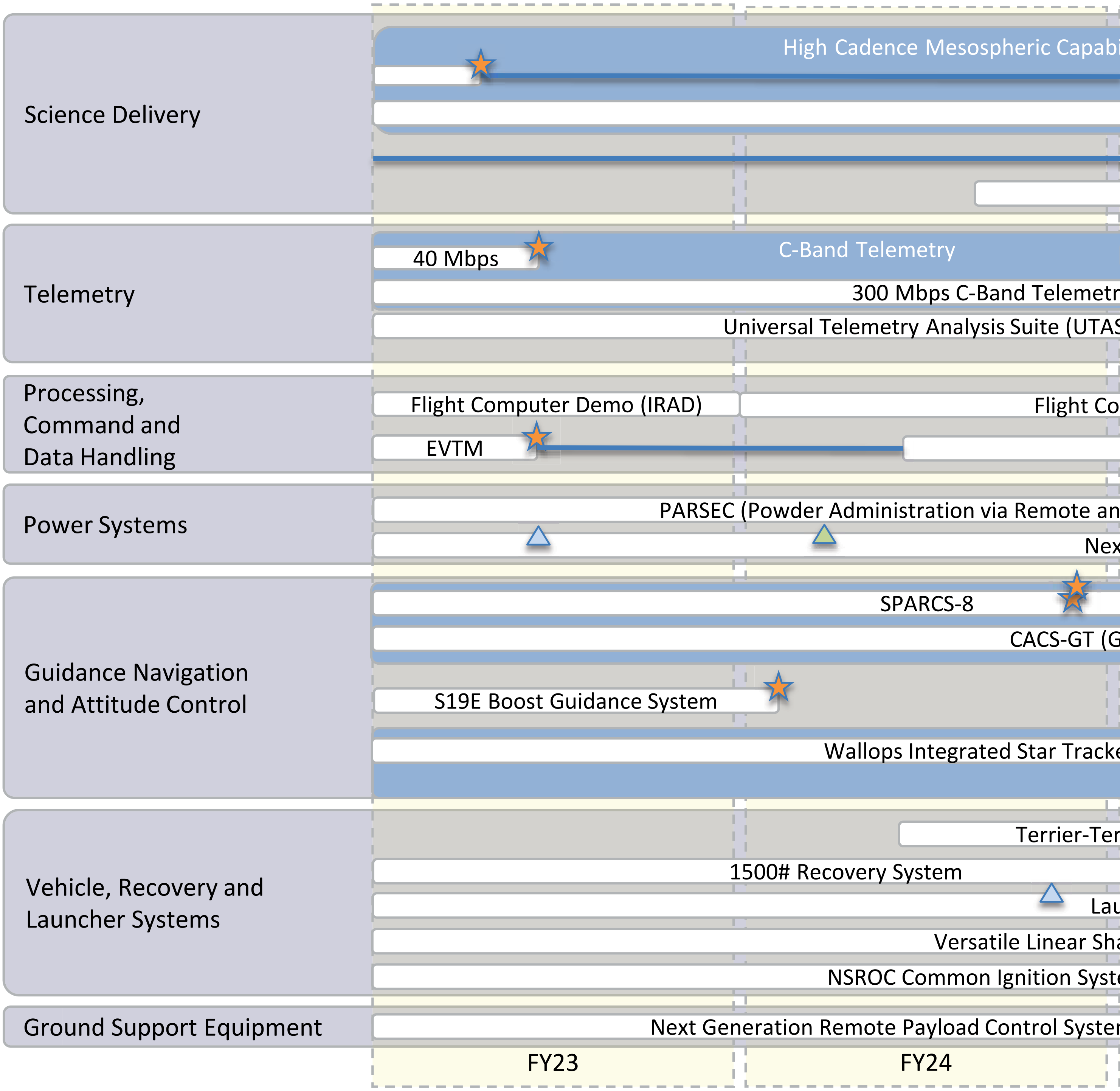
Several design improvements were made to WaIST this year, in-part based on data from the SubTEC-9 flight. The star tracking algorithm was enhanced, making it more resilient to stray light. The electronics were re-packaged to improve the speed of the ethernet interface and to use standard unregulated battery voltage as an input. WaIST will be flown on SubTEC-10, as the primary star tracker for the new celestial ACS (CACS-GT) with a Star Tracker 5000 flown for post-flight comparison purposes.

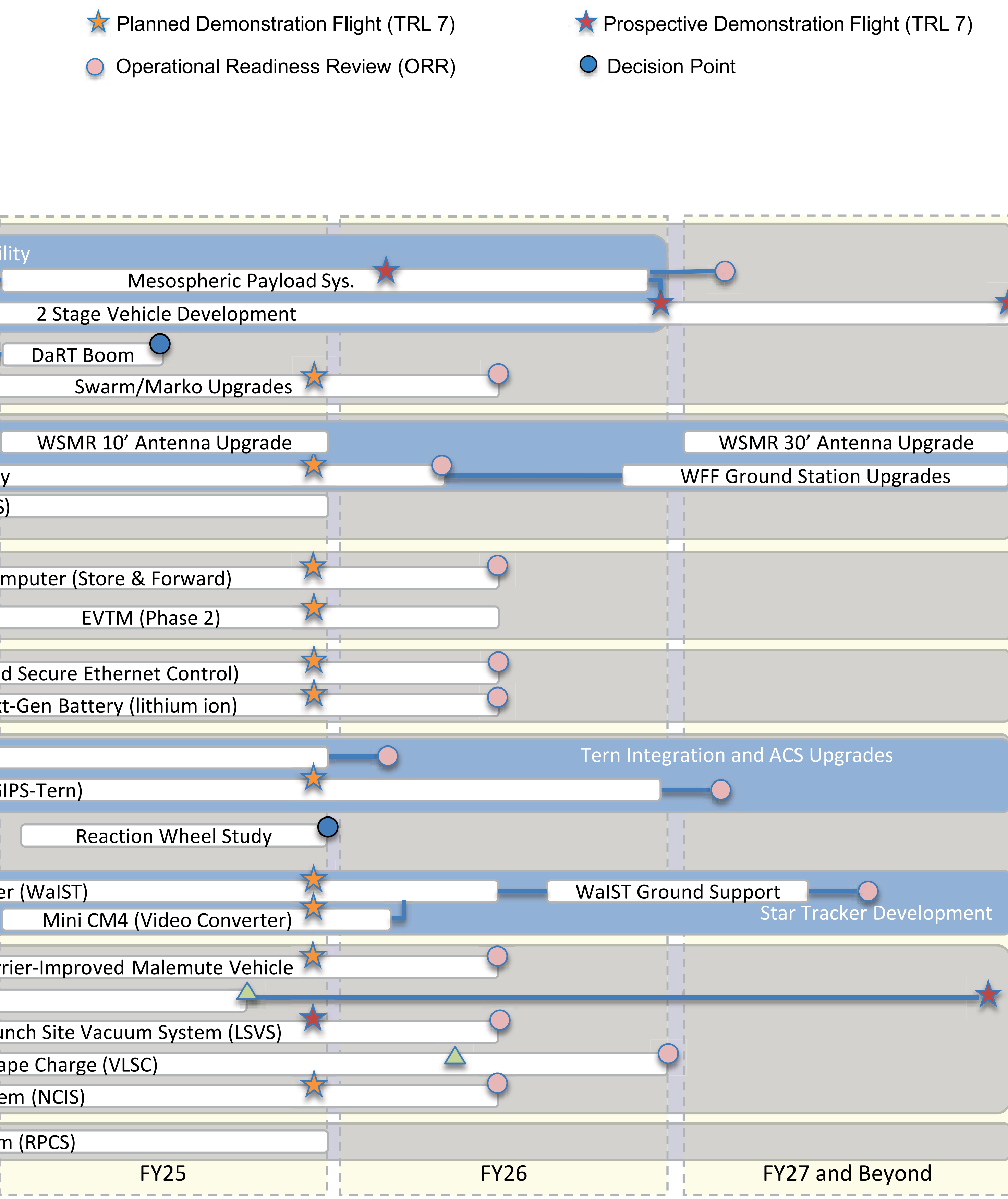
Lens Calibration of the WaIST Prototype
Credit: Zach Peterson

Technology Roadmap

△ Demonstration in Relevant Env. (TRL 6)

△ Med. Fidelity Prototype Demo. in Relevant Env. (TRL 5)




Planned Demonstration Flight (TRL 7)
Prospective Demonstration Flight (TRL 7)
Operational Readiness Review (ORR)
Decision Point
ility
Mesospheric Payload Sys.
2 Stage Vehicle Development
DaRT Boom
Swarm/Marko Upgrades
WSMR 10’ Antenna Upgrade
WSMR 30’ Antenna Upgrade
y
WFF Ground Station Upgrades
S)
mputer (Store & Forward)
EVTM (Phase 2)
d Secure Ethernet Control)
xt-Gen Battery (lithium ion)
Tern Integration and ACS Upgrades
SIPS-Tern)
Reaction Wheel Study
er (WaIST)
WaIST Ground Support
Mini CM4 (Video Converter)
Star Tracker Development
rrier-Improved Malemute Vehicle
unch Site Vacuum System (LSVS)
ape Charge (VLSC)
em (NCIS)
m (RPCS)
FY25
FY26
FY27 and Beyond


On the Horizon

In Fiscal Year (FY) 25 operations will continue from regularly used launch sites, Wallops Island, VA, White Sands Missile Range, NM, Poker Flat Research Range, AK, Andoya Space, Norway, and Kwajalein, Marshall Islands. Currently 18 missions are manifested for flight in FY 2025.

Remote Campaigns 2025

AndØya Space, Norway

Two Vorticity Experiment (VortEx) payloads are launching from Andøya Space with the launch window opening October 27th. These payloads were originally scheduled for launch in March 2023 in conjunction with two additional VortEx payloads, but were re-scheduled due to weather related delays. The science objective of the Vorticity Experiment (VortEx) is to better understand nonlinear gravity wave interactions in the upper mesosphere and lower thermosphere, the formation of vortices, and the importance of mesoscale stratified turbulence. The Principal Investigator is Dr. Lehmacher/Clemson University.

Poker Flat Research Range (PFRR), AK

Two separate campaigns are scheduled for PFRR in 2025. The first, comprising two missions, Ground Imaging to Rocket investigation of Auroral Fast Features (GIRAFF) and Black and Diffuse Aurora Science Surveyor (BADASS) is scheduled for January 2025.

GIRAFF includes two payloads launched using Black Brant IX vehicles, and is a combined rocket and ground-based imaging experiment to investigate the physical processes responsible for creating the Flickering and Fast Pulsating Aurora. The Principal Investigator is Dr. Michell/NASA Goddard Space Flight Center.

BADASS also utilizes a Black Brant IX launch vehicle and the primary objective of the experiment is to explore the processes responsible for creating the optical variations observable withing the diffuse aurora with the specific target of the black aurora. The Principal Investigator is Dr. Samara/NASA Goddard Space Flight Center.

The second campaign at PFRR is scheduled for March 2025 and includes three payloads for the Auroral Waves Excited by Substorm Onset Magnectic Events (AWESOME) mission. Two paylods launch with Terrier-Improved Malemutes and one on a Black Brant XII-A. AWESOME will study the density, wind, and composition perturbations that occur in Earth's high latitude thermosphere in response to impulsive local forcing during auroral substorms. The research is motivated by the premise that generation of acoustic-gravity waves plays a far greater role in the substorm response than is generally recognized or implemented in current models.

Roi Namur, Kwajalein Atoll, Marshall Islands

The sounding rockets program is returning to Kwajalein to launch the Sporadic E Electrodynamics (SEED) mission in June 2025.

The goal of the SEED missions is to collect the first simultaneous multipoint spatial and temporal observations of low-latitude Sporadic-E layers and their associated electrodynamics and neutral dynamics. Two Terrier-Improved Malemute vehicles will be launched for SEED. The two payloads will launch within 30 minutes of each other, each releasing trimethylaluminum (TMA) puffs. Four instrumented sub-payloads are also deployed from each main payload. The experiment will be supported by ground based observations from ARPA Long-Range Tracking And Instrumentation Radar (ALTAIR), digisonde, and GPS receivers.

Wallops Island, VA and White Sands Missile Range (WSMR), NM operations 2025

Launches from Wallops Island and WSMR will cover Geospace Science, Solar Physics and Technology Development disciplines. A total of eight launches will be supported, four from each site.

Geospace Science campaign from Peru

Campaign planning for a Peru launch opportunity in 2028 is ongoing. SRPO and other NASA personnel have visited the Punta Lobos launch site. Meetings have been held with Peruvian counterparts and an assessment of current range capabilities, as well as, required improvements and upgrades are being discussed.

Sounding Rocket Launch Sites

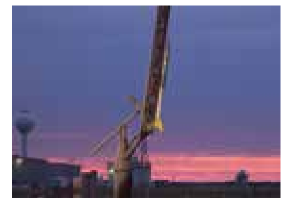
Poker Flat, Alaska

Esrange, Sweden

Kwajalein, Marshall Is.

Andøya, Norway

Arnhem Space Center, Australia



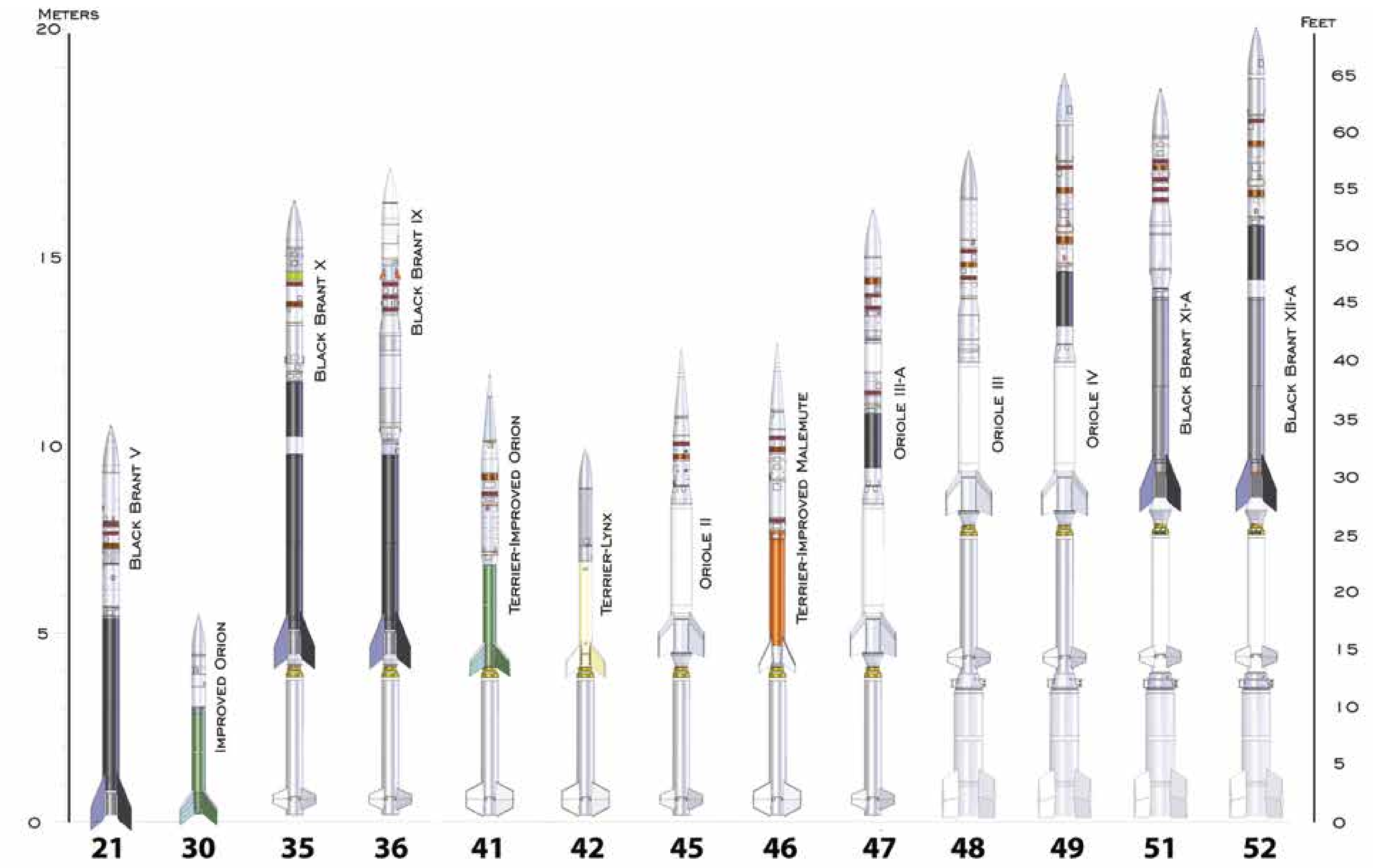
Wallops Island, Virginia

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

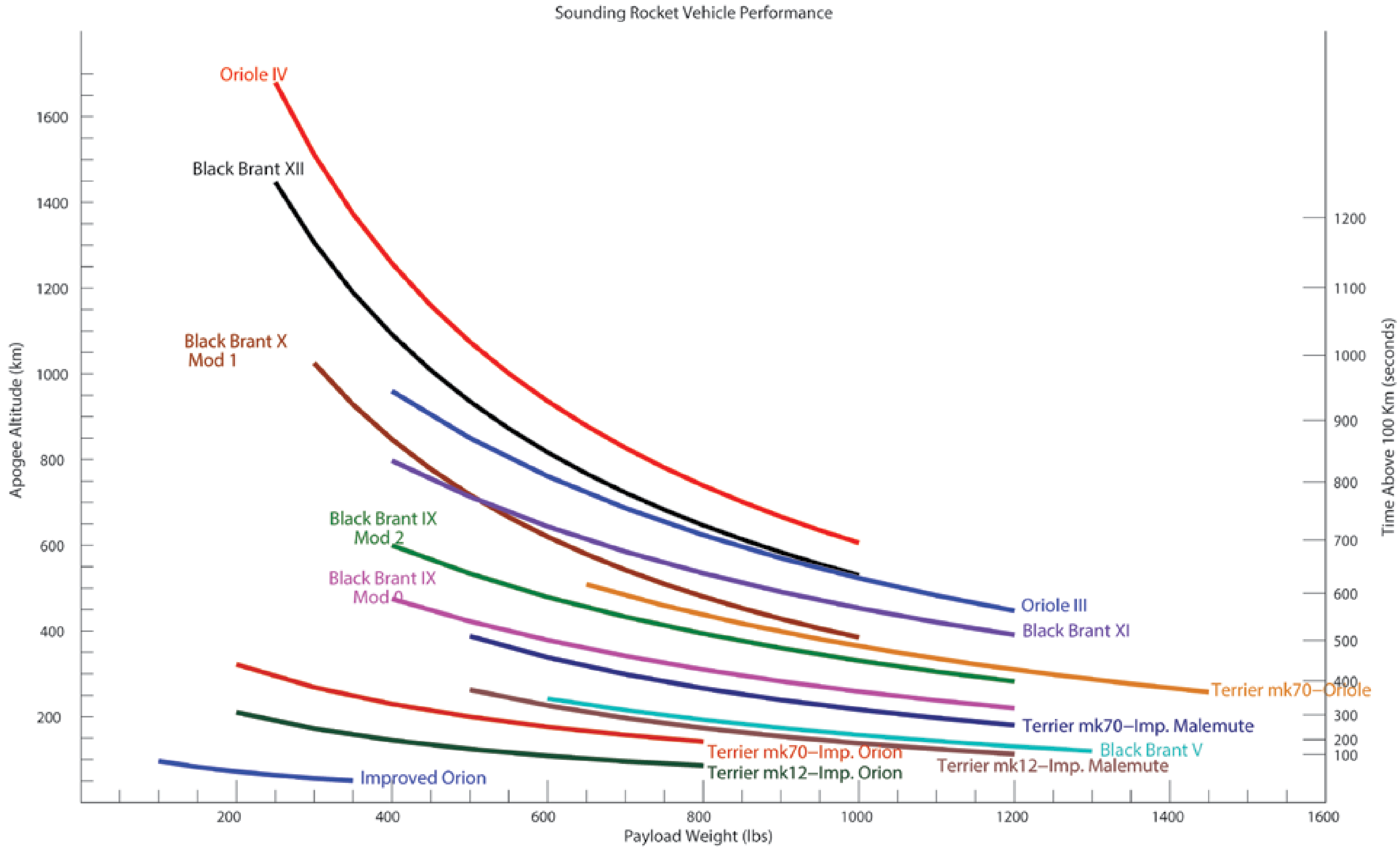
1. Kwajalein Atoll, Marshall Islands
2. Barking Sands, HI
3. Poker Flat, AK
4. White Sands, NM
5. Punta Lobos, Peru *
6. Alcantara, Brazil *
7. Camp Tortuguero, Puerto Rico *
8. Wallops Island, VA
9. Fort Churchill, Canada *
10. Greenland (Thule & Sondre Stromfjord) *
11. Andøya, Norway
12. Esrange,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

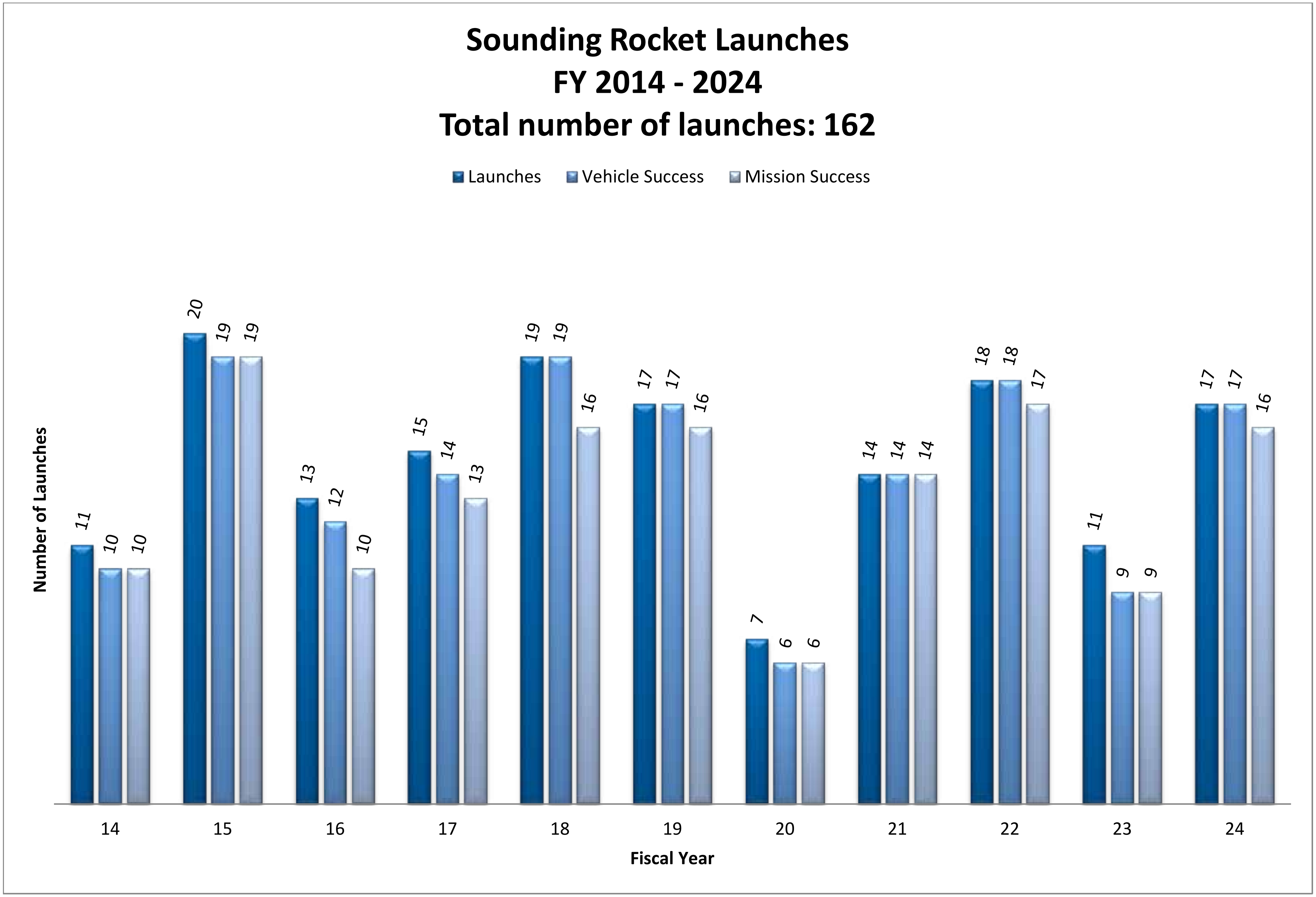
* Inactive launch sites

Sounding Rocket Vehicles



Sounding Rocket Vehicle Performance




Sounding Rocket Launches
FY 2014 - 2024
Total number of launches: 162
Launches
Vehicle Success
Mission Success
Number of Launches
11
10
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20
19
19
13
12
10
15
14
13
19
19
16
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Fiscal Year

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Giovanni Rosanova
Chief

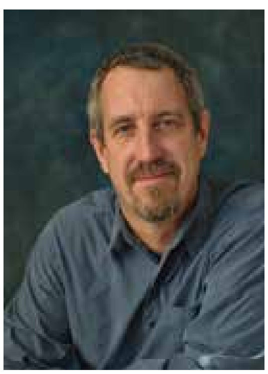
Scott Bissett
Deputy Chief

Rebecca Arcomano
Mission Manager

Julie Bloxom
Business Management

Daniel Bowden
Operations Manager

Ernie Bowden
Mission Manager



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45.007 GE DISSIPATION launches form
Poker Flat Research Range, AK on
November 8, 2023.
NASA Photo/Lee Wingfield

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