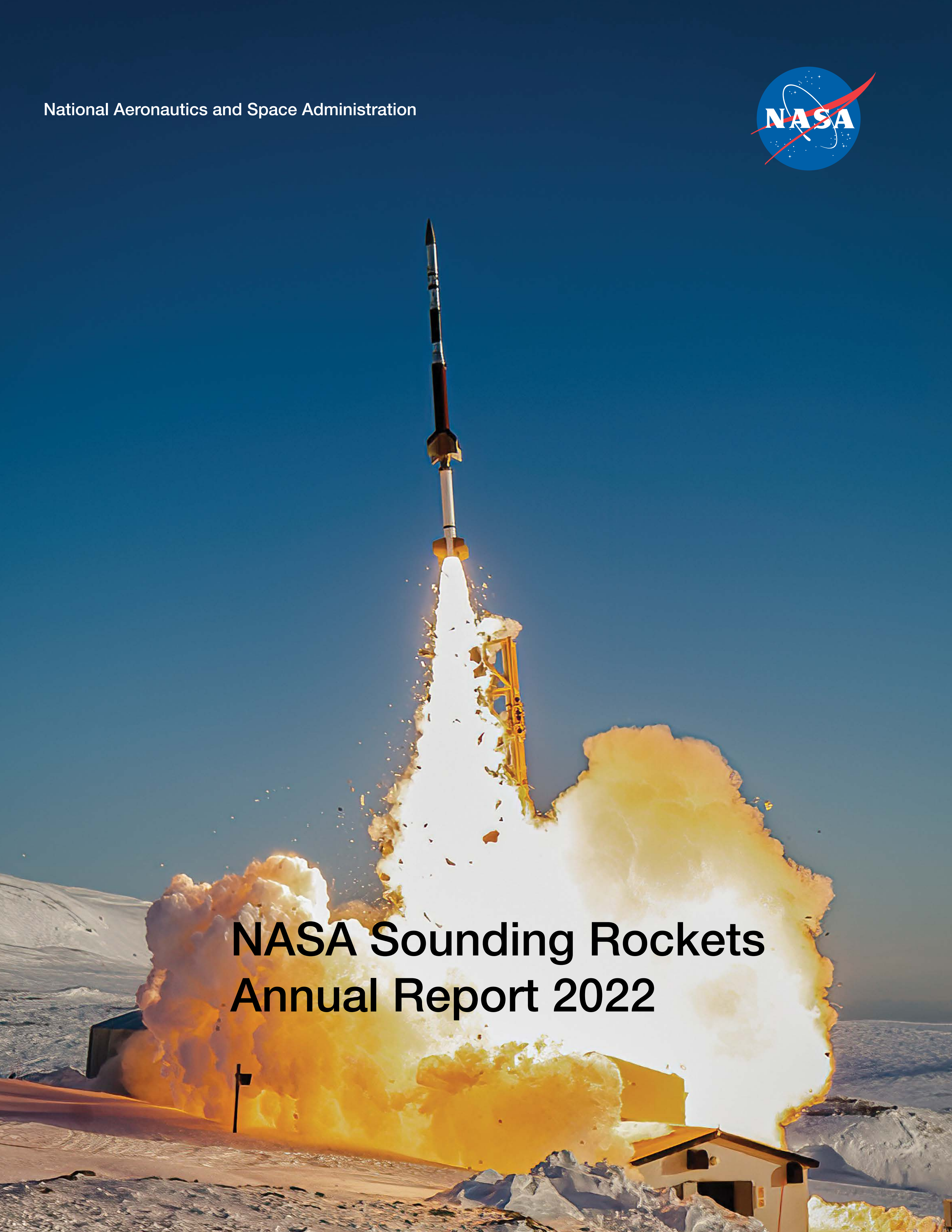
National Aeronautics and Space Administration

NASA Sounding Rockets Annual Report 2022



Message from the Chief

Giovanni Rosanova, Jr.
Chief, Sounding Rockets Program Office

The end of the year is the time we reflect on the past year's accomplishments and look to what the future will hold. I'm excited to report that Fiscal Year 2022 saw one of our major efforts succeed; southern hemisphere Astrophysics missions launched from Australia. The Sounding Rockets Program Office (SRPO) has been planning these missions for several years, and when we were very close to execution, COVID hit. Our mission - to launch rockets where the science takes us – is enthusiastically supported and executed by both the NASA Sounding Rocket Operations Contract (NSROC) contractor workforce and management, and our civil service personnel. Setting up a range and completing a launch campaign in Nhulunbuy, Northern Territory, Australia was no exception. We safely built a launch range with our partner Equatorial Launch Australia at the Arnhem Space Center. Mobile assets were shipped from Wallops and installed at the range. The Wallops Range & Mission Management Office (RMMO), the Range Operations Contract (ROC), and, the Wallops Safety Office were all partners in this effort and key to our success. Additionally, the Aircraft Office provided the C-130 for payload and motor transport to Australia. Even the shipping contractor Ridgeway provided a representative to assist in clearing the cargo for entry into Australia. Remote campaigns are labor intensive and require tremendous effort by all involved and could not be achieved without the extraordinary dedication and personal sacrifice of our personnel. Many of our team members stayed in Australia for the duration of the campaign, including the setup, meaning they were away from home for months. I truly appreciate their willingness to do whatever it takes, while working safely at remote locations. More details about the missions flown from Australia, as well as an overview of the campaign are available in this report.

In addition to the Australia campaign, we also launched from our regular launch sites in White Sands, NM, Poker Flat, Alaska, Svalbard, Norway, and, Wallops Island, VA. A total of 18 rockets were launched, supporting Solar Physics, Geospace Science, Astrophysics, Education, and the Department of Defense. The number of missions launched is similar to our pre-COVID flight rate and about average for the program for the past 10 years. We achieved a 94% success rate for this year.

The SRPO management team has been augmented to include Catherine Hesh as the Assistant Chief and Scott Bissett as the Deputy Chief. Both have many years of experience with the program and were able to immediately start performing their new duties. Additionally, Brittany Empson and Josh Yaccobucci, both experienced sounding rocketeers, have joined the Program Office. Brittany as an Operations Manager, and Josh as the Technology Manager.

We wish Chris Koehler/Colorado Space Grant well in his new role at the University of Colorado Engineering Department. Chris has been the Principal Investigator for the RockOn and RockSat student launch programs since 2008, and he will be deeply missed. Chris, in partnership with NASA and NSROC, created these truly unique student flight opportunities that have reached thousands of students around the nation. All is not lost with Chris' departure. With approval from NASA HQ, SRPO and the Office of STEM Engagement will take over the management of these programs starting with the 2023 flight opportunities, see: https://www.nasa.gov/sounding-rockets/rocksat-programs. I am excited that we will be able to keep these programs going, and contributing to the future national STEM workforce.

The flight manifest for FY 2023 currently includes 22 flights, from four launch ranges and includes five disciplines; Astrophysics, Solar Physics, Geospace Science, Education and Technology test flights. SubTEC-9, scheduled for launch in the spring of 2023, is the next in the series of payload support systems test flights. The Technology Development section of this report details systems to be flown on this mission.

Two other technology flights are scheduled for FY 2023 to test a new vehicle configuration specifically aimed for Mesospheric research. The Science community has expressed a need for a type of vehicle that enables high launch cadence, is relatively easy to stage, is cost effective, and reaches altitudes of about 125 km. Our first design uses a single stage Orion, with a dart front-end housing the scientific instrumentation. The project named MesOrion, currently includes two test flights scheduled for launch in early 2023.

Other exciting missions we have lined up for FY 2023 include two flights for Dr. Bounds/University of Iowa. The Aurora Current and Electrodynamics Structure II (ACES II) includes a High Flyer and a Low Flyer, both Terrier-Black Brants, and will investigate various aspects of the Aurora Borealis. ACES II is scheduled to launch from Andøya Space, Norway in November 2022.

In February 2023 the launch window opens for the Vorticity Experiment or VortEX campaign for Dr. Lemacher. VortEX includes four launches, two Terrier-Orion and two Terrier-Black Brant vehicles. The science objective of VortEx is to characterize mesoscale dynamics (10-500 km) in the upper mesosphere and lower thermosphere (90-120 km), a region which also contains the Earth's turbopause. The rockets will be launched in salvos of one Terrier-Orion and one Terrier-Black Brant in close sequence when science conditions are favorable.

The Beam Plasma Interactions Experiment (Beam PIE), scheduled for launch from Poker Flat Research Range, AK in April 2023, aims to demonstrate, for the first time, advanced RF linear electron accelerator instrumentation for space experiments. This mission for Dr. Reeves/Los Alamos National Laboratory will fly on a four stage Black Brant XII-A vehicle.

These are only a subset of our planned flights. All manifested flights contribute to overall NASA science objectives and further our knowledge of our near space environment, as well as the farther reaches of space.

After leading this program for five years, I'm continuously awed by the expertise of the team, both civil service and contractor. The dedication to the mission, resilience, grit, and camaraderie exhibited by our team is exceptional. Every single person I witness, whether building hardware or managing missions, is fully engaged and doing their very best job to ensure missions fly successfully and safely. With that, I wish you the very best for the new year.

Giovanni Rosanova, Jr.

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Cover photo: Endurance launch, Svalbard, Norway

Credit: Leif Jonny Eilertsen/Andoya Space, Norway

Sounding Rockets Overview

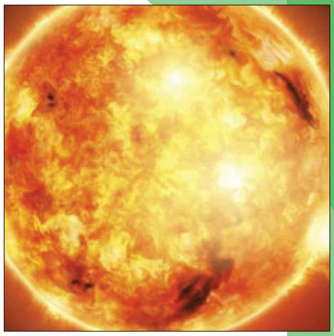
The Sounding Rockets Program supports the NASA Science Mission Directorate's strategic vision and goals for Earth Science, Heliophysics and Astrophysics. The 20+ suborbital missions flown annually by the program provide researchers with unparalleled opportunities to build, test, and fly new instrument and sensor design concepts while simultaneously conducting world-class scientific research. Coupled with a hands-on approach to instrument design, integration and flight, the short mission life-cycle helps ensure that the next generation of space scientists receive the training and experience necessary to move on to NASA's larger, more complex space science missions. The cost structure and risk posture under which the program is managed stimulates innovation and technology maturation and enables rapid response to scientific events.

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).

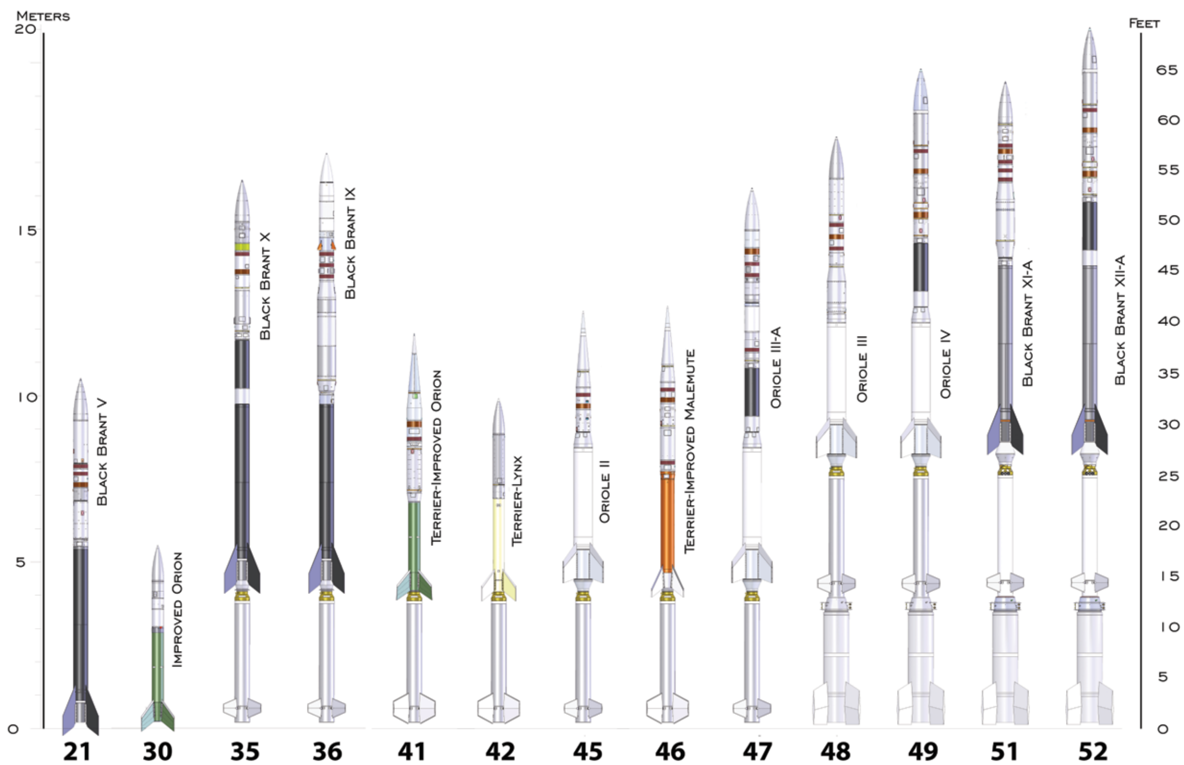
Additionally, sounding rockets are well suited for testing new technologies for future space missions. For example, parachute technologies for the Mars 2020 mission were tested on sounding rockets.

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.

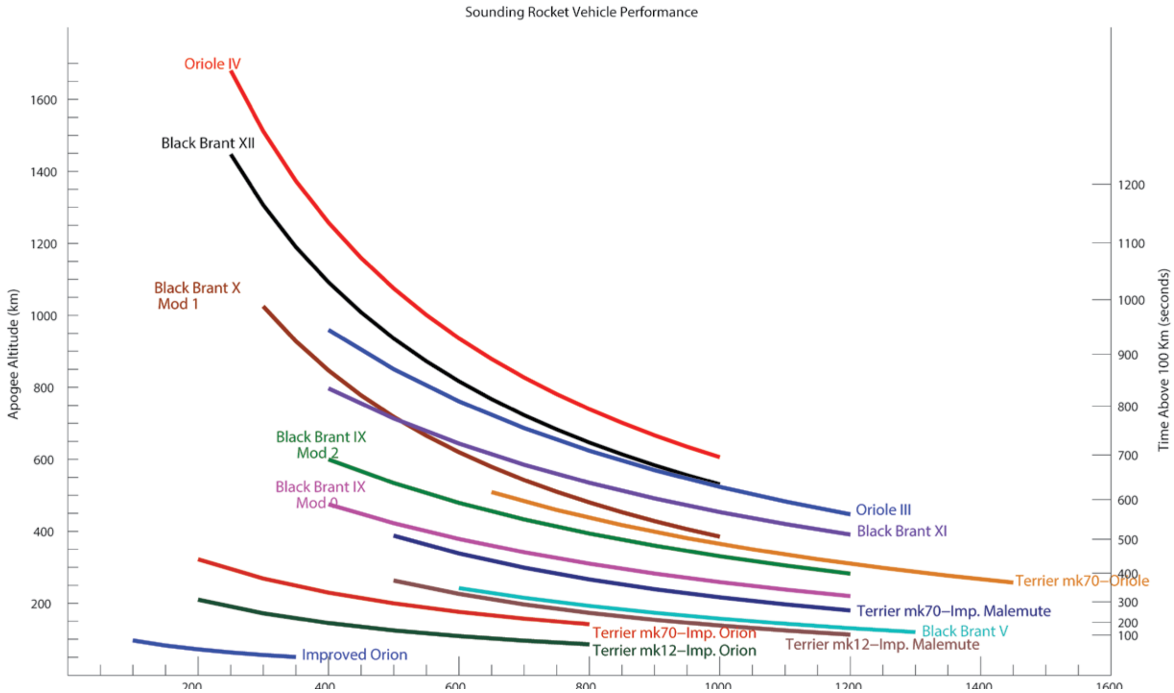
Extensive experience, over 2,500 missions flown, has lead to streamlined processes and efficient design, manufacturing and assembly techniques. Management and technical support is provided for all facets of a mission and includes engineering design, manufacturing, integration, and testing and evaluation. 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.
By NSROC Mechanical Section

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.
Photos by: Berit Bland/NSROC

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.
Photo by: Berit Bland/NSROC

Sub-systems

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

The boost guidance system controls the path of the rocket during the initial 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.

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

Magnetic Attitude Control Systems testing.
Photo by: Berit Bland/NSROC

compressed gas that is released through small nozzles located on the payload skin.

Open shutter door with instrument visible during testing at Wallops. Photo by: Berit Bland/NSROC

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.

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.

Payload recovery at White Sands Missile Range, NM. Photo by: Visual Information Branch/WSMR.

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

Testing and Evaluation

The launch and flight phases of a sounding rocket mission are 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, to a series of environmental elements such as vibration, bending, heating, spin, de-spin, and vacuum exposure.

Vibration Testing


Payload on vibration table.
Photo by: Berit Bland/NSROC

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.

Bend Testing


Bend testing of payload.
Photo by: Berit Bland/NSROC

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.

Spin Testing - Operational and Deployment


Payload with deployed booms and instruments.
Photo by: Berit Bland/NSROC

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

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

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.
Photo by: Berit Bland/NSROC

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.
Photo by: Berit Bland/NSROC

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.

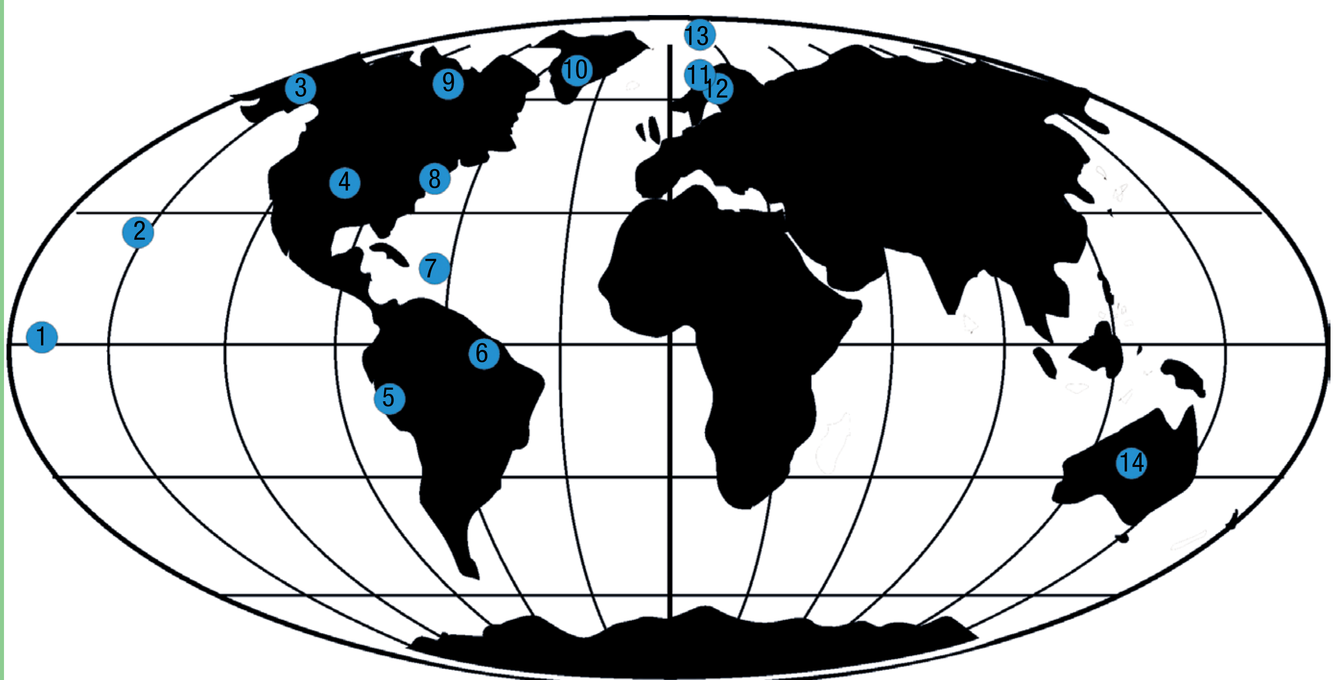
Payload ready to enter the thermal–vacuum chamber.
Photo by: Berit Bland/NSROC

Launch operations support

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

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

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



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

Endurance launches from Svalbard, Norway
Photo by; Brian Bonsteel/Wallops Imaging Lab

Astrophysics Missions 2022

NASA/ESA Hubble Space Telescope image of Alpha Centauri A (left) and Alpha Centauri B (right). The image was captured by the Wide Field and Planetary Camera 2 (WFPC2).

Credit: ESA/Hubble & NASA

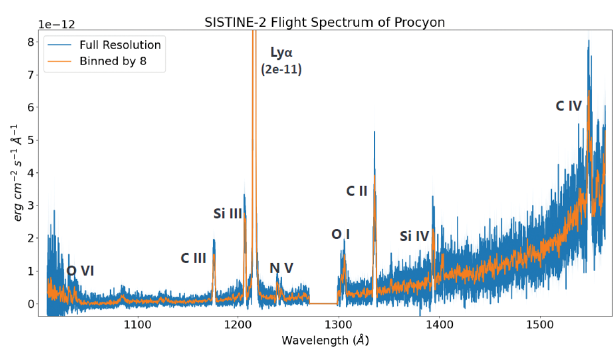
Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet host stars (SISTINE) 2

SISTINE 2 was successfully launched on a NASA sounding rocket on November 8, 2021 from the White Sands Missile Range in New Mexico.

SISTINE 2 was designed to make measurements of the ultraviolet radiation environment around low-mass stars. Characterization of exoplanet atmospheres, including the potential for habitability, requires an understanding of the interaction with the host star's ultraviolet (UV) radiation environment.

SISTINE team at White Sands.
Credit: Julia Gallegos/Visual Information Branch/WSMR.

F-type stars* are characterized by having a larger habitable zone (HZ) compared to stars of lower masses. The target for SISTINE-2 was the Procyon A+B binary star system composed of a late main sequence F-type star and a cool white dwarf companion. The primary target is Procyon A, with Procyon B as a secondary target. Procyon A is a good candidate for characterization of a low-to-intermediate mass star for which there are no models that accurately predict the FUV spectral energy distribution (SED). The SISTINE-2 flight data of Procyon A is shown at right, these data are currently being used to predict atmospheric escape rates from rocky exoplanets and will be published by lead graduate student Fernando Cruz-Aguirre in 2023.



SISTINE−2 flight data of Procyon A
Credit: Dr. France/University of Colorado

This was the second flight of SISTINE. SISTINE was refurbished after this flight and was flown again from Equatorial Launch Australia (ELA), near Nhulunbuy, Northern Territory in July of 2022.

* An F-type main-sequence star is a hydrogen-fusing star of spectral type F and luminosity class V. These stars have approximately 1.0 to 1.4 times the mass of the Sun and surface temperatures between 6,000 and 7,600 K. This temperature range gives the F-type stars a yellow-white hue.

Principal Investigator: *Dr. France/University of Coloardo* • ***Mission Number(s):*** *36.373 UG*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *November 8, 2021*

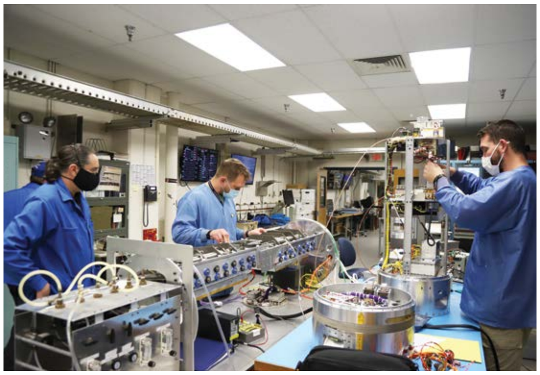
Diffuse X-ray emission from the Local galaxy (DXL)

X-rays from space bombard Earth on a daily basis. The sources and characteristics of these X-rays are not clearly understood. The purpose of the DXL mission was to investigate the sources of soft X-rays that speed towards Earth from elsewhere in our galaxy. Soft X-rays can make changes in the Earth's ionosphere which can disturb radio communications and the accuracy of GPS navigation systems. They have lower energy as compared to hard X-rays.

Very low energy diffuse X-rays from space are believed to come from two sources; the first source is located outside our solar system and is generated by remnants of multiple supernovae explosions forming what is now called the Local Hot Bubble region of our galaxy, the second source is within the solar system and is generated by the solar wind charge exchange. Data from DXL will be used to gain a better understanding of the nature and characteristics of these sources.

This was the fourth launch of the DXL instrument. The first flight in 2012 confirmed the Local Hot Bubble as a source of these X-rays. Data from the flight indicated that only about 40 percent of the soft X-ray background originates within the solar system, which means the LHB is the dominant source.

DXL team on Wallops Island before launch.
Credit: Wallops Imaging Lab



DXL integration.
Credit: Berit Bland/NSROC

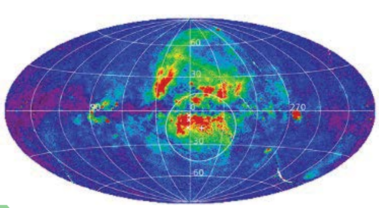
Principal Investigator: *Dr. Galeazzi/University of Miami*• ***Mission Number(s):*** *36.363 UH*
Launch site: *Wallops Island, VA* • ***Launch date:*** *January 9, 2022*

X-ray Quantum Calorimeter (XQC)

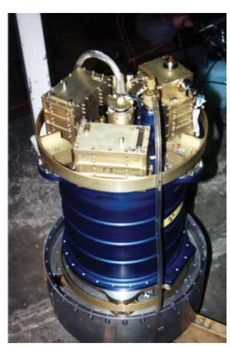
The night sky glows with X-ray light coming from all directions. Much of this diffuse X-ray background is produced by million-degree gas occupying regions of the interstellar medium, a complex mixture of atomic gases, molecules, and dust that fills the space between stars in our Galaxy. The unique X-ray detectors flown on the XQC mission, cooled to one-twentieth of a degree above absolute zero, measured the energies of arriving X rays ten times more accurately than current orbiting X-ray observatories, an improvement needed to better understand the interstellar medium and its influence on the structure and evolution of galaxies and stars.

For this seventh flight of XQC, the mission targeted an interesting region of bright X rays visible from the southern hemisphere with a launch from the newly established range at Arnhem Space Center in Australia. Scientists believe the X rays come from diffuse hot gas heated by supernovae, the brilliant eruptions of dying stars.

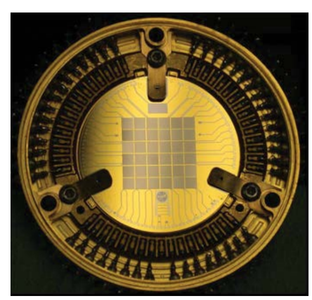
XQC team in Australia.
Photo by: Brian Bonsteel/Wallops Imaging Lab



Target: the Galactic center soft X–ray bulge.
Image provided by: Dr.McCammon/University of Wisconsin.



XQC 0.05 Kelvin refrigerator
Image provided by: Dr.McCammon/ University of Wisconsin.



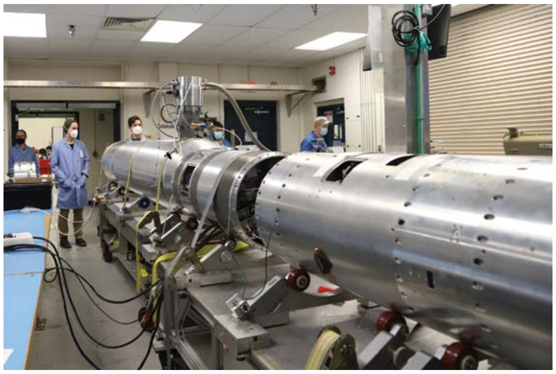
Microcalorimeter detectors
Image provided by: Dr.McCammon/ University of Wisconsin.

Principal Investigator: *Dr. McCammon/University of Wisconsin* • ***Mission Number(s):*** *36.347 UH*
Launch site: *Arnhem Space Center, Australia* • ***Launch date:*** *June 26, 2022*

Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet host stars (SISTINE) 3

SISTINE 3 was designed to make measurements of the ultraviolet radiation environment around low-mass stars and the effects of that UV on potential exoplanet atmospheres, including the gases thought to be signs of life.

SISTINE 3 measured the ultraviolet light output from α Centauri A and B, two stars of the three-star α Centauri system that are the closest stars to our Sun. A southern hemisphere launch was required to study these stars as they are not accessible from our standard northern hemisphere launch ranges. The data from this mission will be used in conjunction with the complementary data from the Dual-channel Extreme Ultraviolet Continuum Spectrograph (DEUCE) also launched from Australia and studying α Centauri.



SISTINE 3 during testing at NASA Wallops Flight Facility.
Photo by: Berit Bland/NSROC

SISTINE 3 launch from Arnhem Space Center, Australia.
Photo by: Brian Bonsteel/Wallops Imaging Lab

SISTINE 3 recovery, Arnhem Space Center, Australia.
Photo by: Brian Bonsteel/Wallops Imaging Lab

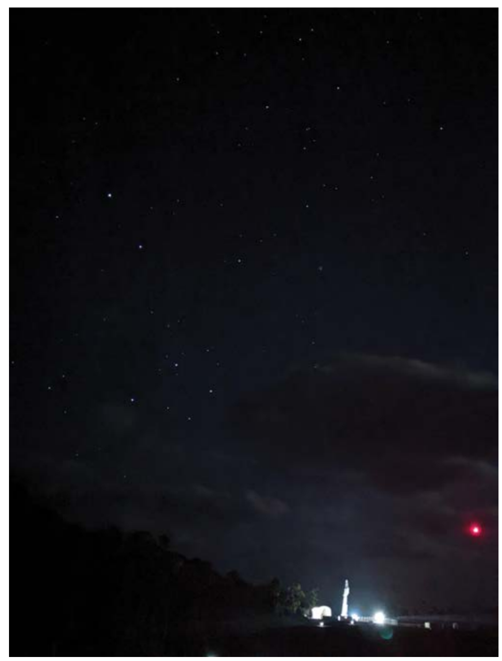
Principal Investigator: *Dr. France/University of Coloardo* • ***Mission Number(s):*** *36.339 UG*
Launch site: *Arnhem Space Center, Australia* • ***Launch date:*** *July 6, 2022*

Dual-channel Extreme Ultraviolet Continuum Spectrograph (DEUCE)

The DEUCE mission launched for the fourth and final time from the Arnhem Space Center in Australia as part of campaign to measure the 550 – 1050 angstrom EUV spectrum of the α Centauri A and B System, which contains the closest sun-like star to Earth. The EUV radiation output of stars other than the sun remains a large source of uncertainty for our understanding of the evolution of exoplanetary systems. This DEUCE launch data represents a unique input for models of planets orbiting sun-like stars.

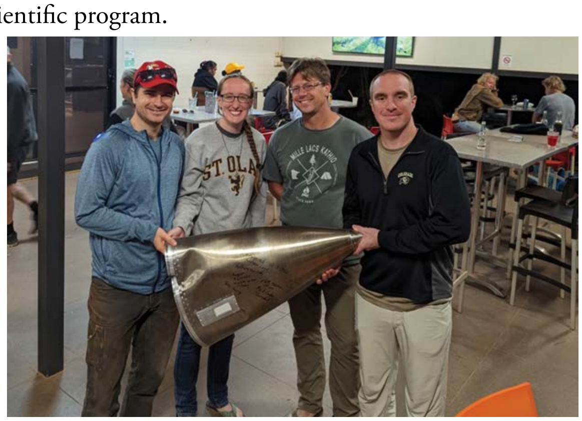
The University of Colorado DEUCE team posing in front of 36.350 on the launcher at the Equatorial Launch Australia (ELA) facility. From left to right: PhD student Alex Haughton, PI Brian Fleming, PhD student and project lead Emily Witt, and Engineer Alex Sico.
Photo by: Brian Bonsteel/Wallops Imaging Lab

The data from this mission will be used in conjunction with complementary data from the 36.339 Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet host stars (SISTINE) payload, which also launched from Australia to observe α Centauri. DEUCE successfully recorded a spectrum and was recovered to be returned to the University of Colorado for decommissioning.



The launcher raised and the Equatorial Launch Australia (ELA) site with the target star for both 36.339 SISTINE and 36.350 DEUCE, Alpha Centauri, visible overhead.

The DEUCE program flight tested the largest ever space science microchannel plate detector, a 200 x 200 mm cross delay line detector from Sensor Sciences, helping to qualify large format detectors for the next-generation of NASA missions. This final launch was also the 16th flight of the DEUCE telescope, dating back to 1989, including two previous launched from Woomera, Australia. Three PhD graduate students, two early career researchers, and several undergraduate students have been supported by this scientific program.



The somewhat tired University of Colorado team for 36.350 DEUCE posing with the nose cone right after the two–day recovery effort. The team is posing at the Gove Boat Club in Nhulunbuy, Northern Territory and spent the evening discussing the campaign and passing around the nose cones for photos with the locals. From left to right: PhD student Alex Haughton, PhD student and project lead Emily Witt, PI Brian Fleming, and Engineer Alex Sico.

DEUCE logo.
Credit: Dr. Fleming/University of Colorado

Principal Investigator: *Dr. Fleming/University of Colorado* • ***Mission Number(s):*** *36.350 UG*
Launch site: *Arnhem Space Center, Australia* • ***Launch date:*** *July 11, 2022*

Micro-X

Micro-X combines a high-energy-resolution X-ray microcalorimeter array with an imaging mirror to obtain non-dispersive X-ray imaging spectra from an astronomical source.

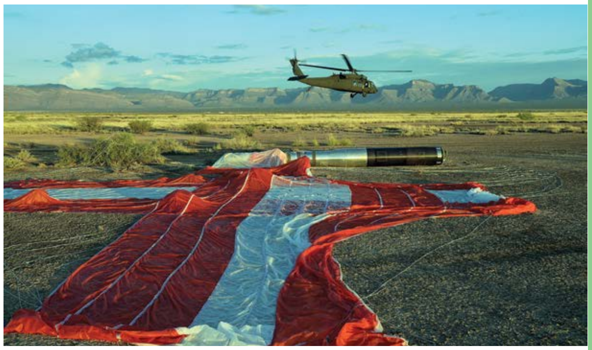
As a photon is absorbed in a microcalorimeter and its energy converted to heat, the resulting temperature rise can be measured by the resistance change of a Superconducting Transition Edge Sensor (TES). These microcalorimeters need to be cooled to temperatures of about a hundredth of a degree above absolute zero to function properly, while surviving the 10s of gs experienced during launch. In the X-ray band, high resolution spectroscopy has, with few exceptions, only been available for point sources. This leaves nearly all the brightest extended sources inaccessible for detailed study at the highest spectral resolution. Micro-X fills this need: the energy resolution of TESs combined with the imaging of the mirror means Micro-X can observe extended X-ray sources with unique sensitivity.

The goals of Micro-X are to:

- study Supernova Remnants and dark matter interactions using high energy resolution X-ray observations
- advance the technology readiness level of TES detectors and Superconducting Quantum Interference Device (SQUID) readout technologies for future space operations

This, the second flight of Micro-X, targeted the Cassiopea A Supernova Remnant (SNR). The flight achieved comprehensive success, and obtained the first astronomical X-ray spectra using TES technology. This data is under active analysis and will be published in 2013. The Micro-X program also flew the first TES and SQUID multiplexers in space in its maiden flight in 2018.

Micro–X team at WSMR, NM.
Photo by: Visual Information Branch/WSMR



Payload after impact with recovery helicopter.
Photo by: Visual Information Branch/WSMR

Micro–X recovery operations.
Photo by: Visual Information Branch/WSMR

Principal Investigator: *Dr. Figueroa/Northwestern University* • ***Mission Number(s):*** *36.355 UH*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *August 22, 2022*

The Rockets for Extended-source X-ray Spectroscopy I (tREXS I)

The Rockets for Extended-source X-ray Spectroscopy (tREXS) are a series of suborbital rockets designed by the McEntaffer group at Penn State to observe soft-X-ray emission from extended astronomical sources such as supernova remnants. The first flight of tREXS, tREXS I, observed the Cygnus Loop Supernova Remnant from White Sands Missile Range on September 26th, 2022, at 04:10 GMT. An image of Cygnus taken by ROSAT is shown in Figure 1. As a relatively close, middle-aged SNR, the Cygnus Loop offers an excellent target to study the evolution of SNRs and the interaction of the SNR ejecta with the surrounding interstellar medium (ISM). The Cygnus Loop SNR is thought to have originated from a core-collapse supernova in a pre-existing cavity created either from precursor winds or as the result of a natural void between interstellar clouds.

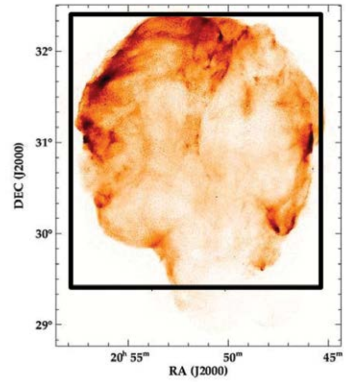


Figure 1: Cygnus Loop viewed by ROSAT in the X–ray. The black square represents the field of view of the tREXS instrument. Image credit: Levenson, N. A., J. R. Graham, and S. L. Snowden (1999) "The Cygnus Loop: A Soft–shelled Supernova Remnant," The Astrophysical Journal, 526(2), pp. 874–880.

The instrument onboard tREXS I is a soft-X-ray spectrometer designed and built at Penn State that utilizes mechanical beam-shaping optics, reflection gratings, and 11 large-format CMOS sensors to detect emission from diffuse X-ray sources. The spectrometer is optimized for X-ray emission lines from hot (≈1 million Kelvin) astrophysical plasmas, such as those present in supernova remnants. Key X-ray emission lines, such as O VII, O VIII, C VI, and N VI can be used as diagnostics to better understand the physical characteristics of the plasma, such as the temperature, abundances, and density.

The mechanical beam-shaping optics (MBS) onboard tREXS I consist of two identical modules made up of 45 precisely aligned nickel plates. Each plate consists of 241 wires with a certain width and period. An image of one of the nickel plates is shown on the left side of Figure 2. The right side of Figure 2 shows the 45 plates aligned into the MBS module. The positioning of the wires and plates inside the module act to block light that is not converging to a designed focus. Figure 3 shows the front of an MBS module as more plates are aligned and bonded. Note the central line becoming smaller until it is too small to be seen in the image with all 45 plates.

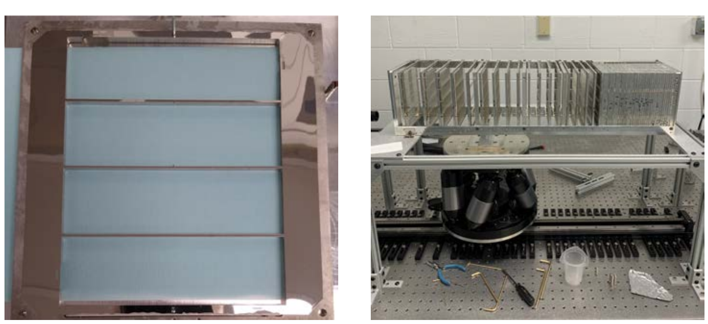


Figure 2: Left: Electroformed nickel plate consisting of 241 ~0.1 mm wide wires. The nickel plate is mounted onto an aluminum frame for mechanical support. Right: A tREXS MBS module with all 45 plates aligned and bonded into the support structure.

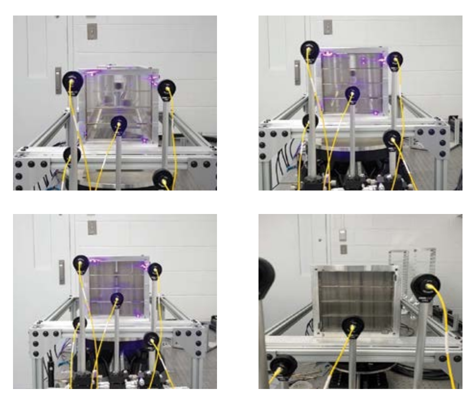


Figure 3: tREXS MBS module as plates are aligned. Note the central line becoming narrower as more plates are added. Top left: 3 plates; top right: 15 plates; bottom left: 28 plates; bottom right: 45 plates.

Principal Investigator: *Dr. McEntaffer/Pennsylvania State University* • ***Mission Number(s):*** *36.367 UH*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *September 26, 2022*

After the MBS modules scuplt a converging beam, the X-rays reach modules of X-ray reflection gratings that diffract the X-rays according to their wavelength to produce a spectrum. The X-ray reflection gratings were produced at Penn State's Nanofabrication Lab in the Materials Research Institute. Nanofabrication techniques such as electron-beam lithography, reactive ion plasma etching, chemical etching, and electron-beam evaporation are required to produce X-ray reflection gratings due to their small periods, ≈180 nanometers, and feature sizes, ≈80 nanometers. A scanning electron microscope (SEM) image of a test grating representative of the tREXS flight gratings is shown in Figure 4. The sawtooth profile of the grooves shown in the image is the result of a potassium hydoxide wet chemical etch. The groove profile is representative of a blazed grating, which preferentially diffracts light in a certain direction to increase throughput of certain wavelength/order combinations.

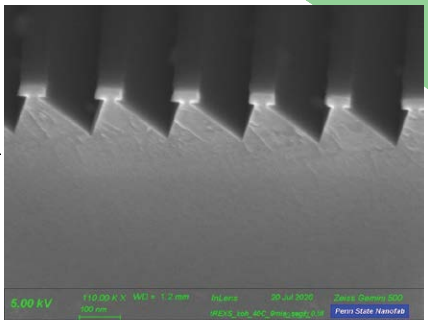


Figure 4: Scanning Electron Microscope (SEM) image of a sample grating that is representative of the tREXS flight gratings. The grating was plasma etched into crystal silicon and the sawtooth profile created using a potassium hydroxide wet etch. The period of the grating is 181 nanometers.

Two master gratings were produced at Penn State which were then replicated 100 times each using Substrate Conformal Imprint Lithography (SCIL) by Philips in the Netherlands. The grating replicas were coated with a 15-nm layer of Ni for X-ray reflectivity and then diced into 109 x 100 mm rectangles out of the 150-mm diameter fused silicon wafer they were replicated onto. The replicas were aligned and bonded into two stacks of 38 gratings, shown in Figure 5. The MBS and grating modules were aligned to one another on a 20" bulkhead using a coordinate measuring machine (CMM) contact measurement arm, shown in Figure 6.

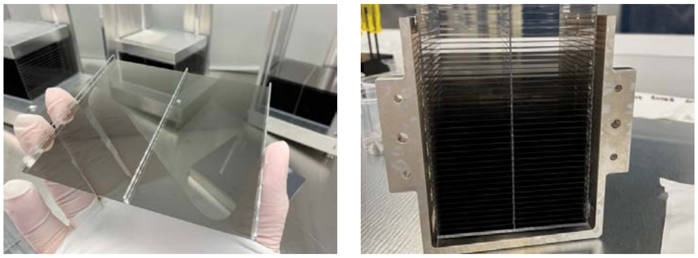


Figure 5 Left: tREXS grating replica after nickel deposition and dicing. Three fused silica spacers were bonded to the surface of the grating for alignment purposes: Right: Completed grating module stack consisting of 38 gratings.

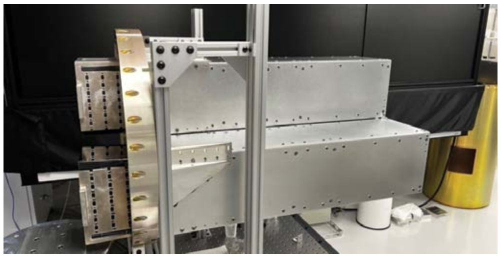


Figure 6: The aligned MBS and grating modules. X–rays enter the MBS modules from the right and travel to the grating arrays in the left side of the image.

The final component of the instrument is the camera at the focal plane. The camera consists of 11 CMOS X-ray detectors made by e2V, the CIS113 Vega, and a custom electronics package designed and built at Penn State. Each detector has ≈8.8 million 16-um pixels and is approximately 70 x 30 mm. The fully assembled camera is ≈100 Megapixels and covers 23 cm2. The camera's size and location are designed to capture the relevant X-ray lines coming from the gratings for the emission lines of interest in Cygnus and similar astrophysical plasmas. The camera is shown in Figure 7.

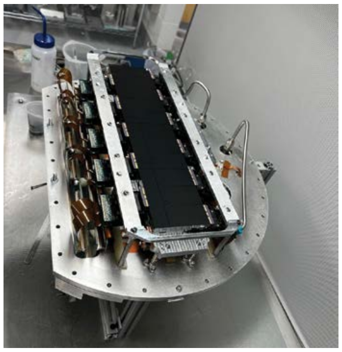


Figure 7: tREXS focal plane camera. The camera consists of 11 CMOS X–ray detectors with approximately 100 million pixels and a physical footprint of 23 cm2.

tREXS I completed integration and testing at Wallops Flight Facility in late August 2022 before making its way to White Sands Missile Range for a late September launch. The payload was successfully recovered post launch and the flight data analysis is currently underway.

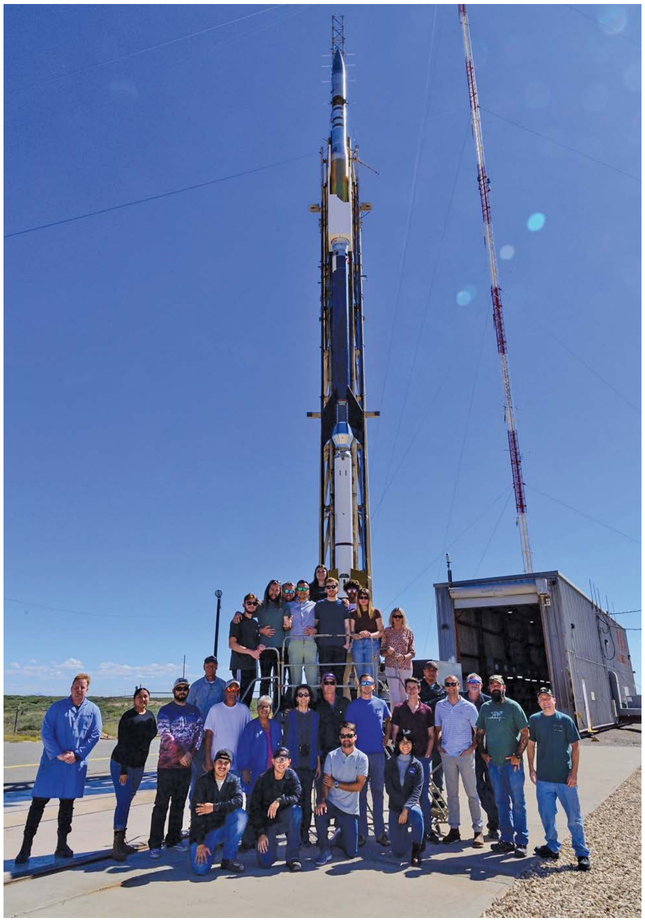


Figure 8: tREXS team made up of the McEntaffer group from Penn State and personnel from NASA's Sounding Rockets Program Office, White Sands Missile Range, and the NASA Sounding Rockets Operations Contract.

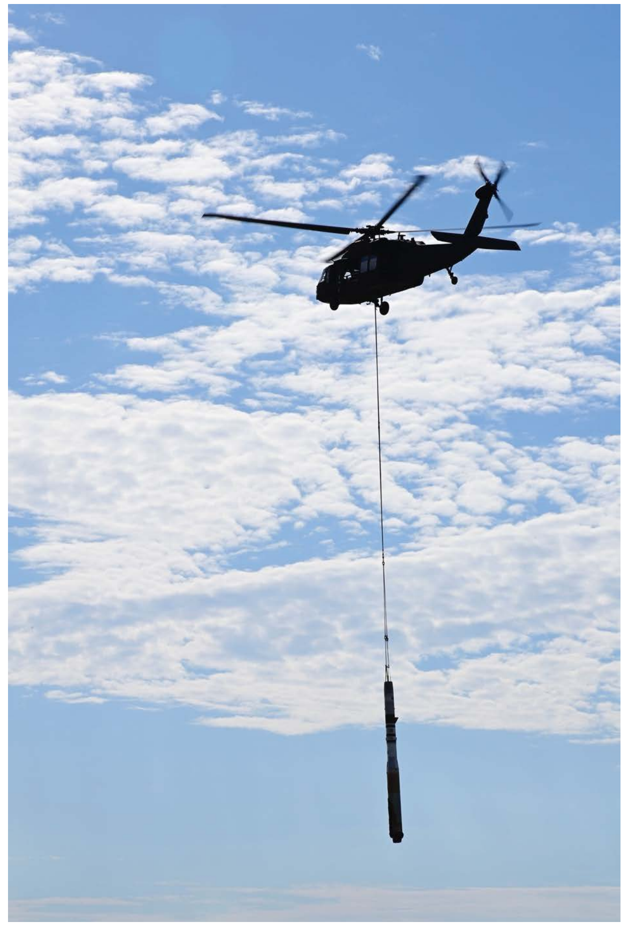
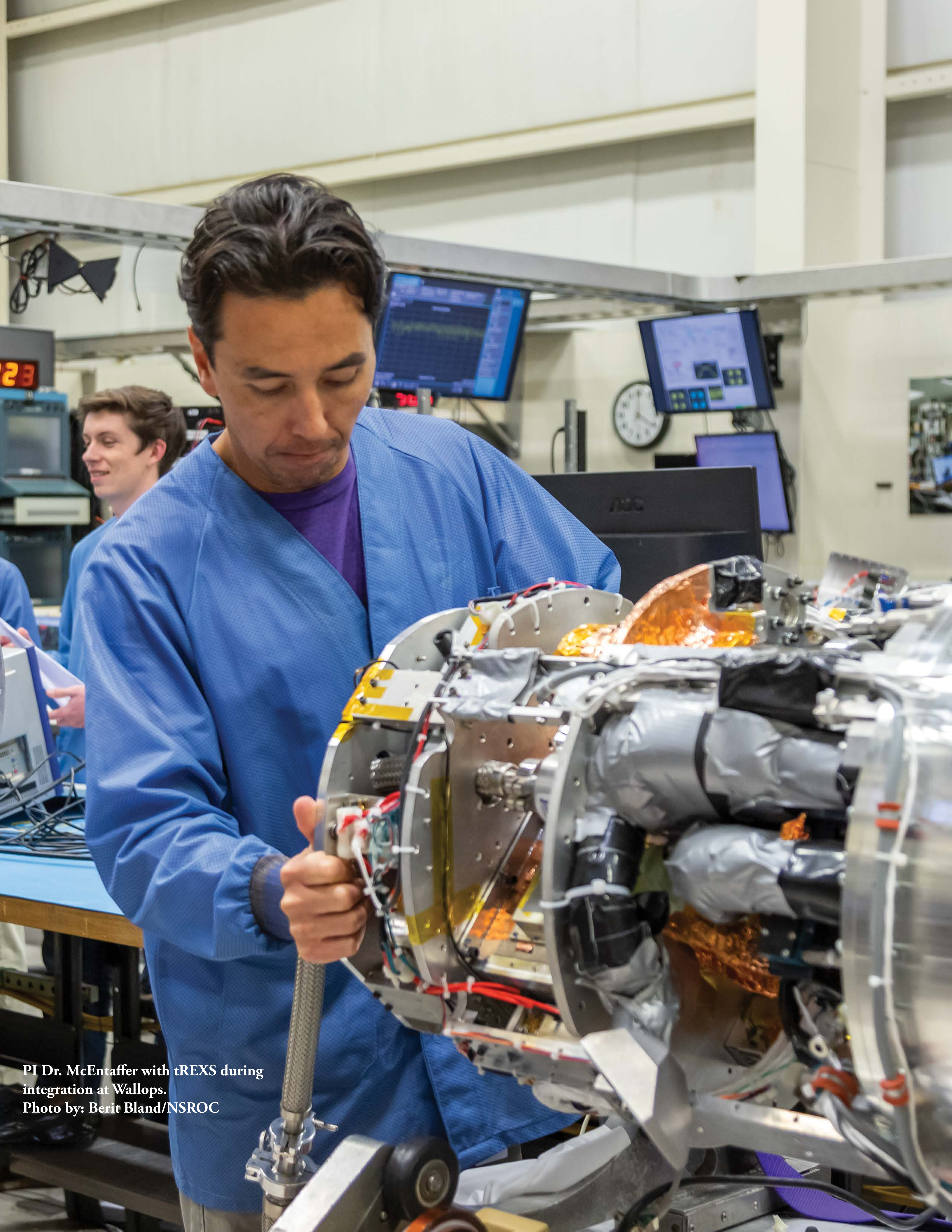


Figure 9: the tREXS payload being moved out of muddy ground during recovery so the helicopters could safely land.

Figure 10: tREXS recovery team.



PI Dr. McEntaffer with tREXS during integration at Wallops.
Photo by: Berit Bland/NSROC

Geospace Missions 2022

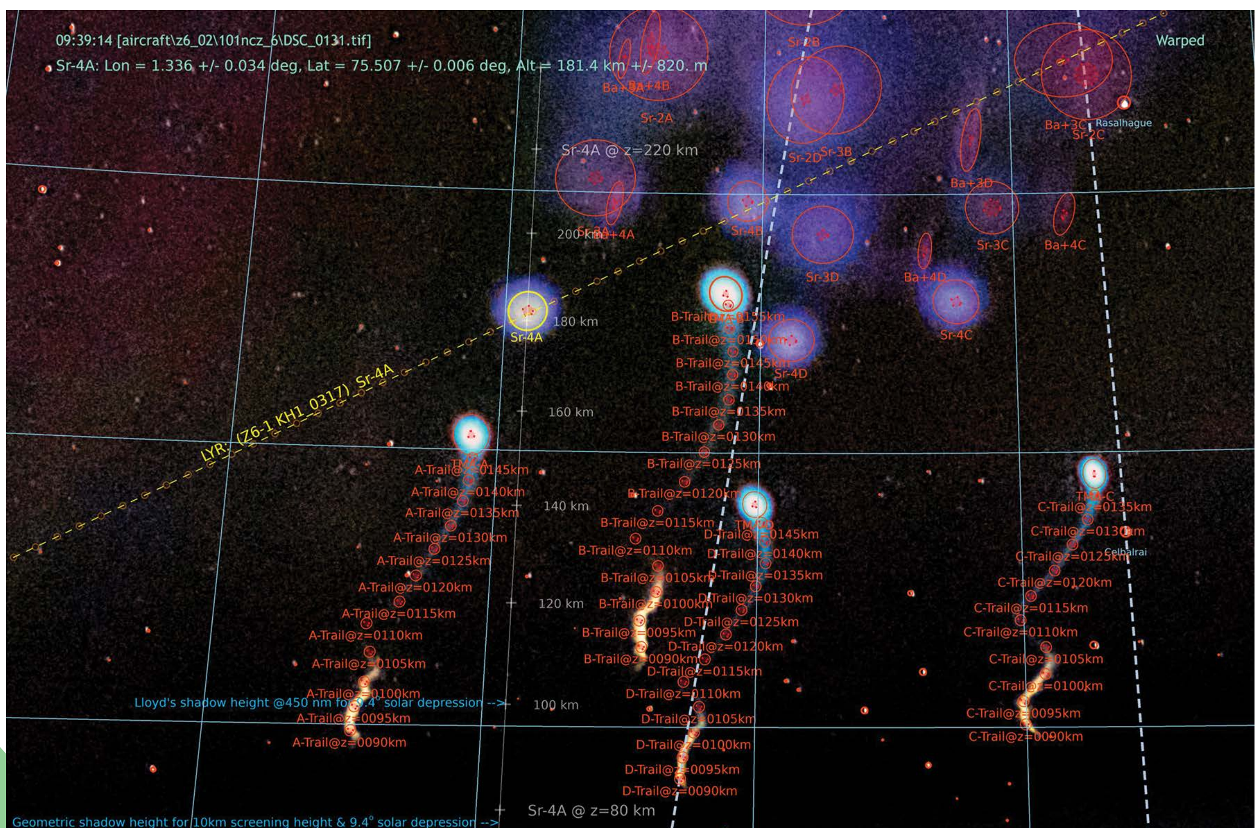
Aurora over Poker Flat Research Range, AK
Photo by: Terry Zaperach/Wallops Imaging Lab

Cusp-Region Experiment 2 (C-REX 2)

The scientific objective of C-REX-2 was to identify mechanisms that create a region of enhanced mass density at 400 km altitude that appears to be a permanent feature of Earth's cusp-region thermosphere. This phenomenon is currently a major scientific puzzle because, although models suggest ways in which the increased mass could be supported against gravity, these mechanisms should have easily visible signatures -- which have yet to be observed in the real atmosphere. The rocket launched from Andoya Space Center on December 1, 2021, and flew northward out over the Greenland Sea. It carried a combination of payload instruments that characterized the ionosphere, as well as a salvo of ejected sub-payloads that released vapor tracers to track neutral winds and ion drifts. All instruments functioned correctly. The resulting data are rich and complex, and analysis is ongoing.

C–REX 2 integration at NASA Wallops.
Photo by: Berit Bland/NSROC

Camera setup onboard aircraft to image vapor tracers.
Photo by: Dr. Conde



Example of triangulation analysis of some of the tracer clouds.
Photo by: Dr. Conde

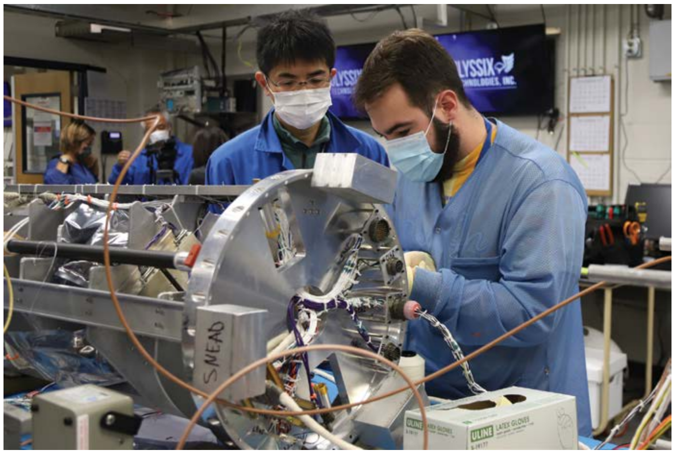
Principal Investigator: *Dr. Conde/University of Alaska* • ***Mission Number(s):*** *49.004 UE*
Launch site: *Andoya Space, Norway* • ***Launch date:*** *December 1, 2021*

Loss through Auroral Microburst Pulsations (LAMP)

The overall objective of the Loss thru Auroral Microburst Precipitation (LAMP) mission was to measure pulsating aurora, the highest energy aurora, to investigate if it plays a role in emptying the radiation belts.

The mission studied the spatial distribution of auroral microbursts with respect to pulsating patches, and characterize the precipitating electron energy distribution. LAMP accomplished this by observing pulsating aurora with a suite of instruments to examine auroral electrons, plasma, magnetic fields, and the optical components of the pulsating aurora.

Additional ground based instruments, including all sky cameras, high frame rate cameras, magnetometers at both Poker Flat Research Range and Fort Yukon, provided additional data to characterize the aurora.



LAMP integration at NASA Wallops.
Photo credit: Berit Bland/NSROC

LAMP launch from Poker Flat Research Range, AK.
Photo credit: Terry Zaperach/Wallops Imaging Lab

Principal Investigator: *Dr. Halford/NASA GSFC* • ***Mission Number(s):*** *36.351 GE*
Launch site: *Poker Flat Research Range, AK* • ***Launch date:*** *March 5, 2022*

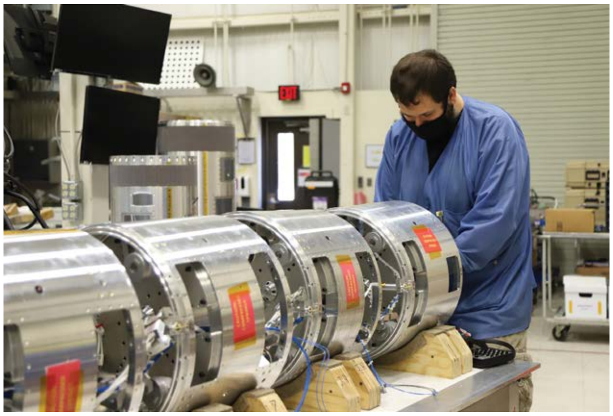
Ion-Neutral Coupling During Active Aurora (INCAA)

The science objective for the INCAA sounding rocket mission was to understand the interactions between the plasma and the neutral atmosphere during active aurora, and how this interaction affects energy deposition in the E-region ionosphere.

The measurement strategy was to measure the ion demagnetization altitude and altitude resolved Joule heating rate. The mission measured all terms in the ion momentum equation with altitude resolution of less than one kilometer, and also used complimentary groundbased instrumentation from incoherent scatter radar and Fabry Perot interferometers to quantify the local ionospheric state parameters and regional neutral wind morphology, respectively.

The objective was to understand a single event with many measurements and use this event as a representative case. To accomplish these science objectives, the mission used two sounding rocket payloads launched from Poker Flat Research Range, AK: an instrumented payload 46.031 that contained a suite of plasma and neutral instrumentation and the chemical tracer payload, 36.360.

The experiments on the instrumented payload were provided by collaborators from Clemson University, University of California – Berkeley, and University of Calgary. The payloads launched within 10 minutes of each other. In addition to ground-based imagers and magnetometers, FPI network and, to the extent possible, the Poker Flat Incoherent Scatter Radar (PFISR) were used to assist in the launch decision.



INCAA integration at NASA Wallops.
Photo by: Berit Bland/NSROC

INCAA vapor trails.
Photo provided by Dr. Kaeppler

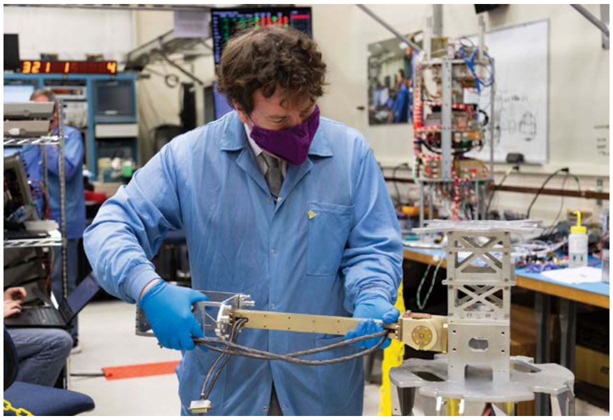
Principal Investigator: *Dr. Kaeppler/Clemson University* • ***Mission Number(s):*** *36.360 & 46.031 UE*
Launch site: *Poker Flat Research Range, AK* • ***Launch date:*** *April 7, 2022*

Endurance

The objective of Endurance was to make the first measurement of the weak "ambipolar" electric field generated by Earth's ionosphere. This field is thought to play a critical role in the upwelling and escape of ionospheric ions, and thus potentially in the evolution of Earth's atmosphere. The results will enable us to determine the importance to ion escape of this previously unmeasured fundamental property of our planet, which will aid in a better understanding of what makes Earth habitable. Endurance carried six science instruments to measure the total electrical potential drop below the spacecraft, and the physical parameters required to understand the physics of what generates the ambipolar field. The mission was be supported by simultaneous observations of solar and geomagnetic activity, and by the European Incoherent Scatter Scientific Association (EISCAT) Radar array. Endurance's flight was a success, with all instruments deploying, functioning well, and returning good data. Analysis of Endurance data is currently ongoing.

The flight was the first on a Terrier-Oriole-Nihka (Oriole III-A).

Endurance build–up before launch in Svalbard.
Photo credit: Brian Bonsteel/Wallops Imaging Lab



Endurance integraion at NASA Wallops.
Photo credit: Berit Bland/NSROC

Endurance comms test in Svalbard, Norway.
Photo credit: Brian Bonsteel/Wallops Imaging Lab

Principal Investigator: *Dr. Collinson/NASA GSFC* • ***Mission Number(s):*** *47.001 GE*
Launch site: *Svalbard, Norway* • ***Launch date:*** *May 11, 2022*

SpEED Demon

Sporadic E Electro Dynamics Demonstration (SpEED Demon) mission, was a technology demonstration mission for the future Sporadic E Electro Dynamics (SEED) campaign, scheduled for Kwajalein, Marshall Islands in Summer 2024.

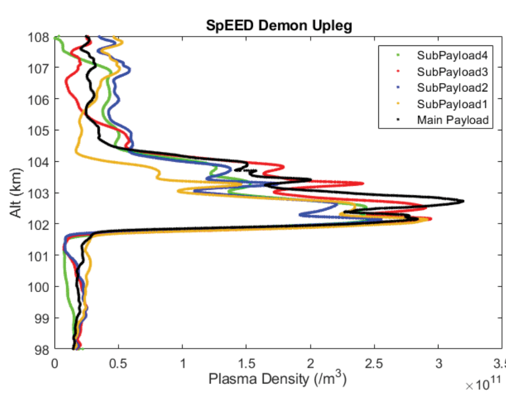
The main payload was comprehensively instrumented for plasma and neutral dynamics measurements: a Sweeping Langmuir Probe for plasma density and electron temperature, a pair of multi-Needle Langmuir Probes for 5 KHz electron density, Positive Ion Probe for relative ion density, ionization gauges and sensitive accelerometers for background neutral density, a suite of sensitive magnetometers, and a pair of electric field measurements. The main payload ejected four instrumented sub payloads, each carrying an ion density measurement along with a sensitive magnetometer and an accelerometer capable of performing 'falling sphere' analogous neutral density measurements.

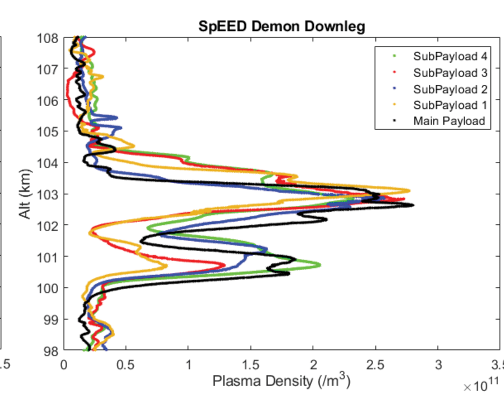
SpEED Demon's goal was to reduce risk surrounding new experiment instrumentation and possibly capture comparative mid-latitude science with in-situ measurements of sporadic E (E_S) layers with the same instruments planned for flight on SEED.

Overall science objectives included:

- Measure the in-situ spatial patchiness of the E_S layers at mid-latitude.
- Detect and measure the magnitude of any field aligned currents associated with E_S layers at mid-latitude.

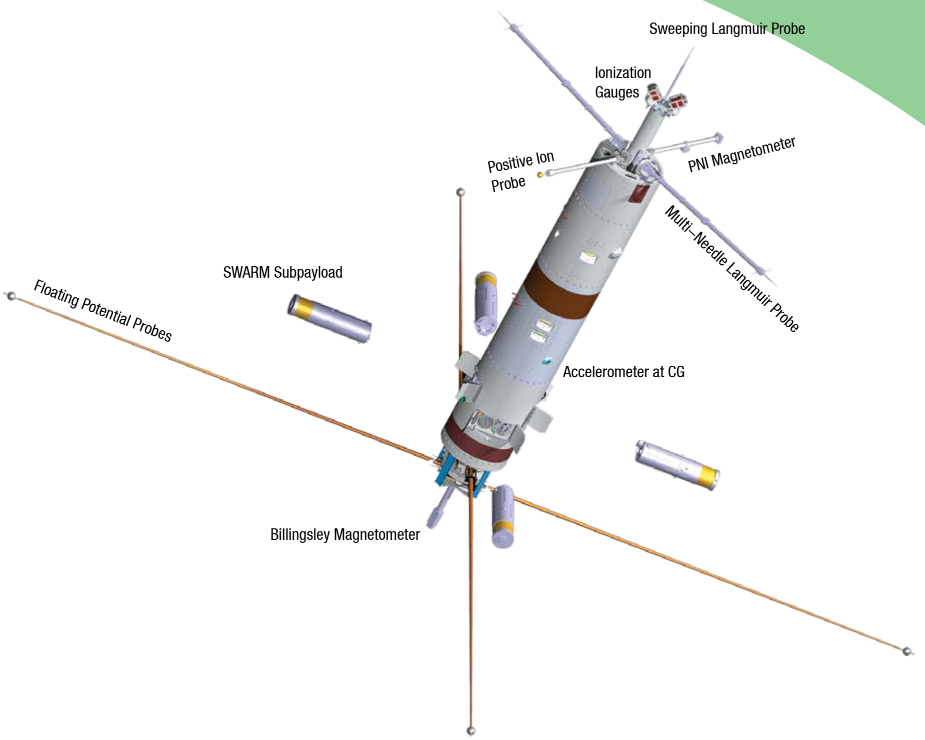
Ground based observations from the VIPIR radar and Wallops Digisonde were used to monitor the overhead ionosphere, and Haytsack Radar at Millstone Hill provided magnetically connected F region observations. The rocket was launched on Aug 24, 2022 at 01:16 GMT and the payload flew through an E_S layer on both upleg and downleg. All four instrumented subpayloads along with the main payload observed the Es layer in-situ as shown in the preliminary data plots here. The subpayloads were within ~100 m of the main payload during the upleg E_S layer passage and spatially separated by ~1 km from the main payload during the downleg E_S layer passage. SpEED demon marked the *first simultaneous multi-point in-situ observations of E_S layers from 5 spatially separated points.*





Preliminary data plots show E_S on both upleg and downleg as observed by all subpayloads and the main payload.
Plots provided by Dr. Barjatya

Principal Investigator: *Dr. Barjatya/Embry Riddle* • ***Mission Number(s):*** *46.025 UE*
Launch site: *Wallops Island, VA* • ***Launch date:*** *August 24, 2022*

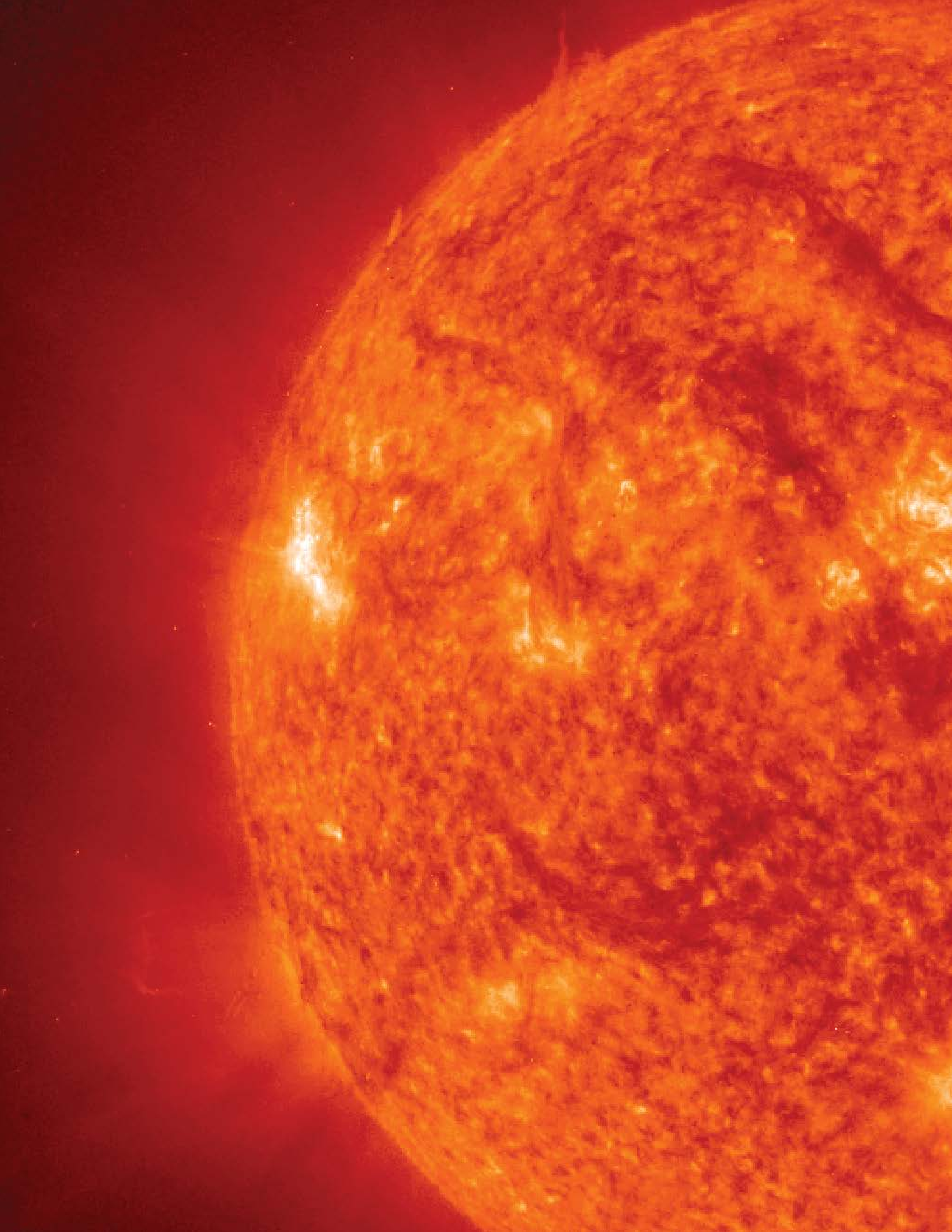


SpEED Demon payload model.
Image provided by Dr. Barjatya/Embry Riddle.

Dr. Robert Clayton/Embry Riddle and Felissa Selby/NSROC working on the SpEED Demon payload.
Photo by Dr. Barjatya/Embry Riddle.

Instrumented subpayloads.
Photo by: Dr. Barjatya

Sounding Rocket Symposium participants (back row) and SpEED Demon payload team (front row) in front of the Terrier–Improved Malemute with payload on Wallops Island.
Photo by: Berit Bland/NSROC




Solar Physics 2022

Chromospheric LAyer Spectro-Polarimeter 2.1 (CLASP 2.1)

The aim of CLASP 2.1 was the mapping of circular polarization of the Mg II h & k lines from a solar active region caused by scattering and magnetic effects. The wavelength range of CLASP2.1 is 279.2 — 280.7 nm.

CLASP 2.1 team at White Sands Missile Range, NM.
Photo by: Mike Smith, WSMR Visual Information Branch

Magnetism drives much of the Sun's activity, such as solar flares, and the objective of CLASP 2.1 was to measure the magnetic field of the chromosphere, an important and poorly understood layer of the Sun's atmosphere.

Flares and other activity on the Sun's surface can affect people both on Earth and in space. While harmful radiation from a flare can't pass through Earth's atmosphere to physically affect people on the ground, these bursts of radiation can interfere with radio and GPS signals. Extremely intense solar activity can even cause power outages. The massive doses of radiation that accompany solar flares also pose a threat to astronauts outside the protection of Earth's magnetic field. By understanding the magnetic field in the Sun, we can learn to predict when these events are going to happen. The information could help scientists warn energy companies about high-risk events or tell astronauts when it's safe to do a spacewalk.

CLASP 2.1 was designed to measure the effects of the magnetic field in the chromosphere, where super-hot solar material emits ultraviolet light. The Sun-gazing CLASP telescope feeds ultraviolet light to a spectrograph. In the presence of a magnetic field, spectral lines sometimes split (Zeeman effect). This splitting of spectral lines also polarizes the light, and causes individual light waves to oscillate in a certain direction, or even in a circular motion.

The design of the CLASP telescope and spectrometer allows precise measurements of the polarization, in multiple spectral lines formed in the chromosphere, and thus provides a means to probe the magnetic field at multiple layers of the Sun's atmosphere simultaneously. This technique was demonstrated in the 2019 flight of CLASP2 (36.332 NS/McKenzie); the CLASP2.1 mission in 2021 took advantage of a novel implementation of the SPARCS pointing systems to achieve these "spectro-polarimetric" measurements of magnetism across a much wider area than previously achieved.

Principal Investigator: *Dr. McKenzie/NASA MSFC* • ***Mission Number(s):*** *36.374 NS*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *October 8, 2021*

HElium Resonance Scatter in the Corona and HELiosphere (HERSCHEL)

The HElium Resonance Scatter in the Corona and HELiosphere (HERSCHEL) program was designed to investigate:

1. Origin of the slow solar wind.
2. Variation of helium abundance in coronal structures.
3. Facilitate future investigation of Coronal Mass Ejections (CMEs), kinematics, and solar cycle evolution of the electron, proton, and, helium corona.

Instruments included in HERSCHEL:
HERSCHEL Helium Coronagraph (HECOR): Externally occulted coronagraph with no re-imaging optics operating at 30.4nm.

Sounding CORonagraph Experiment (SCORE): Externally occulted coronagraph with re-imaging optics (including internal occulter, field stop, and Lyot stop) operating at 34.4nm, 120nm, and broadband visible.

HERSCHEL EUV Imaging Telescope (HEIT): Narrow band EUV imager operating at 30.4nm, 28.4nm, 18.5nm and 17.3nm (SECCHI EUVI "lab model").

HERSCHEL team at White Sands Missile Range, NM.
Photo by: Visual Information Branch/WSMR

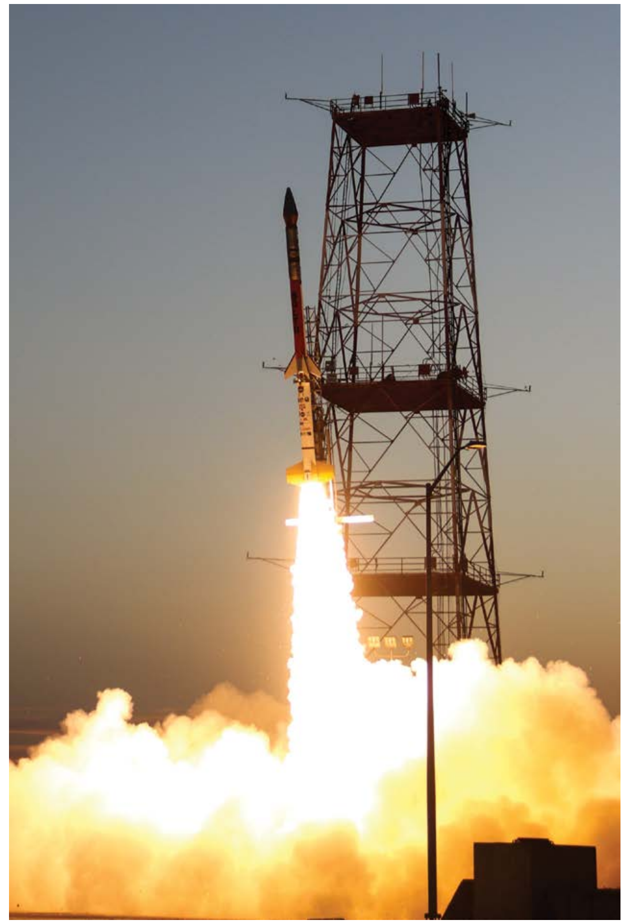
HERSCHEL recovery operations.
Photo by: Visual Information Branch/WSMR

Principal Investigator: *Dr. Tun/Naval Research Laboratory* • ***Mission Number(s):*** *36.307 DS*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *March 9, 2022*

Reimbursable Missions 2022

Boundary Layer Turbulence 2 (BOLT 2) on the rail on Wallops Island, VA
Photo by: Wallops Imaging Lab

Boundary Layer Turbulence 2 (BOLT 2)


BOLT–2 launch from Wallops Island, VA.
Photo by: Terry Zaperach/Wallops Imaging Lab

Critical to understanding heating on high speed vehicles is the need to understand high-speed boundary layer turbulence because the heating rate through a turbulent boundary layer is 5 to 8 times higher than that through a laminar boundary layer resulting in greater demands on surface materials for high-speed vehicles. This phenomenon is impossible to replicate in today's ground wind tunnel facilities and, therefore, the BOundary Layer Turbulence (BOLT) 2 project, led by Texas A&M, was established to explore measurements of high-speed turbulence in flight on a sounding rocket, integrated and launched by the NASA Wallops Flight Facility. The flight geometry, a non-axisymmetric, concave surface with swept leading edges, manufactured and instrumented by CUBRC, was specifically chosen to elicit complex physics that emerge due to this shape and relevant to the Department of the Air Force. BOLT 2, launched on a Terrier/Improved Malemute stack, successfully reached the Mach and Reynolds numbers desired in order to study high-speed turbulence. The BOLT 2 flight geometry featured over 400 channels of data that, for the first time, measured heat flux, high-frequency pressure, skin friction and temperature data over two scientific windows of flight. This data is also part of a first-ever comparison of pre-flight data from a wind tunnel entry in the CUBRC, a collaborator with Texas A&M, LENS II facility to the flight data using identical hardware for an unprecedented uncertainty quantification opportunity.

This mission was highly successful and excellent science was obtained. Collaborative participation with the Air Force Research Laboratory, NASA Langley Research Center, University of Arizona, University of Maryland, University of Minnesota, University of Queensland and the US Air Force Academy, significantly contributed to the informed placement of the sensors to capture salient physics. In close coordination of the BOLT 2 flight experiment, several stratospheric weather measurement teams, led by University of Colorado Boulder and Honeywell, were acquiring in-situ and remote data, respectively, to characterize the freestream conditions, a known contributor to high-speed turbulent behavior. Measurements included the traditional state variables (pressure, temperature, wind velocity) using light detection and ranging (LIDAR) but also freestream turbulence intensity and particulate size and concentrations using weather balloons.

Principal Investigator: *Dr. Bowersox/Texas A&M University* • ***Mission Number(s):*** *46.027 DR*
Launch site: *Wallops Island, VA* • ***Launch date:*** *March 21, 2022*

The project was in memory of Dr. Michael Holden, a long-time contributor to the understanding of all aerodynamic flows but, especially, very high-speed flows. His mark on the project is the first-ever pre-flight test of a flight geometry in a wind tunnel. His mark on the world is the knowledge he brought to the high-speed aerodynamic community, the US Olympic ski team and decades of mentoring the next generation of aerodynamicists.

BOLT–2 team in front of the Terrier–Improved Malemute launch vehicle on Wallops Island, VA.
Photo by: Terry Zaperach/Wallops Imaging Lab

Education Missions 2022


Level 1
RockOn!
Level 2
RockSat-C
Level 3
RockSat-X

RockOn & RockSat-C

The RockOn! workshop was conducted virtually in 2022. This was the 14th 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.

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.

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.

Cubes in Space is a program for middle school students that allows them the opportunity to design an experiment that fits in a 40 x 40 x 40 mm cube. The cubes were flown inside the nose cone of the RockOn payload. Seventy-five middle school experiments, with approximately 375 participating students, were flown on the RockOn! mission.

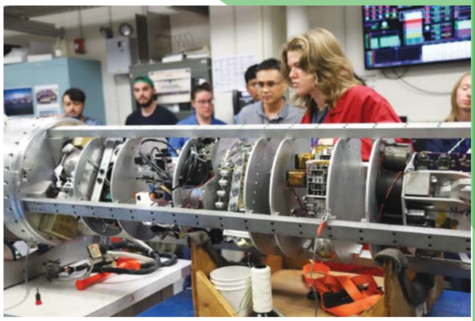
Photos by: Berit Bland/NSROC

Student flight opportunities website: https://www.nasa.gov/sounding-rockets/rocksat-programs

Principal Investigator: *Mr. Koehler/Colorado Space Grant Consortium* • ***Mission Number(s):*** *41.131 UO*
Launch site: *Wallops Island, VA* • ***Launch date:*** *June 24, 2022*

RockSat-X

RockSat-X was successfully launched from Wallops Island, VA on August 11, 2022. 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.



The following experiments were flown on RockSat-X in 2022:

College of the Canyons

The team is developing an autonomous autorotational device that will provide a reusable descent method for a payload vehicle in the event of an electrical systems failure. Utilizing aerodynamic design and telemetry data collection, the team investigated how a payload's velocity involved in assisted pitched blade design maximized autorotation upon re-entry into an atmosphere.

University of Hawaii Community Colleges

The team is conducting research on the feasibility of using a sublimation–fueled motor for providing low-power vernier thrust. The specific impulse of the sublimate camphor will be determined by a static ground test and by deploying the rocket from the sounding rocket at apogee. On board cameras recorded the sublimation rocket's flight parameters. This data was supplemented by an inertial measurement unit and a multi-axis accelerometer that provided a baseline for the payload's flight trajectory.

Northwest Nazarene University

The team investigated if Deep Meta Reinforcement Learning is a viable method for adaptive astro-robotics and demonstrated a viable soft robotic fluid for future space applications.

Photos by: Berit Bland/NSROC

Community Colleges of Colorado

The team seeks to improve on a legacy deployable boom arm by changing the mechanism used to generate torque with interlocking gears, use a 360-degree camera to shoot high-definition video with a clear view of the rocket and experiments, and created an experiment that tested bit flips caused from high energy radiation.

Principal Investigator: *Mr. Koehler/Colorado Space Grant Consortium* • ***Mission Number(s):*** *46.036 UO*
Launch site: *Wallops Island, VA* • ***Launch date:*** *August 11, 2022*

Virginia Tech

The team is developing a Langmuir probe system capable of recording and recovering current-voltage curve characteristics while in flight between the E and F layers of the ionosphere.

University of Kentucky

The team seeks to demonstrate the successful ejection of a capsule from an altitude of 93 miles and to gather and transmit data from an instrumented capsule throughout its flight. The method of ejecting the capsule is planned to be used for a future International Space Station mission.

Post launch exuberance.
Photo by Berit Bland/NSROC

Technology Development

Terrier-Improved Malemute on Wallops Island, VA.
NASA Photo Jamie Adkins

The NASA Sounding Rocket Program (NSRP) continues to assess new technologies in order to expand the capabilities for our science and technology customers, address obsolescence, and to improve efficiency. The major initiatives of the NSRP technology roadmap continue to focus on:

1. **Sub-payload development** – turn deployable small payloads into science platforms, and increase the capability of sub-payload systems.
2. **High data rate telemetry and onboard recording** – increase the amount of science data obtained on each flight.
3. **Miniaturization and modernization of payload systems** – minimize weight and volume of support system.
4. **High altitude vehicle with reentry and recovery** – allow longer science observation times while still allowing re-flight of science instruments and payload systems.
5. **Mesospheric vehicle and payload** – leverage sub-payload systems to develop miniature yet capable payloads for mesospheric science.

The NSRP leverages resources from NSROC, the NASA Engineering and Technology Directorate (ETD), the WFF Technology Investment Board, Small Business Innovative Research (SBIR), and Internal Research and Development (IRAD) programs to meet our growing technology needs.

The next dedicated technology development flight is SubTEC-9, scheduled for launch the spring of 2023. As with prior technology development missions, SubTEC-9 will carry a multitude of experiments. The high level objectives of the flight are:

- Test high data rate C-band telemetry link (~40 Mbps) to test out both flight and ground components
- Test the ETD Wallops Integrated Star Tracker (WaIST) in a relevant flight environment
- Provide a test flight opportunity for several NSROC and NASA ETD development components and subsystems
- Provide a testflight opportunity for external piggyback experiments

Main objectives for SubTEC-9

High Data Rate C-band Telemetry Link (NSROC)

A C-band telemetry link will be tested and evaluated as an alternative to the currently used S-band systems. Increasing commercial wireless demand is making S-band use less desireable for SRPO. There are several benefits to transitioning to C-band use:

- C-Band allows 540 MB RF bandwidth (lower C-Band)
- C-Band allows for higher data rates and/or more downlinks
- Flight hardware need minimal Non-recurring engineering (NRE) for C-band compatibility
- Minimal ground station upgrades are required for C-band

Objectives of the SubTEC-9 C-band link includes:
- Demonstrate C-Band Downlink Capability & Functionality
- C-band downlink using 40 Mb Axon encoder with RS422 transmitter
- C-band downlink using Etherner Via Telemtery (EVTM)

Two experimental C-band telemetry links will be flown on SubTEC-9. One C-band link is using EVTM, and the other is using the Axon PCM telemetry encoder. This provides two different ways of transmitting data in C-band, one is a direct ethernet stream and the other is transmitting data from a telemetry encoder. EVTM will be used on the upcoming science missions in 2023, 36.384 McCandliss and 36.385 Winebarger.

Wallops Integrated Star Tracker (WaIST) (ETD)

The main objectives are to test the low cost star tracker in a flight environment, and to show lost in space solution on star field. and tracking of identified stars

Additional SubTEC-9 Technology Development Experiments

NSROC Experiments

Space Eye 320 Ethernet Camera

Objective:
– Provide high data rate source for Ethernet Payload
– View of interest: Motor Fins & Earth
The Space Eye Ethernet Camera requires a C-Band Quasonix EVTM (Ethernet via Telemetry) Transmitter.

Gigabit Ethernet Switch W/ Time Stamping

Objective:
– Facilitate communication and data transfer from camera/payload to ground

PAyloadRegulation System Ethernet Controller (PARSEC)

Objective
– To implement an ethernet-based replacement of the traditional PCD.
– Interface with the new Axon Encoder or directly with an ethernet transmitter.
– To scale down into a smaller/lighter form factor than the traditional PCD.

Haigh-Farr GPS/S-band Combo Antenna Design

Objective:
– Provide a second source for wrap-around GPS/S-band combo antenna.
– Specifications to be the same as the existing qualified design for compatibility.

Wallops Solid State Peripheral Control Relay Board (SPECTR)

Objective:

– Replace electro-mechanical relays.

– Allows more events with further reduction of flight hardware and weight.

Next-Gen Battery (Lithium-Ion)

Objective:

– Demonstrate Parallel Pack and Single Pack Design. Battery design allows for paralleling packs in equipment to create a larger capacity, Parallel design as the first option and the single pack design as the alternate

– Power for the PARSEC experiment

Strain Gauge Monitoring System (SGMS)

Objective:

– Test the SGMS in a flight environment

NSROC Ethernet Sensor Suite

Objective:

– To provide a low cost flight test of the Ethernet downlink capability of next generation encoders.

– Data will be collected with an Arduino based device

– Data will be transmitted via Ethernet

– Sensors include: 3-axis Magnetometer, Accelerometer and Gyro, Current Sensing and Voltage Monitoring

Command Uplink (CU) D/A Board Redesign

Objective:

– Consolidate WFF-93 Command Deck functionality into CU D/A Board

– Eliminate the WFF-93 Command Deck in WFF-93 stack

– Make the CU D/A Board all surface mount components

Piggyback Experiments

Printed Hybrid Electronics (PHE) Demonstration

This test will evaluate the performance of PHE, and will include additively manufactured Arduino-type circuits including Temperature and Humidity sensors on the inside and outside of a waterproof sounding rocket payload door. The objectives include collecting data and recovery of circuits from experiment to evaluate performance after flight and robustness of the circuits.

Go

Sub–payload development
- Turn deployable small pay–loads into science platforms
- Increase capability of sub–payload systems

High data rate telemetry and onboard recording
- Increase amount of science data obtained on each flight

Miniaturization ernization of p systems
- Minimize w ume of sup

Core Technologies

Sub–Payloads

- Dual main receiver
- GPS receiver & antenna
- Larger battery packs

- GPS upgrades
- Increased RF range (~40 km) with lower–rate data

Telemetry

- 40 Mbps C–band telemetry development
- Ethernet payload bus communi–cation development

- Ground station upgrades for C–band telemetry

Miniaturization & Modernization

- Tern SPARCS development
- High energy density battery development

- Wallops Integrated Star Tracker (WalST)

- New ignition system
- New power system

New Capability

- Uninstrumented mesospheric vehicle

- Nested skin for high altitude reentry
- Deploying and Retracting Tubular (DaRT) Boom
- Metal additive manufacturing

2020 2021 2022

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port systems

High altitude vehicle with reentry and recovery

- Allows longer science observation times while still allowing re–flight of science instruments and payload systems

Mesospheric vehicle and payload

- Leverage sub–payload systems to develop minia–ture yet capable payloads for mesospheric science

- Increase spring deployment velocity
- 3u CubeSat form factor and deployer

- 300–400 Mbps C–band telemetry development
- High rate (1 Gbps) onboard data recorder development

- Payload lightweight concepts*
- Versatile Linear Shape Charge (FTS)

- Integrated power system devel–opment
- Consolidated ordnance system development

- Low–cost flight computer

- Mesospheric payload & vehicle
- Large diameter payload (>32")

- Mesospheric vehicle
- High altitude vehicle

- High altitude vehicle
- Reaction wheel ACS

2023 | 2024 | 2025

SubTEC–9
Launching 2023

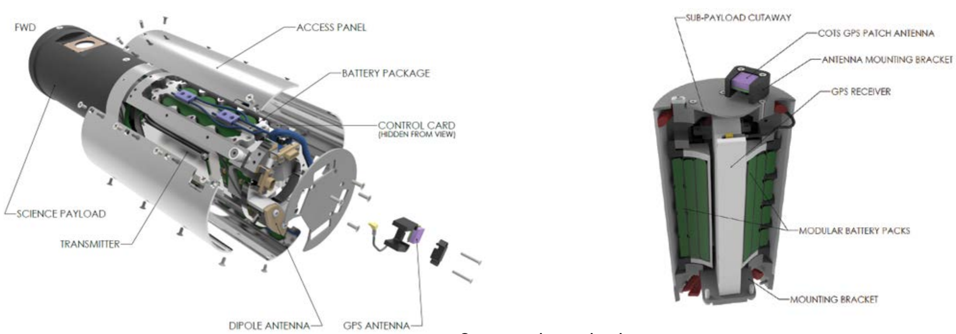
SubTEC–10

Additional Technology Development

In addition to the dedicated technology development missions, such as the upcoming Sub-TEC-9, the SRPO provides support for new technologies flying on science missions.

Swarm Communication is a sounding rocket system that telemeters data from multiple deploying sub-payloads to the main payload via S-band at rates up to 1 Mbps per sub-payload. The SpEED Demon payload (p. 30) was a technology demonstration mission for the future Sporadic E Electro Dynamics (SEED) campaign, scheduled for Kwajalein, Marshall Islands in 2024. SpEED Demon was the second science mission to fly the deployable sub-payloads.

For this flight, the design of the GPS system was revised. A larger GPS antenna was added to the front end of the sub-payload and RF transparent doors were added to the payload. Additional re-rad signals, from the main payload GPS receiver to the sub-payloads during the rocket ascent, were included. The additional re-rad signals improved the probability for getting a GPS signal on the sub-payloads after they eject from the main payload. During the SpEED Demon flight GPS signals were received on all four sub-payloads, which was a great improvement for the Swarm system.

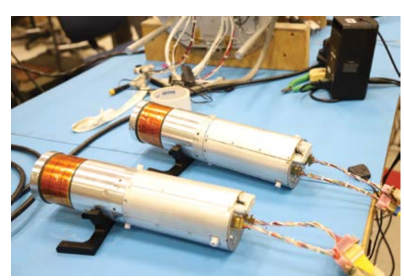


Swarm sub–payloads.
3D models by Josh Yaccobucci/NASA ETD

Basic operation and specifications of the Swarm sub-payloads:

- At altitude sub-payloads are deployed from the main payload by rifled launch tubes either by springs (2.5 m/s) with a range of 1-2 km or by rocket motors (118 m/s) with a range of ~20 km.
- Sub-payloads ("Dallas") contain the science payload, batteries, and avionics. S-band telemetry relays data back to the main payload receiver(s) ("Marko").
- Main payload contains the receive antenna, low noise amplifier (LNA), rejection filter, Marko receiver, and telemetry encoder. Marko compiles all sub-payload data into a single synchronous serial data stream that is transmitted to the ground via S-band telemetry downlink.
- Sub-payloads are approximately 13" long and 3.4" in diameter and weigh approximately 4-5 pounds.
- Available science payload is approximately 5.8" long and 2.7" inner diameter.

The four sub-payloads for SpEED Demon each carried an ion density measurement along with a sensitive magnetometer and an accelerometer capable of performing 'falling sphere' analogous neutral density measurements.



SpEED Demon sub–payloads.
Photo by: Berit Bland/NSROC

SpEED Demon sequence testing.
Photo by: Berit Bland/NSROC

Australia Campaign Report

Australia Campaign

Mobile campaigns are the mainstay of the NASA Sounding Rockets Program (NSRP). To provide southern hemisphere targets for the Astrophysics science community, NSRP collaborated with the newly founded Australian Space Agency (ASA) and Equatorial Launch Australia (ELA), a commercial launch operator, to enable launching three payloads in the summer of 2022. All three payloads, 36.347 McCammon/XQC, 36.339 France/SISTINE, and 36.350 Fleming/DEUCE, had previous successful flights from White Sands Missile Range, NM, and were deemed suitable for this new opportunity.

Site setup

Over a decade in the making, the mobile site setup at ELA's Arnhem Space Center (ASC), near Nhulunbuy, Northern Territory, started in September 2021. Due to COVID-19 restrictions, staff were quarantined for two weeks prior to getting access to the launch site to begin preparations. No previous launch operations have taken place at ASC, and all equipment to launch sounding rockets was shipped from Wallops. In addition to the Sounding Rockets Program Office (SRPO) and NASA Sounding Rocket Operations Contract (NSROC) staff and equipment, the Range and Mission Management Office (RMMO) and Range Operations Contract (ROC) staff and equipment were required to establish the mobile range capabilities.

While site setup staff were quarantined, the ELA finished the final concrete pour for the launch pad, as well as installed all temporary facilities required for the site setup. Due to the ecologically sensitive area all cargo shipped to Nhulunbuy must undergo thorough biosecurity inspections. The inspections required the unpacking of several containers and cleaning of the equipment they housed. While the containers and their content were being cleaned, the road out to the range was graded, a requirement for delivery of the Range support systems. The Range Instrumentation compound (RIC) was also nearly completed while the NASA shipment underwent the biosecurity inspection. When the biosecurity screenings were completed and all containers released, the equipment was delivered to the launch site, approximately 50-minutes from the port, and site setup began.

Site setup was completed by November 2021. The remaining work, including completion of the Rocket Motor Storage and Vehicle Assembly Building (RMS&VAB), Payload Integration Facility (PIF), Range Control Center (RCC), as well as, the addition of ELA administrative buildings, were completed by ELA prior to the arrival of the NASA and Science teams for launch operations in May 2022.


Antenna dish assembly.
Photos by: Brian Bonsteel/Wallops Imaging Lab

Wind tower installation

Medium Mobile Launcher assembly completed.

Launch Operations

The Australia launch campaign began with the 'Advance Team' arriving at ASC in May 2022. The team consisted of the NSROC Launcher Systems team, the ROC team (covering multiple support areas) and the Campaign Manager (CM).

This team completed final facility and systems preparations prior to the arrival of the first payload and science team in June 2022.

Rocket motors and payloads were transported to Australia on the NASA C-130 aircraft. The motors were offloaded in Darwin, Australia and barged to Nhulunbuy. The three payloads and four science team members continued the flight to Nhulunbuy, where payloads were offloaded.

NASA C–130 at Nhulunbuy.
Photo by: Scott Bissett/NASA

35.247 McCammon/XQC

After and uneventful Mission Dress Rehearsal (MDR) for 35.247 McCammon/XQC, the team was ready for the live action. The launch countdown was smooth, but downpours hit the pad several times during countdown operations, significantly increasing the wind variability. This resulted in several holds and resets within the last 3 minutes of the count. The Range Safety Officer and Wind Weighter worked diligently to identify a launch opportunity within wind limits.
The science team is extremely happy and received good data throughout the flight. The Attitude Control System (ACS) performed nominally with all payload and experiment events nominal.

XQC payload being staged.
Photo by: Brian Bonsteel/Wallops Imaging Lab

36.349 France/SISTINE

The launch countdown went smoothly, but mid-level winds posed some problems. Wind weighted launcher setting were red for majority of the countdown operations, but began to get close to the limit as the evening progressed. After many wind weighting reports that were just out of tolerance, balloon data finally came in green and the team proceeded into the hot count only to hold at T-3 minutes when winds went back outside of the limits. Eventually, winds were within limits to facilitate a successful launch. The science team was ecstatic with the collected data and images and all flight events were nominal.

SISTINE on the way to the rail.
Photo by: Brian Bonsteel/Wallops Imaging Lab

36.350 Fleming/DEUCE

Due to the forecast of deteriorating weather conditions, the third and final launch for this campaign was staged a day early. This was enabled by very similar countdown procedures and the successful flights of the XQC and SISTINE payloads. The winds cooperated and were just within limits for the entire evening of the countdown. The countdown operations went relatively smooth and the launch occurred a few minutes after the nominal T-0. The science team's preliminary reports suggest that good data was received and payload pointing was on target. Overall, a nominal flight.

DEUCE science team with rocket.
Photo by: Brian Bonsteel/Wallops Imaging Lab

Recovery Operations

All three payloads, rocket motors and associated hardware were recovered. The NSROC Forward Ogive Recovery Sections (NFORSe) performed nominally and telemetry data confirmed parachute deployments. GPS data on the Black Brant motors and nosecones aided in the recovery operations. For each mission the recovery team left in the morning the day following the launch and located and recovered the payloads, Terriers, Black Brants, nosecones, and drogue chutes. The payloads were in good condition after recovery.

At the conclusion of the campaign all equipment and recovered hardware was packed up and shipped back to the US.

On the Horizon

New and repeat opportunities to conduct science missions in remote locations abound within the SRPO. The new Australian launch range, Arnhem Space Center, saw the first launches in the summer 2022. Operations will continue from regularly used launch sites, Wallops Island, White Sands Missile Range, Poker Flat Research Range and Andoya Space, Norway. Over twenty missions are manifested for flight in FY 2023.

Solar Flare Campaign 2024

This planned campaign will include three solar physics payloads, with launches taking place from Poker Flat Research Range (PFRR), AK. The approximately two-week long launch window opens in early March 2024, during which solar activity will be monitored by scientists using data from the NOAA operated Geostationary Operational Environmental Satellite (GOES). When data from GOES indicate a solar flare is occuring, the payloads will be launched to study the event. By analyzing previous solar cycles, scientists estimate that the opportunity of capturing a flare in progress is fairly high during the selected launch window.

The three instruments participating in this campaign are listed below. FOXSI 4 and Hi-C Flare are planned to launch within minutes of each other to observe the same event. SNIFS will launch independently.

Focusing Optics X-ray Solar Imager (FOXSI) 4

As part of the first solar flare campaign, FOXSI-4 will perform a triggered observation of a large flare. The Pricnipal Investigator for FOXSI-4 is Dr. Glesener/University of Minnesota.

High-Resolution Coronal imager (Hi-C) - Flare

The Hi-C instrument is optimized for detecting high temperature flare lines. The Pricnipal Investigator for Hi-C - Flare is Dr. Savage/NASA Marshall Space Flight Center.

Solar eruptioN Integral Field Spectrograph (SNIFS)

SNIFS is designed to study the high frequency dynamics associated with small nanoflares, spicules, and Rapid Blue-shifted Excursions (RBEs), as well as, large solar flare energy releases in the lower solar atmosphere. The Pricnipal Investigator for SNIFS is Dr. Chamberlin/University of Colorado.

Mars Sample Return support mission, FY 25

The Mars Sample Return (MSR) is a proposed mission to return samples from the surface of Mars to Earth. The mission would use robotic systems and a Mars ascent rocket to collect and send samples of Martian rocks, soils and atmosphere to Earth for detailed chemical and physical analysis. Two sounding rocket missions will be flown FY 2025 to test systems for the Mars Ascent Vehicle (MAV) and parachute for the Sample Retrieval Lander (SRL).

Geospace Science campaign from Peru

Geospace researchers are eager to return to Peru to study ionospheric phenomena at the magnetic equator. The NSRP has facilitated campaigns in Peru twice in the past. In May - June 1975, 19 sounding rockets were launched, and in February - March 1983, when 18 rockets were launched. All rockets were launched from Punta Lobos, near Lima, Peru.

Launch range in Punta Lobos, Peru.

The 1975 campaign was called Antarqui for the Inca god of flight. The atmospheric region studied was measured under quiet and disturbed magnetic field conditions. Measurements included those dealing with the composition of the neutral and ionized atmosphere, density and temperature, and wind, shear, and turbulence. The launches were conducted in conjunction with the operation of instruments on the Atmosphere Explorer-C satellite and a Jicamarca radar.

Nike–Tomahawk on the rail in Peru.

Project Condor was executed in 1983, with 18 NASA sounding rockets launched. A series of coordinated rocket and ground-based measurements were conducted to investigate ionospheric phenomena unique to the geomagnetic equatorial region. The campaign had a number of aeronomic, plasma physics, planetary electrodynamics and other objectives, and utilized a variety of ground-based and in situ observational techniques.

Two Nike–Orions ready to launch

Advances in scientific instruments, payload configurations, radar modes, and ground observing systems promise to provide significant new scientific data and discoveries that go far beyond the achievements of previous NASA rocket campaigns. A rocket/radar campaign from Peru would enable NASA and NSF researchers to explore space physics phenomena found only at Earth's magnetic equator for the first time in several decades. Beyond fundamental scientific research, understanding the equatorial ionosphere is vitally important for space weather research as its intrinsic irregularities and turbulence disrupt space-to-ground radiowave communication and navigation transmissions, such as GPS, more frequently and more dramatically than any other region of the ionosphere except the storm-time auroral ionosphere.

NASA HQ, SRPO, and other interested parties are evaluating operational options and programmatic resources for a future rocket campaign in Peru.

Sounding Rocket Launch Sites

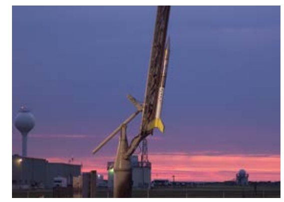

Poker Flat, Alaska

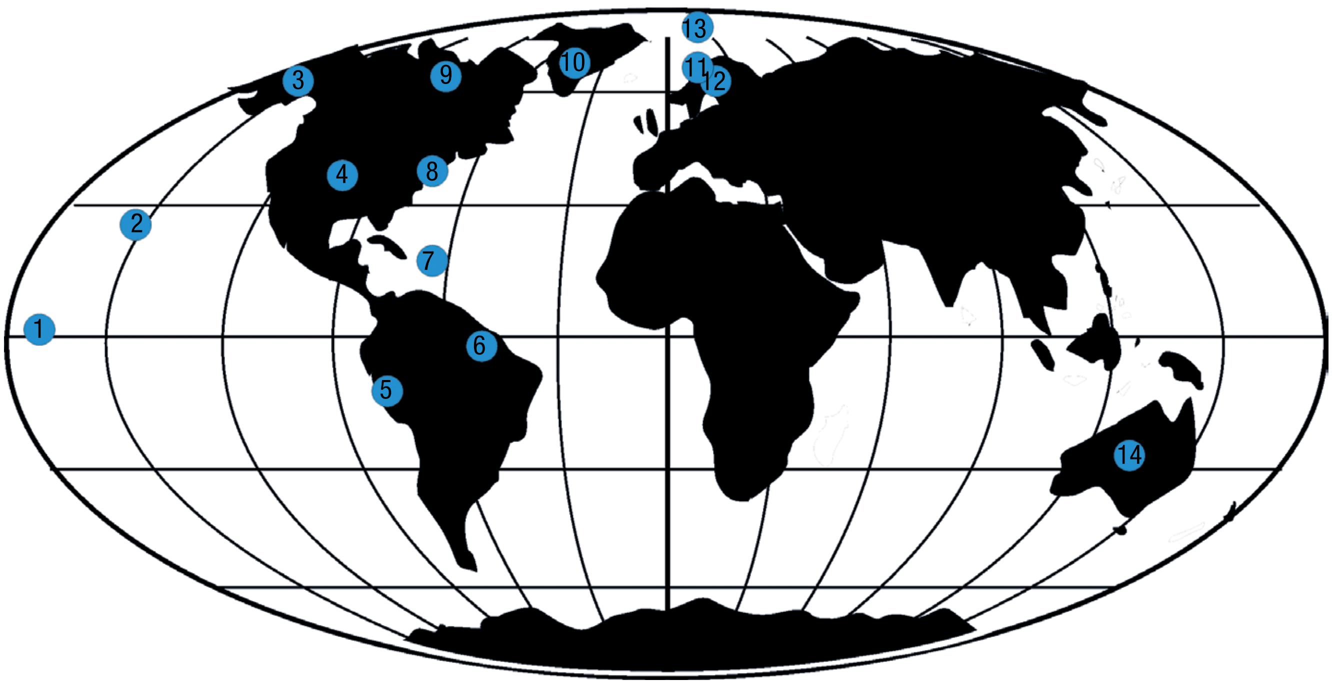

Esrange, Sweden


Kwajalein, Marshall Is.


Andøya, Norway


Arnhem Space Center, Australia


Wallops Island, Virginia

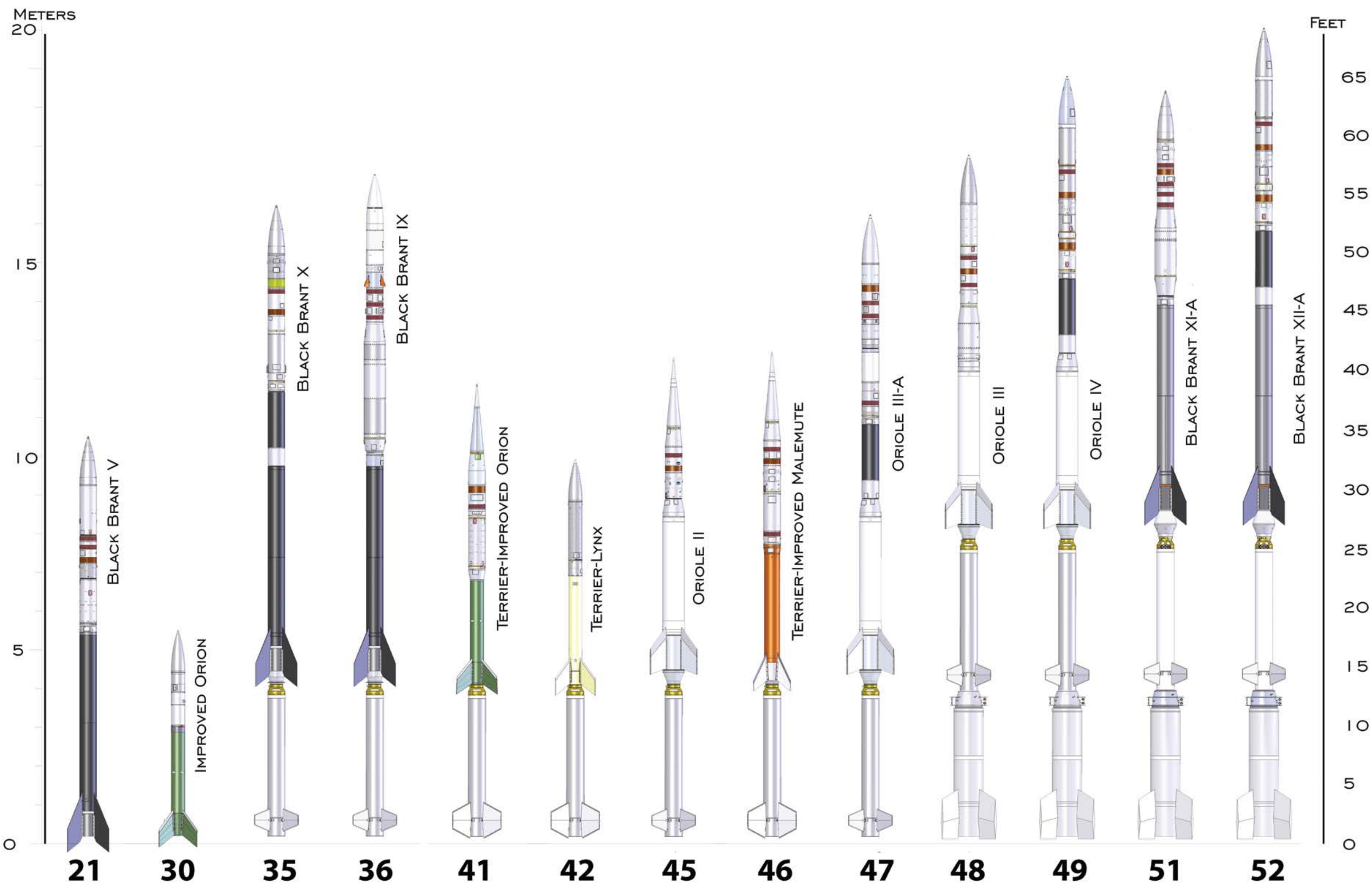


Past and present world wide launch sites used by the Sounding Rockets Program to conduct scientific research:

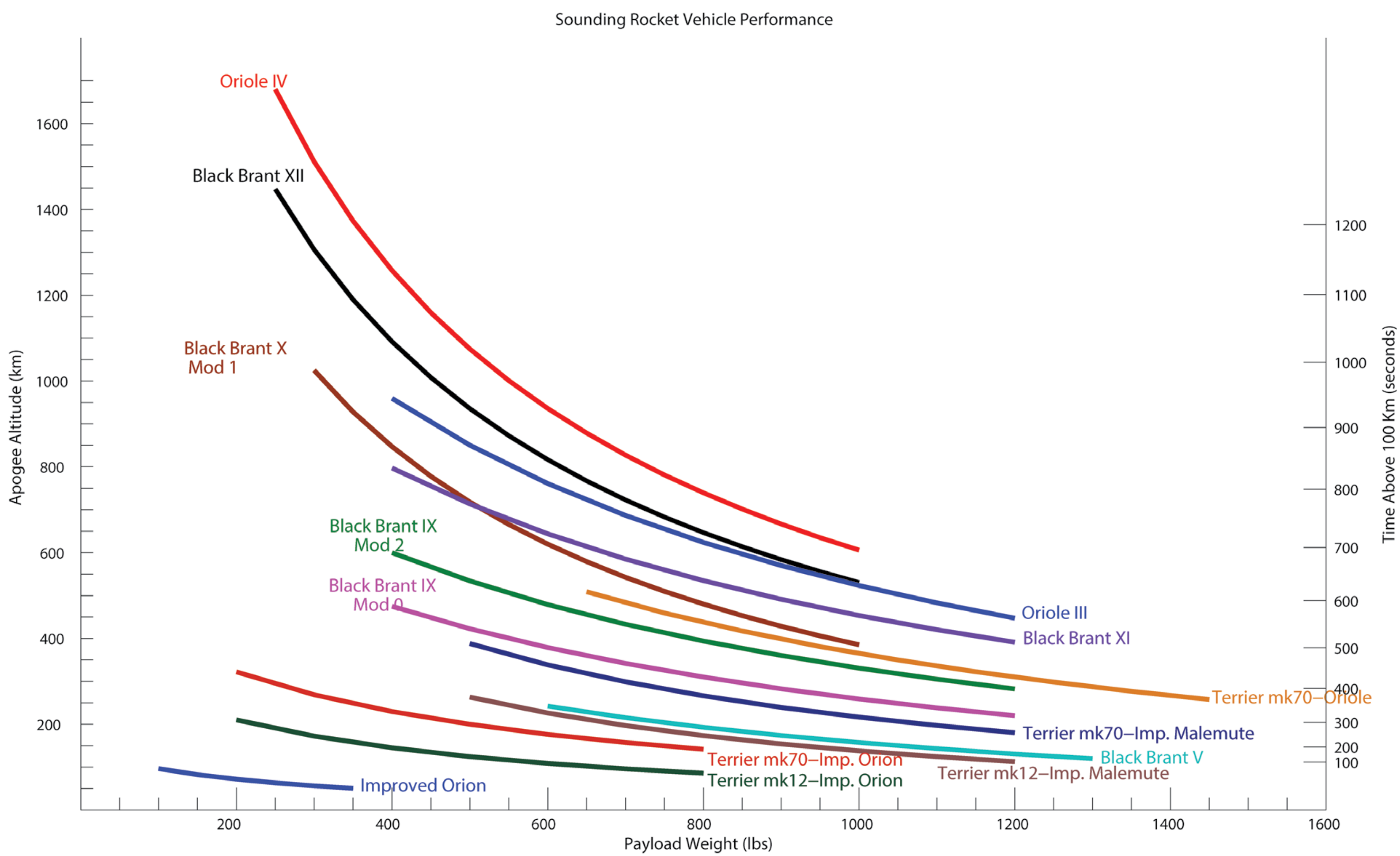
1. Kwajalein Atoll, Marshall Islands
2. Barking Sands, HI
3. Poker Flat, AK
4. White Sands, NM
5. Punta Lobos, Peru *
6. Alcantara, Brazil *
7. Camp Tortuguero, Puerto Rico *
8. Wallops Island, VA
9. Fort Churchill, Canada *
10. Greenland (Thule & Sondre Stromfjord) *
11. Andøya, Norway
12. Esrange,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

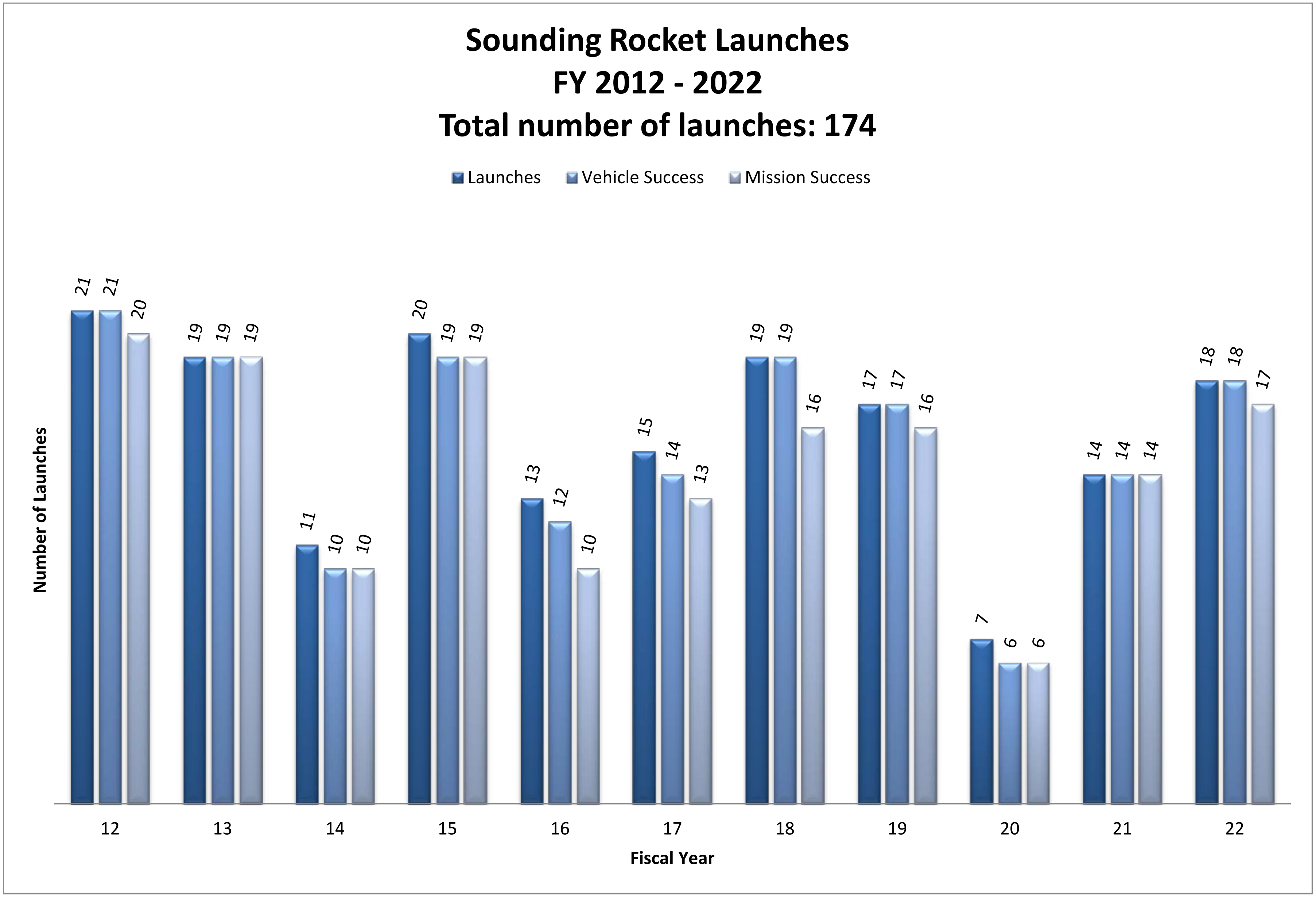
* Inactive launch sites

Sounding Rocket Vehicles



Sounding Rocket Vehicle Performance




Sounding Rocket Launches
FY 2012 - 2022
Total number of launches: 174
Launches
Vehicle Success
Mission Success
Number of Launches
Fiscal Year
12 13 14 15 16 17 18 19 20 21 22
21 21 20
19 19 19
11 10 10
20 19 19
13 12 10
15 14 13
19 19 16
17 17 16
7 6 6
14 14 14
18 18 17

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Brittany Empson
Operations Manager

Scott Hesh
Electrical Engineering

Wyle Maddox
Resources Analyst

Gordon Marsh
Projects Manager

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