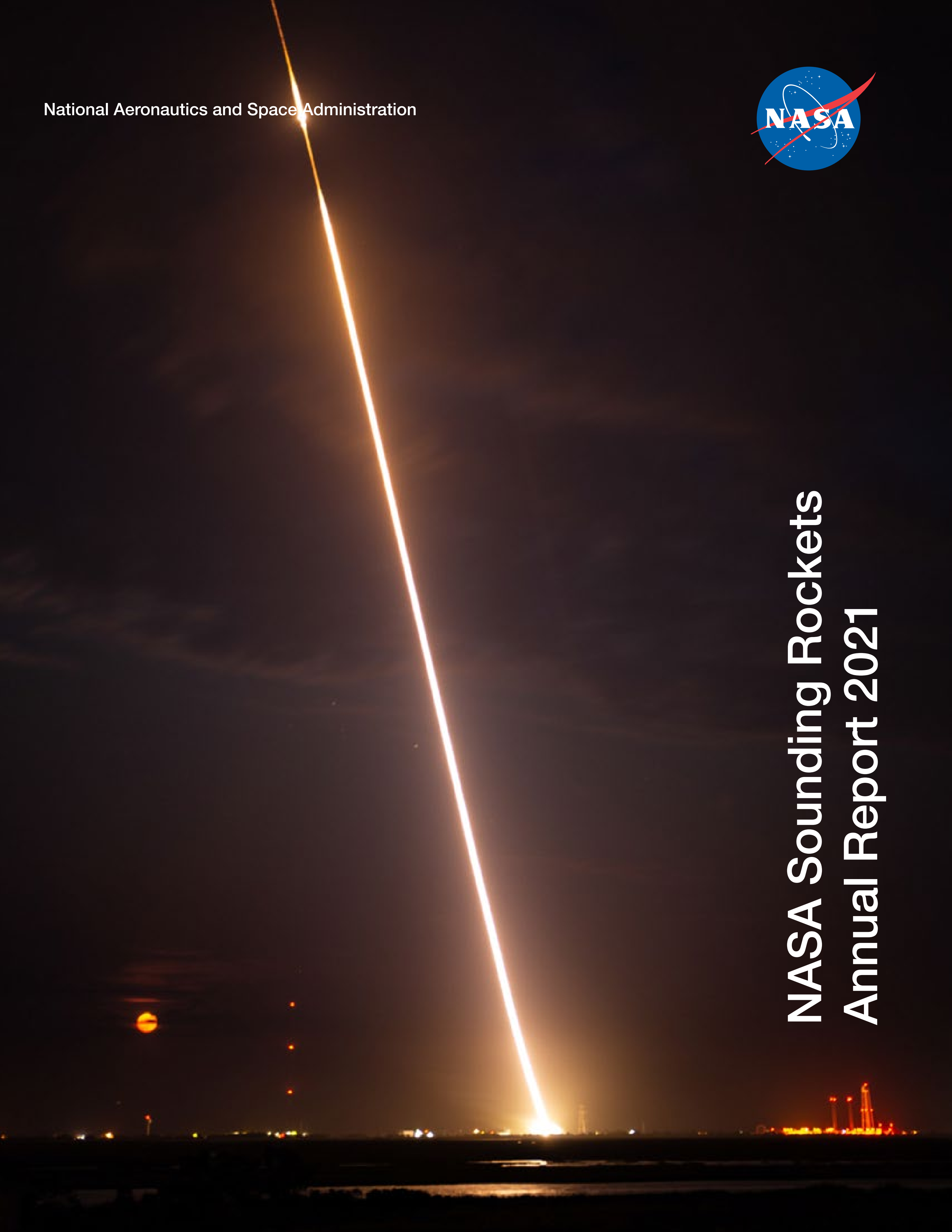
National Aeronautics and Space Administration



NASA Sounding Rockets Annual Report 2021

Message from the Chief

Giovanni Rosanova, Jr.
Chief, Sounding Rockets Program Office

Thanks to the extraordinary resilience and grit of the people in the sounding rockets program, both civil service and contractor, we had a very successful fiscal year 2021. Fourteen missions, covering five disciplines, launched from two ranges, were flown with a success rate of 100%. While the pandemic has made the work environment different in many ways, our adherence to COVID -19 protocols, such as masking and social distancing, allowed missions to be integrated and flown in support of NASA's scientific objectives. Kudos to the entire staff for stepping up during these difficult times.

Our missions this year included four Solar physics flights: the Extreme Ultraviolet Normal-Incidence Spectrograph (EUNIS) and the Marshall Grazing Incidence X-ray Spectrometer (MaGIXS) studied the solar corona in two different wavelengths; Spatial Heterodyne Interferometric Emission Line Dynamics Spectrometer (SHIELDS) investigated particles entering the heliopause; Solar Dynamics Observatory - EUV Variability Experiment (SDO-EVE) calibrated sensors onboard SDO. Astrophysics missions included observations in both the Extreme Ultraviolet (Dual-channel Extreme Ultraviolet Continuum Experiment, or DEUCE) and the Infrared (Cosmic Infrared Background Experiment-2, CIBER-2) parts of the spectrum. Four missions were flown for Geospace Science, and, although infrequent for this discipline, all were launched from Wallops Island, VA. The Kinetic-scale Energy and momentum Transport eXperiment (KINET-X) mission focused on energy and momentum transport between different regions of space, VLF trans-Ionospheric Propagation Experiment Rocket (VIPER) studied very long frequency radio waves and their propagation along the Earth's magnetic field lines, and DYNAMO-2 studied the atmospheric dynamo create by global systems of currents. Additionally, two reimbursable missions were flown. NASA Langley Research Center studied transonic buffet acting on launch vehicles, using a vehicle specially designed for this purpose, and Sandia National Laboratories flew a High Operational Tempo, or HOTShot, mission testing newly developed components for space flight on a Terrier-Improved Malemute.

We were delighted to welcome back our student missions after a one-year delay due to COVID. Both the RockOn and RockSat-X missions were flown in 2021. RockOn, the workshop flight opportunity, is the first step in developing student experiments for spaceflight. In the past the workshop has been held at Wallops Flight Facility, but due to COVID restrictions this year's workshop was held virtually. Content for the virtual workshop was developed by the PI Institution, Colorado Space Grant Consortium. These experiments, as well as the RockSat-C experiments were flown in June 2021. RockSat-X, with the most advanced student experiments, was flown in August 2021.

One of the highlights for 2021 was the range setup trip to Australia. The launches, originally planned for 2020, are now on schedule for 2022. Three astrophysics missions will be launched from this new range, Equatorial Launch Australia (ELA), near Nhulunbuy, Northern Territory. Launchers and ground support equipment were setup during the summer 2021, and ELA is continuing site preparations to ensure range is ready before launch operations commence. This is an incredible step toward realizing a vision of returning to Australia for southern hemisphere research after almost three decades. Kudos to the setup team from SRPO, NSROC, and the Wallops Range who endured a two week quarantine, then several weeks of hard work in intense Australian heat to establish this capability.

After some schedule slips due to COVID, the launch manifest is filling up for the near future. A total of 22 launches are currently manifested (two have already been launched) for FY 22. Similarly, FY 23 has 22 missions manifested. Future launches include some very exciting projects: Mars Ascent Vehicle (MAV) flight tests for a collaborative team from Jet Propulsion Laboratory (JPL) and Marshall Space Flight Center (MSFC) and Advanced Supersonic Parachute Inflation Research and Experiments (ASPIRE) 2 for JPL. These projects include launches during FY 24 and 25. Additionally, we are looking forward to supporting a solar physics campaign from Poker Flat Research Range, AK in FY 24. Three missions will be launched to study solar flares. The operations will be similar to our Geospace Science missions, and the launches will occur during a launch window of approximately two weeks. Scientists will monitor solar activity and evaluate flare intensity before committing to a launch. We are keen to expand the operations envelope for our solar researchers.

On November 30, 2021, John Hickman, Deputy Chief for the Sounding Rockets Program, retired after 36 years of service to NASA. Several long serving NSROC employees, including 41-year sounding rocket veteran, Jim Diehl, also will retire by the end of the calendar year. I wish to thank John, Jim, and the others for their outstanding contributions to the program, and wish them a safe, healthy, and enjoyable retirement. Their diligence and efforts have made all the difference throughout the years.

As the year nears its end, we often take stock of the events, good and bad, that make each year unique. Needless to say, 2020 and 2021, were overwhelmed with health concerns due to the COVID-19 pandemic, however, I am, as always, inspired by the individuals that form the great teams that support the sounding rockets program. Without the team effort, excitement, and the sense of duty exhibited by each of you, the program would not be what it is.

I wish all of you a great 2022. Onward and upward!

Giovanni Rosanova, Jr.

Table of Contents

Cover photo: VIPER launch from Wallops Island, VA.
Credit: Wallops Imaging Lab

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. Sub-systems, 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. 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).

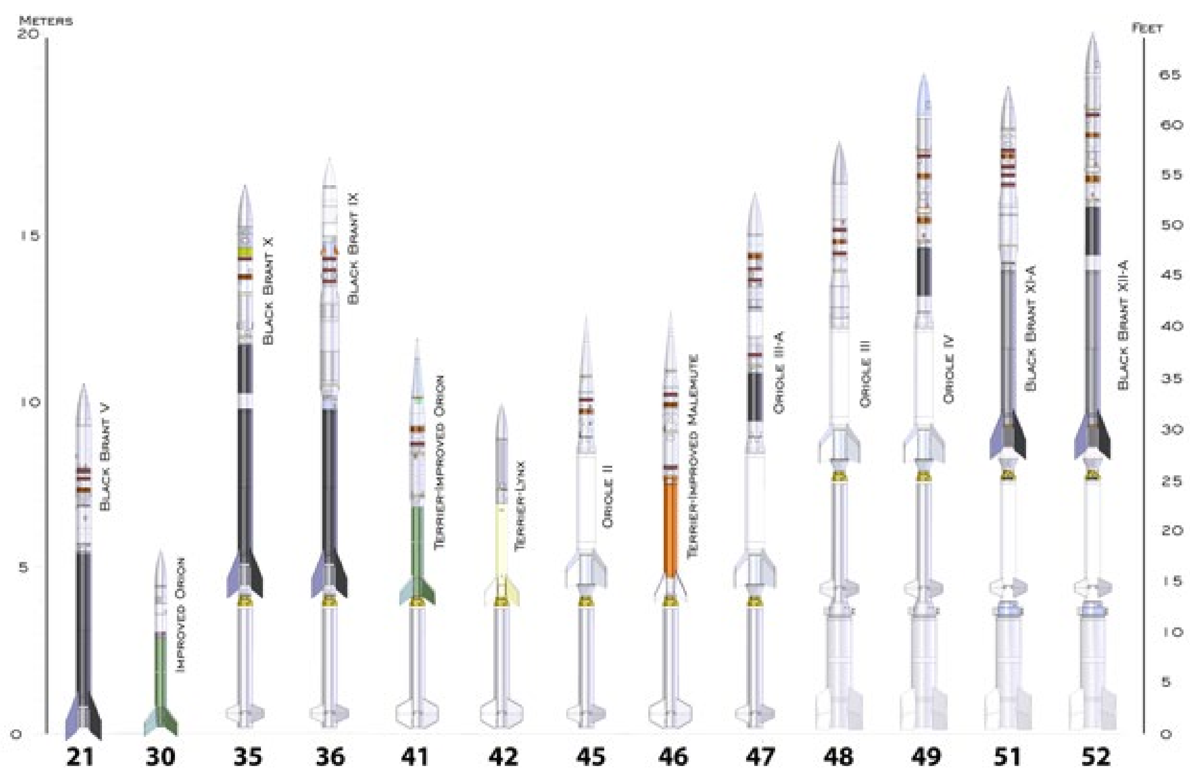
Additionally, sounding rockets are well suited for testing new technologies for future space missions. For example, parachute technologies for the Mars 2020 mission were tested on sounding rockets.

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.

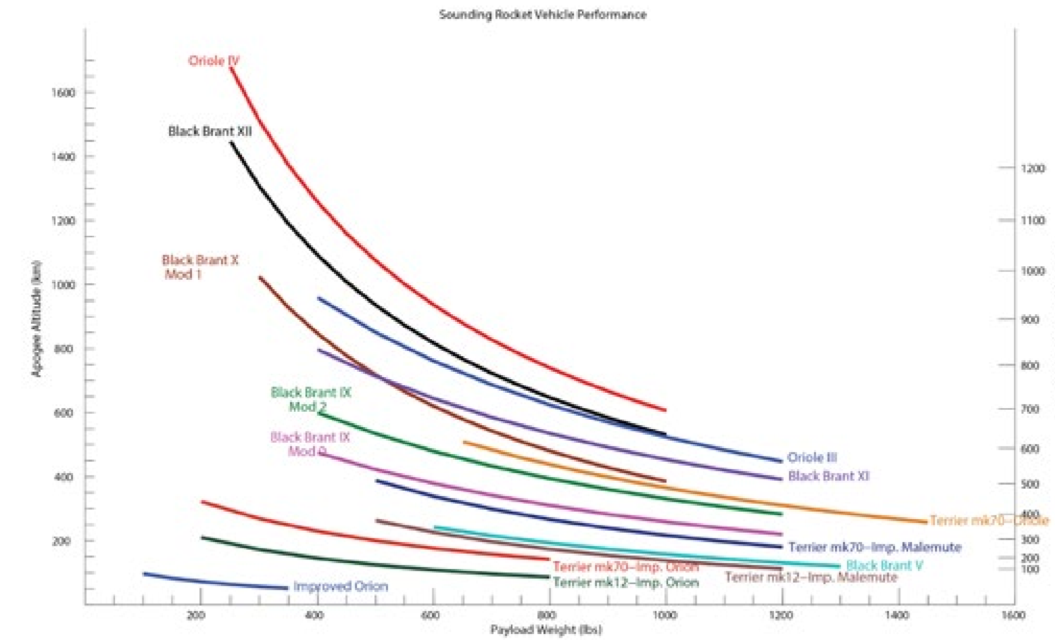
Extensive experience, over 2,500 missions flown, has lead to streamlined processes and efficient design, manufacturing and assembly techniques. Management and technical support is provided for all facets of a mission and includes engineering design, manufacturing, integration, and testing and evaluation. 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 manu facturing 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 18 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 compressed gas that is released through small nozzles located on the payload skin.

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

Electrically operated vacuum doors are available for most telescope payloads.

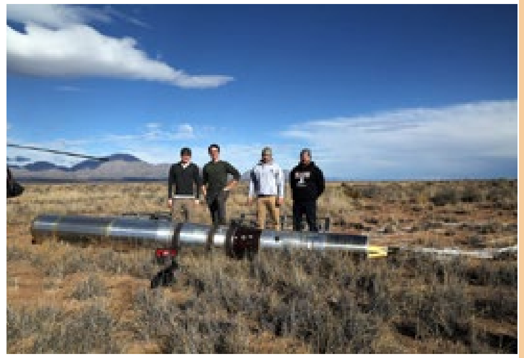
Open shutter door with instrument visible during testing at Wallops. Photo by: Berit Bland/NSROC

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.

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



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

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

Payload place on mass properties measurement table.
Photo by: Berit Bland/NSROC

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.

Static And Dynamic Balancing

Payload being prepared for balancing.
Photo by: Berit Bland/NSROC

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.

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

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

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.

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.

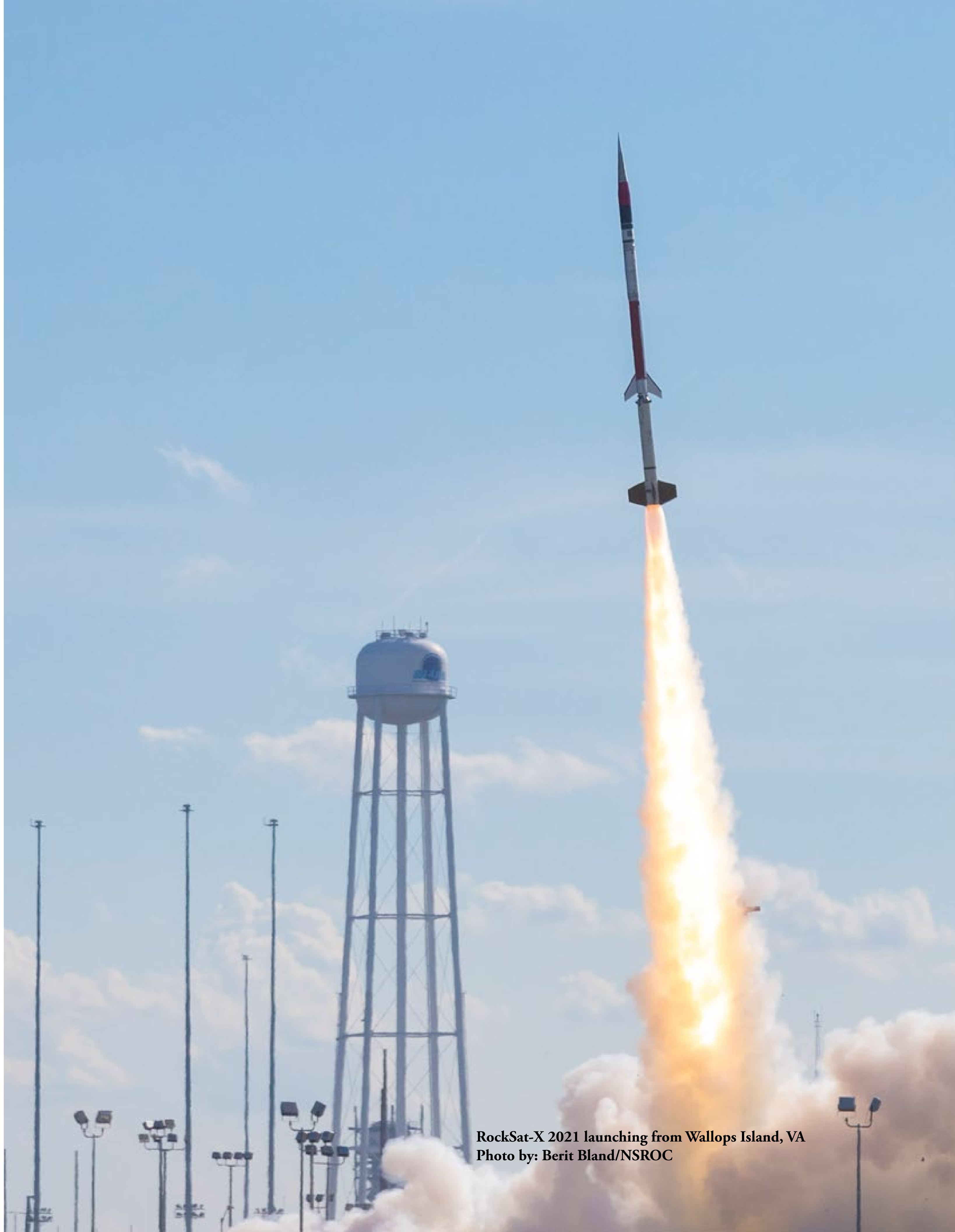
The Sounding Rockets Program, in cooperation with the Wallops Range, provide all necessary personnel and equipment to conduct successful missions anywhere in the world.

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)

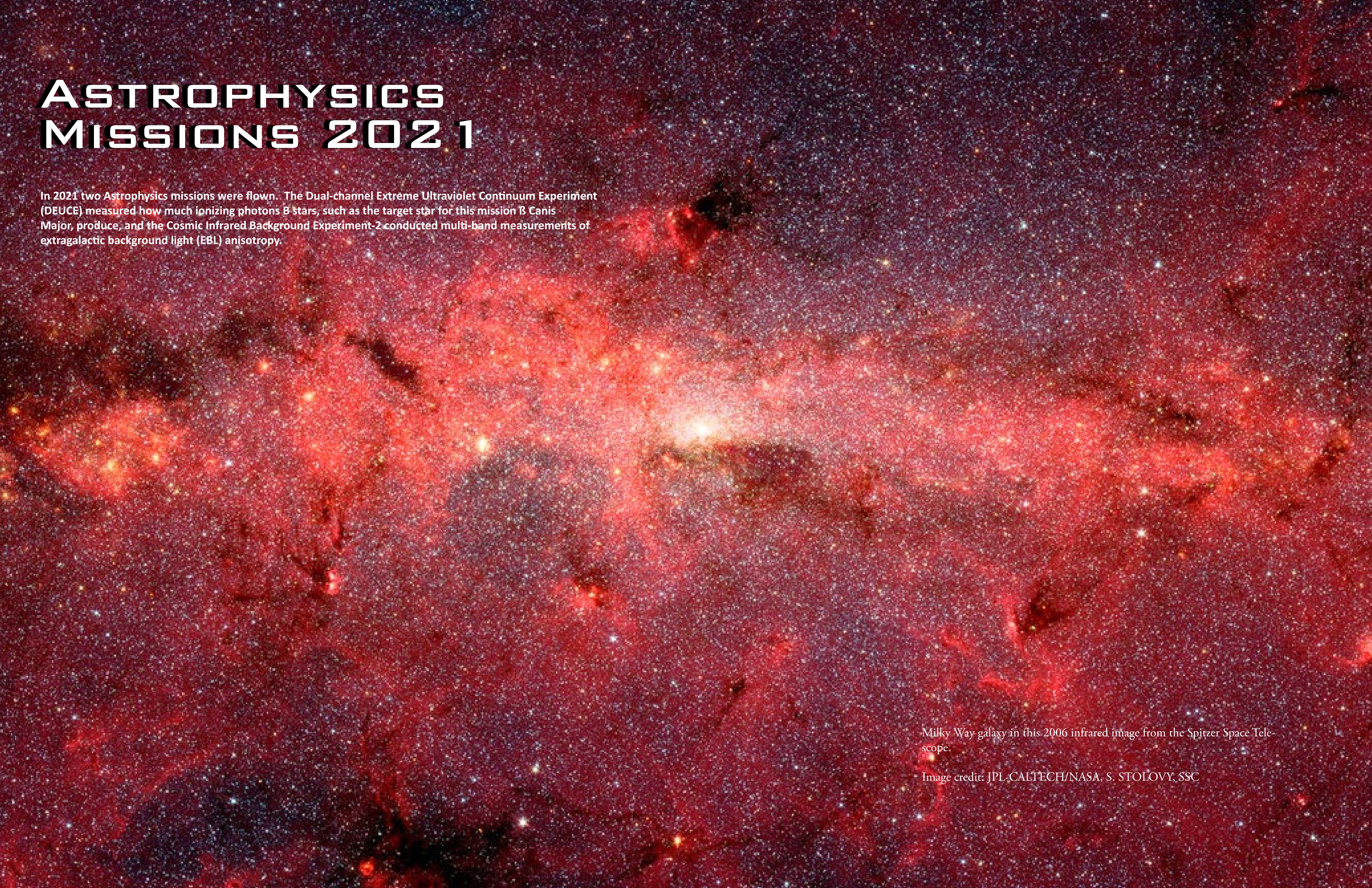
* Inactive launch sites



RockSat-X 2021 launching from Wallops Island, VA
Photo by: Berit Bland/NSROC

Astrophysics Missions 2021

In 2021 two Astrophysics missions were flown. The Dual-channel Extreme Ultraviolet Continuum Experiment (DEUCE) measured how much ionizing photons B stars, such as the target star for this mission ß Canis Major, produce, and the Cosmic Infrared Background Experiment-2 conducted multi-band measurements of extragalactic background light (EBL) anisotropy.



Milky Way galaxy in this 2006 infrared image from the Spitzer Space Telescope.

Image credit: JPL-CALTECH/NASA, S. STOLOVY, SSC

Dual-channel Extreme Ultraviolet Continuum Experiment (DEUCE)

The Dual-channel Extreme Ultraviolet Continuum Experiment (DEUCE) is a spectrograph operating from 650 to 1100 Å. DEUCE measured how much ionizing photons B stars, such as the target star for this mission ß canis major, produce. DEUCE was successfully flown from White Sands Missile Range, NM on November 2, 2020.

DEUCE has two modes; a low resolution, high throughput mode operating from 650 – 890 Å, and a high resolution, low throughput channel from 650 – 1100 Å. The stellar brightness changes dramatically above 912 Å and below 912 Å and therefore the two modes are necessary. The change in intensity is unknown, and may range from 10/1 to 10,000/1. DEUCE measured the flux of local, bright, hot stars that have very little intervening absorbing material in the interstellar medium. There are no preexisting measurements of the flux of these types of stars in the critical 700 – 900 Å regime, and the fundamental objective of DEUCE is to understand how bright these types of stars are in the 700 – 900 Å regime.

This was also a test flight for a new variant of the NASA ETD designed Autonomous Rocket Tracker (ART) For this mission two trackers were integrated into the nosecone and bolted to the skin. ART relays GPS coordinates to a remote user via the Iridium satellite network, and enables tracking and locating vehicle and payload parts after impact. This was the third flight for ART and the first of this configuration.

This was the third flight of DEUCE.

DEUCE payload team before launch.
Photo by: Visual Information Branch/WSMR

DEUCE science team members with payload during recovery operations.
Photo by: Visual Information Branch/WSMR

Principal Investigator: *Dr. James Green/University of Coloardo*• ***Mission Number(s):*** *36.368 UG*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *November 2, 2020*

Cosmic Infrared Background Experiment-2 (CIBER)

CIBER-2 is a near-infrared rocket-borne instrument designed to conduct comprehensive multi-band measurements of extragalactic background light (EBL) anisotropy on arcsecond to degree angular scales. CIBER-2 builds on the successful measurements and proven methodology of the predecessor CIBER-1 instrument.

CIBER-2 investigated the spectral and spatial properties of the extragalactic near-infrared background, and required acquisition of multiple targets with minimal contamination from terrestrial sources of infrared emission.

The Extragalactic Infrared Background (EBL) is the integrated light from all of the infrared sources in the Universe. In the near IR, these photons are produced by stars as a by-product of nucleosynthesis. Measurement of the near IR EBL therefore constrains the stellar content of the Universe.

Data from CIBER-2 will help determine the origin and history of EBL fluctuations by carrying out multi-wavelength imaging in 6 spectral bands from 0.5 to 2.0 µm.

CIBER-2 was specifically designed to help disentangle the reionization signal from emission from sources at lower wavelength. One of the primary CIBER-1 results was unexpectedly bright, large-angle fluctuations at wavelengths of 1.1 and 1.6 microns, which may be identified with stars flung outside of galaxies or other new populations that result from large-scale structure formation. The CIBER-2 data set will give us our most complete view of the near-IR background to date.

CIBER–2 in the cleanroom at Wallops Flight Facility.

Cleanroom inspection of CIBER–2.

CIBER–2 science team in the Attitude Control Systems Lab at Wallops Flight Facility.

Photos by: Berit Bland/NSROC

Principal Investigator: *Dr. Michael Zemcov/Rochester Institute of Technology* • ***Mission Number(s):*** *36.281 UG*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *June 7, 2021*

Geospace Missions 2021

Three Geospace Science missions, all from Wallops Island, VA, were launched in 2021. Kinetic-scale Energy and momentum Transport eXperiment (KiNet-X), studied space plasmas, Vlf trans-Ionospheric Propagation Experiment Rocket (VIPER) studied very low frequency radio, or VLF, waves that are produced by both natural and artificial means, and Dynamo-2 studied the upper atmosphere and its interactions with the ionosphere.

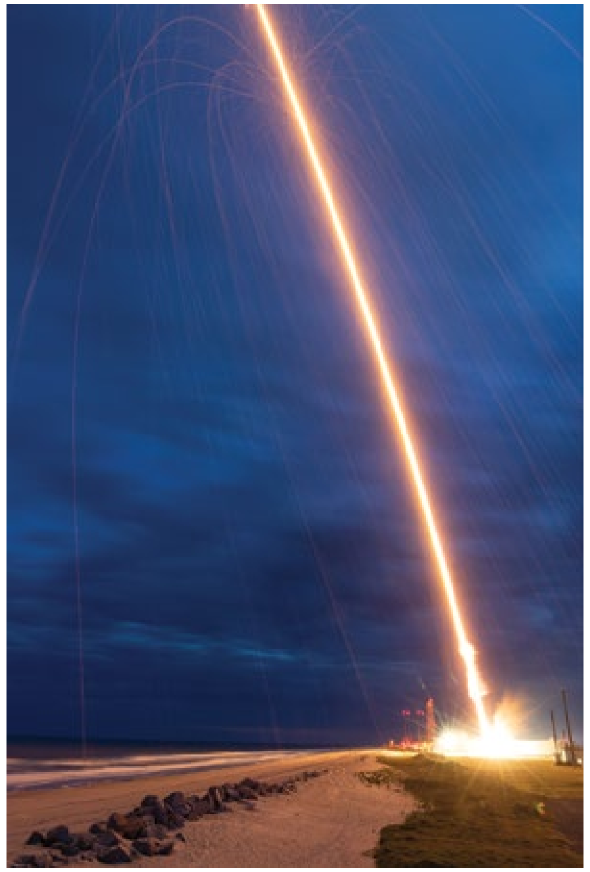
Background image: Wallops Island Launch Range
NASA Photo

Kinetic-scale Energy and momentum Transport eXperiment (KiNet-X)

KiNet-X was designed to study a very fundamental problem in space plasmas; how are energy and momentum transported between different regions of space that are magnetically connected?

Auroras, for example, are formed when particles in the Earth's near-space environment interact with the atmosphere. The electrons in Earth's space environment and in the solar wind have relatively low energies; yet the aurora is generated by very high energy electrons. What is this energization mechanism?

Another example of energy and momentum transport is the Io-Jupiter interaction. Io is the most volcanically active object in the solar system and has a tenuous atmosphere. The interaction between Io's atmosphere and Jupiter's space environment leads to an Io-induced auroral spot in Jupiter's atmosphere. We know the power generated by Io's interaction, and we know the auroral power from the spot, but how are energy and momentum transported along the connecting magnetic field line? KiNET-X is like a mini-Io with two barium vapor clouds that were emitted from the rocket's payload to generate a magnetic field perturbation, leading to energized electrons.



KiNet–X launch from Wallops Island, VA.
Photo credit: Allison Stancil–Erwin/NASA

Barium vapor clouds from KiNET–X.
Photo credit: Dr. Delamere

The KiNET-X experiment, with known input parameters, was designed to quantify the flow of energy to the electrons. In-situ instruments measured the energized electrons directly. In addition, specialized cameras in Bermuda and on an aircraft were used to observe the interactions.

The KiNet-X experiment consisted of a single rocket launch carrying seven separable payloads. Diagnostic instrumentation was carried on the main payload and four small subpayloads, while the barium vapor clouds were released from two additional larger subpayloads. This allowed for a multiple-point view of the disturbances created by the barium vapor releases. The four small subpayloads made measurements of the space environment through which the barium-vapor-induced disturbance traveled.

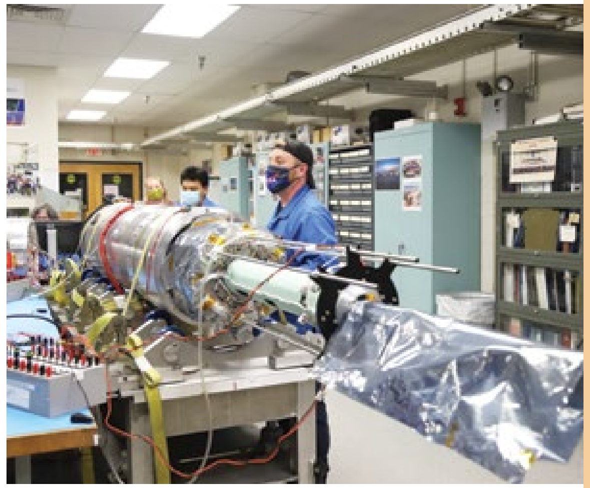
Principal Investigator: *Dr. Delamere/University of Alaska* • ***Mission Number(s):*** *52.007 UE*
Launch site: *Wallops Island, VA* • ***Launch date:*** *May 7, 2021*

Vlf trans-Ionospheric Propagation Experiment Rocket (VIPER)

VIPER studied very low frequency radio, or VLF, waves that are produced by both natural (e.g. lightning) and artificial means. During the day these waves are trapped or absorbed by the Earth's ionosphere. At night some of the waves escape through the ionosphere and accelerate electrons in the Van Allen Radiation Belt.

At night, the lower layers of the ionosphere are much less dense, and more of the VLF can leak through,propagate along the Earth's magnetic field lines, and endup interacting with the high energy electrons trapped in the Van Allen Radiation Belts. The Van Allen Radiation belts, of intense energetic electron fluxes, cover a range of distances from the Earth, from as close as 14,300 miles altitude (~4.4 Earth radii) out to 23,500 miles altitude (~7 Earth radii). GPS satellites orbit at around 4.4 Earth radii, and geosynchronous satellites at about 6.6 Earth radii. Satellites in those orbits are often engulfed by the Van Allen Radiation Belts and have to tolerate the effects those energetic particles have on electronics and materials. By making accurate measurements of the VLF electromagnetic fields and the properties of the ionosphere below, at, and above the absorption and reflection layers in the ionosphere, VIPER provides a novel data set for comparison with existing numericalmodels of the fields and the ionosphere, as well asobservations made in the past of the escaping VLF radiation at higher altitudes and on the ground.

VIPER launch from Wallops Island, VA
Photo credit: Allison Stancil–Erwin/NASA



VIPER payload during integration at Wallops.
Photo credit: Berit Bland/NASA

While many ground-based and orbital observations of the VLF absorption/reflections/transmission have been made, VIPER is the first mission to make measurements right in the region where all the action happens. There are models of what to expect in such regions, but actual measurements are key to pin down the details of those models, as well as, to develop the instruments required to explore more challenging regions.

In addition to the in-situ measurements made by VIPER as it flies through the area of interest, the mission also will employ numerous ground-based systems, including thosei n Maine, North Carolina, Georgia, Colorado and Virginia.

Principal Investigator: *Dr. John Bonnell/University of Berkeley* • ***Mission Number(s):*** *46.028 UE*
Launch site: *Wallops Island, VA* • ***Launch date:*** *May 27, 2021*

Dynamo-2

Two rockets with scientific instruments were launched to study the upper atmosphere and how it interacts with the ionosphere. The rockets, both two-stage Terrier-Black Brants were flown on July 7 (36.358) and July 11 (36.357). The Dynamo-2 flights build on discoveries made by the first Dynamo payloads launched im 2013.

Atmospheric dynamos create global systems of currents driven by winds within the conducting upper atmospheres of magnetized planets, such as Earth, Jupiter, and Saturn. The Earth's atmospheric dynamo is accessible to detailed scientific study and can be explored directly with probes on sounding rockets, revealing the interdependency of the forces that drive the dynamo and their consequential patterns of currents and electric felds.

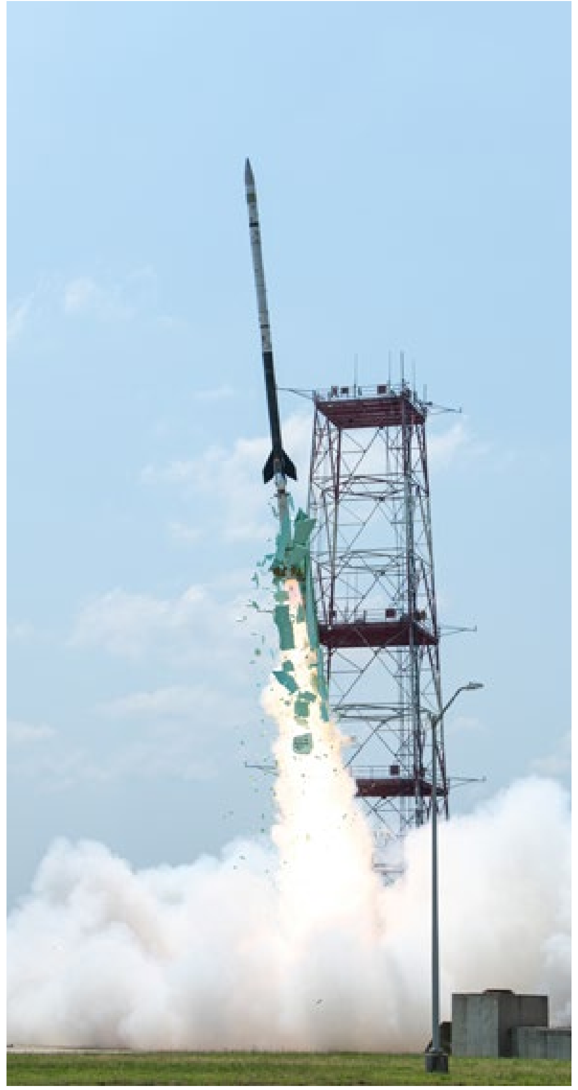
The Dynamo-2 mission incoporated rocket borne, ground based, and satellite based data.

Two identical instrumented payloads were carried to an apogee of 135 km with instruments to measure DC electric fields, plasma density, currents, neutral winds, neutral density and temperature, and ion mass distributions.

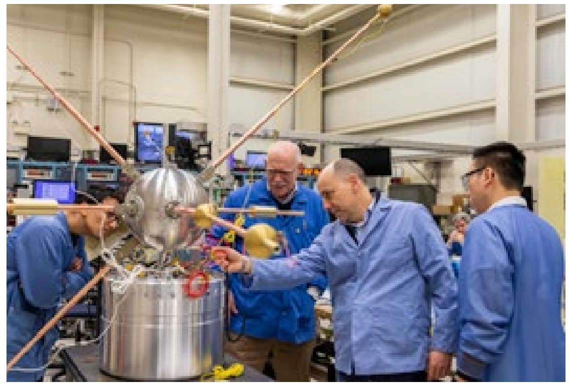
NASA's Ionospheric Connection Explorer (ICON) satellite gathered measurements of winds in the same volume as the sounding rockets over Wallops. It also gathered simultaneous ion drifts (electric fields) in the F-region ionosphere at low latitudes.

A magnetometer at Wallops provided local current measurements and helped determine the launch conditions. The world wide magnetometer network helped characterize the mid-latitude current patterns on the day of each flight.

The Vertical Incidence Pulsed Ionospheric Radar (VIPIR) and digital ionosonde at Wallops provided plasma density profiles, and evidence of gravity waves, and the presence of sporadic-E.

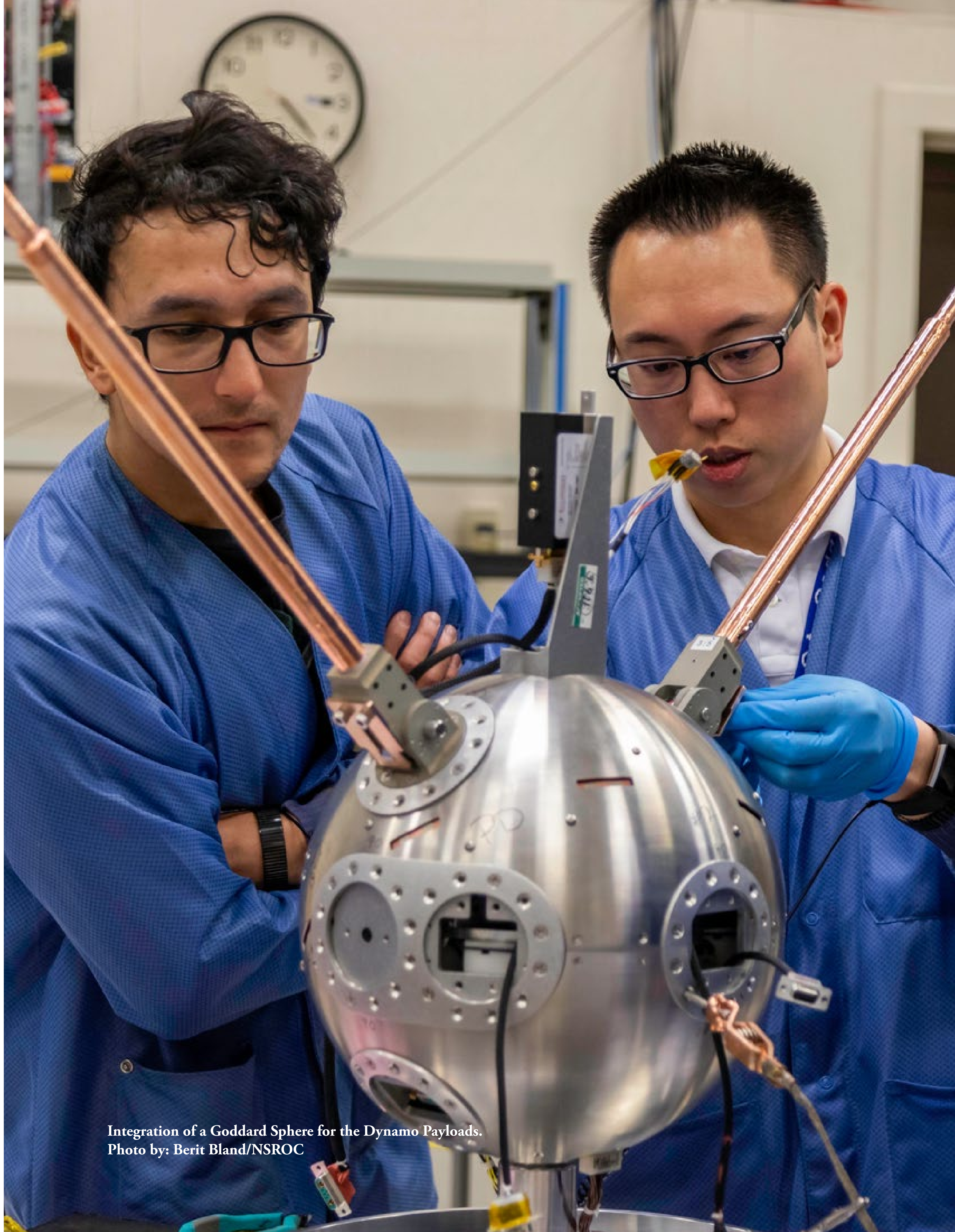


First Dynamo–2 rocket launches from Wallops Island, VA.
Photo by: NASA Wallops Imaging Lab

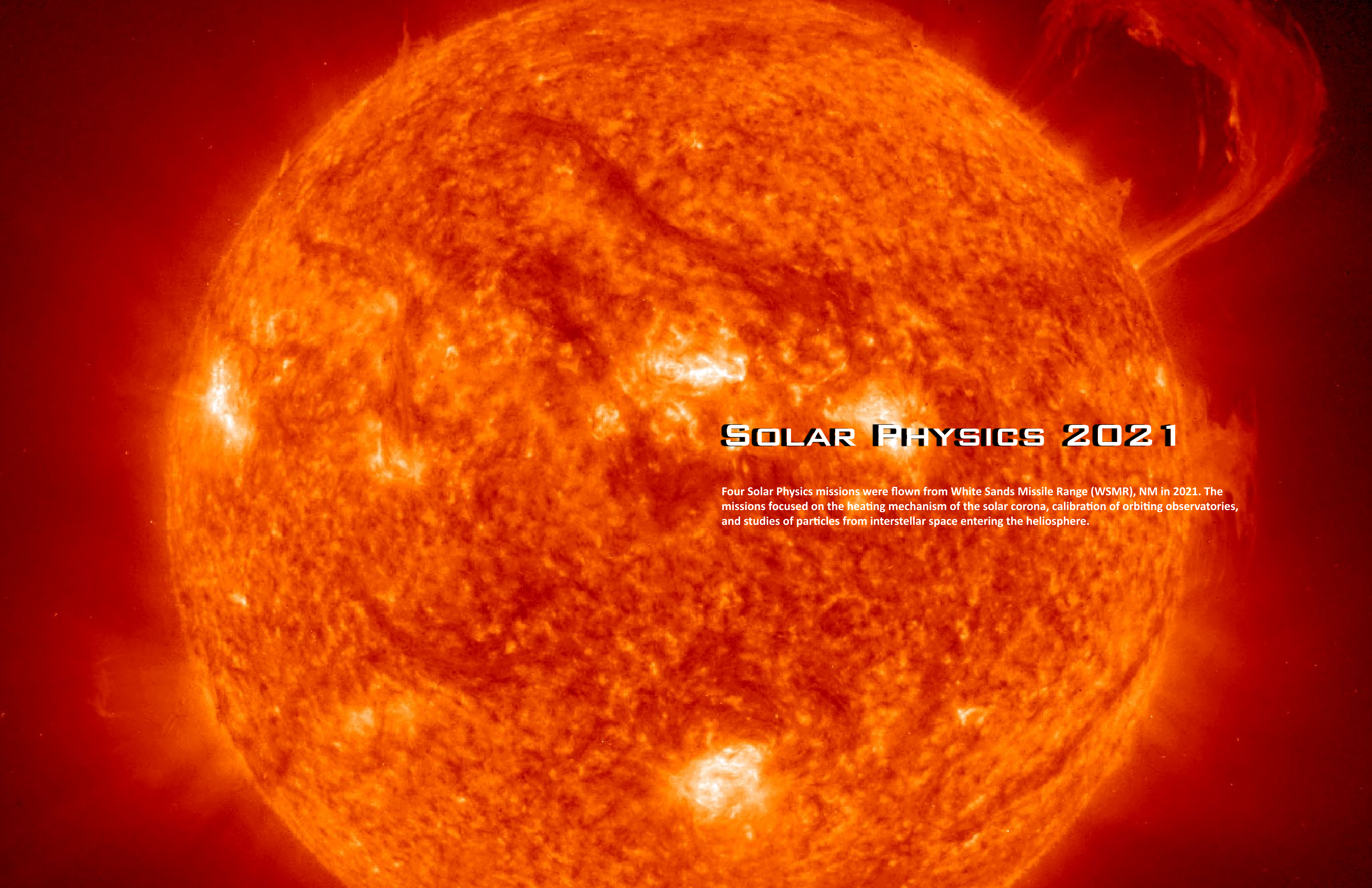


Principal Investigator, Dr. Pfaff (third from right) and the science team work on the Goddard Sphere portion of the Dynamo payload.
Photo by:Berit Bland/NSROC

Principal Investigator: *Dr. Robert Pfaff/NASA Goddard Space Flight Center* • ***Mission Number(s):*** *36.357&36.358 GE*
Launch site: *Wallops Island, VA* • ***Launch date:*** *July 7 & 11, 2021*



Integration of a Goddard Sphere for the Dynamo Payloads.
Photo by: Berit Bland/NSROC



Solar Physics 2021

Four Solar Physics missions were flown from White Sands Missile Range (WSMR), NM in 2021. The missions focused on the heating mechanism of the solar corona, calibration of orbiting observatories, and studies of particles from interstellar space entering the heliosphere.

Spatial Heterodyne Interferometric Emission Line Dynamics Spectrometer (SHIELDS)

The SHIELDS mission studied particles from the interstellar medium entering the heliosphere, a magnetic bubble created by the sun. As the heliosphere moves through the Local Bubble, a low-density region of the galactic interstellar medium, at roughly 52,000 mph (84,000 kph), particles from interstellar space fall on the heliosphere.

SHIELDS measured light from neutral hydrogen atoms originally from interstellar space. These neutral atoms, with a balanced number of protons and electrons, must pass through a barrier formed by charged particles in the heliopause. This barrier alters the paths of the netural atoms. SHIELDS was designed to reconstruct the trajectories of the neutral particles to determine where they originated. Measuring how the wavelength, from neutral hydrogen, stretches or contracts reveals the particles' speed. SHIELDS will produce a map to reconstruct the shape and varying density of matter at the heliopause.

SHIELDS will further our understanding of the distribution of matter in the Local Bubble. The density of the bubble is estimated at about 1/10 of the rest of the Milky Way's main disk, but the distribution is unknown.

The properties of the galaxy's magnetic field are largely unknown, but the heliopause is compressed in specific ways based on the strength and orientation of the galactic magnetic field. SHIELDS can detect these changes.

Data from the SHIELDS mission is currently being analyzed.

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

SHIELDS science team at Wallops during integration.
Photo by: Berit Bland/NSROC

Principal Investigator: *Dr. Walter Harris/University of Arizone•* ***Mission Number(s):*** *36.324 US*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *April 19, 2021*

Extreme Ultraviolet Normal-Incidence Spectrograph (EUNIS)

This, the fourth mission for EUNIS, was similar to the prior flight in 2013 and was intended to further enhance the theory of coronal heating by nanoflares on the Sun.

During the 2013 flight, EUNIS scanned an active region – a magnetically complex area on the Sun, often the site of solar flares and sunspots – when a spectral line from iron that had lost 18 of its 26 electrons (Fe XIX) was observed.

Fe XIX is formed at temperatures between about 14 and 16 million degrees Fahrenheit. These ions are typically associated with flares and not with the quiescent active regions that EUNIS observed. These observations added to the debate about coronal heating on the Sun. While the Sun's surface is about 10,000 degrees F, the corona, is 300 times hotter despite being farther from the core.

The observations in 2013 boosts the theory that 'nanoflares', tiny magnetic explosions, are responsible for the coronal heating. These nanoflares are usually too small to detect, yet should leave behind bursts of extreme heat as observetd by EUNIS.

For the 2021 flight the EUNIS instrument suite was modified to capture even brighter spectral lines from Fe XIX. It will also capture lines from Fe XVIII, which is nearly as hot.

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

The 2013 mission included two channels, 30-37 and 52-63 nm. For the 2021 mission a 9-11 nm channel replaced the 30-37 nm channel.

EUNIS's measurements resolve a few specific wavelengths extremely precisely, helping calibrate orbital spacecraft, such as the Solar Dynamics Observatory (SDO).

Principal Investigator: *Dr. Adrian Daw/NASA Goddard Space Flight Center* • ***Mission Number(s):*** *36.322 GS*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *May 18, 2021*

Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)

The MaGIXS mission included a high-powered camera, telescope, and X-ray spectrometer containing a matched pair of grazing incidence parabolic mirrors – to study "soft" X-rays at a wavelength that has not been previously observed in detail. Specifically, MaGIXS aimed to further our understanding of how the Sun's corona, the atmosphere, is heated to temperatures much higher than the Sun's surface.


MaGIXS on the pad at WSMR.
Photo by: Visual Information Branch/WSMR

Past soft X-ray spectrometer missions have only observed the Sun's corona over a fairly large field of view, or with limited energy diagnostic capabilities. MaGIXS, by comparison, was the first imager to measure specific temperature distributions at different parts of an active solar region. That precision data will help scientists resolve the debate concerning how – and how often – the corona is superheated.

Shedding new light on coronal heating mechanisms could help researchers better understand and even predict potential solar flares and coronal mass ejections, both of which occur most often in connection with regional spikes in coronal heating. These violent outbursts can interfere with communications satellites and electronic systems, eve causing physical drag on satellites as Earth's atmosphere expands to absorb the added solar energy.

Additionally, the MaGIXS sounding rocket mission also served as a testbed for instrumentation for future NASA missions to study solar flares in greater detail, possibly tying their origins to measurable coronal activity and helping demonstrate how advanced flight hardware and space systems can be hardened to withstand these high-energy flares and mass ejections.

Principal Investigator: *Dr. Amy Winebarger/NASA Marshall Space Flight Center* • ***Mission Number(s):*** *36.319 NS*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *July 30, 2021*

Solar Dynamics Observatory - EUV Variability Experiment (SDO-EVE)

The primary objective for this mission is to provide an underflight calibration for the EUV Variability Experiment (EVE) aboard the NASA Solar Dynamics Observatory (SDO) satellite.


EVE team at WSMR.
Photo by: Visual Information Branch/WSMR

The EVE program provides solar EUV irradiance data for NASA's Living With the Star (LWS) program, including near real-time data products for use in operational atmospheric models that specify the space environment and to assist in forecasting space weather operations.

This was the 10th underflight calibration for the EUV Variability Experiment (EVE) aboard the NASA Solar Dynamics Observatory (SDO) satellite. Prior calibration missions have been flown on May 3, 2010, October 28, 2006, April 14, 2008, March 23, 2011, June 23, 2012, October 21, 2013, May 21, 2015 (LV failure), June 1, 2016, and June 18, 2018.

This mission also provided underflight calibrations for several solar EUV imagers aboard orbiting observatories.

NASA 36.353 was a reflight of NASA 36.336 but with some changes:
The Compact SOLSTICE (CSOL) solar FUV-MUV spectrograph and the GOES-R prototype XRS solar X-ray photometers were removed.

Three Solar Photometer Array (SPA) units to provide special calibrations for Hydrogen Lyman-alpha (121.6 nm), X-ray bands (0.1-2 nm), and EUV bands (10-35 nm) were added.

Principal Investigator: *Dr. Thomas Woods/University of Colorado* • ***Mission Number(s):*** *36.353 US*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *September 9, 2021*

Reimbursable Missions 2021

Two reimbursable missions were flown in 2021. The Aerodynamic Buffet Flight Test (ABFT), launched from White Sands Missile Range, NM, investigated the unsteady aerodynamic environment acting on a launch vehicle in the transonic flight regime, called transonic buffet. HOTShot, part of the HOTShot program, launched from Wallops Island, VA and collected scientific data that benefits aerospace research.

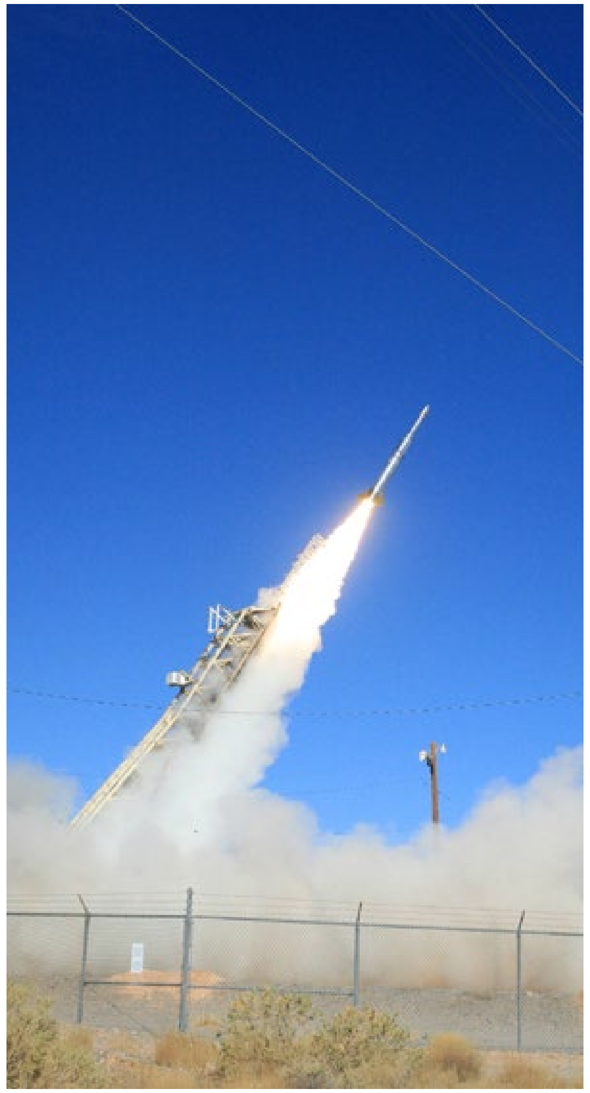
Background image: HOTShot launches from Wallops Island, VA
Photo Credit: NASA Photo/Lee Wingfield

Aerodynamic Buffet Flight Test (ABFT)

The ABFT investigated the unsteady aerodynamic environment acting on a launch vehicle in the transonic flight regime, called transonic buffet, by measuring the constantly-changing surface pressures on a rocket using several hundred miniature pressure transducers imbedded in the skin of the vehicle.

The measurements will be used to better understand the shortcoming, and help improve, current analytical methods used to model this aerodynamic environment and how it interacts with the structure of a launch vehicle. Current state-of-the-art prediction methods are based on wind tunnel data measured at quasi-steady test conditions. These conditions do not simulate the constantly-accelerating trajectory conditions of a launch and may result in less accurate load predictions, ultimately requiring heavier than necessary vehicle structures to account for these uncertainties. Since transonic buffet loads are some of the largest contributors to the structural design requirements, improving these prediction methods loads may lead to lighter, more efficient, and more capable launch vehicles.

This mission also demonstrated the "Ship and Shoot" operations concept. Due to the complex assembly process the payload/vehicle will be completely assembled for flight and shipped to the field in two sections. Shipment in a controlled environment will enable minimal testing in the field prior to loading on the rail. This approach enables reduced duration of field operations, reduced field hazardous operations, increased quality assurance, and will result in cost savings to the program.



ABFT lift–off from White Sands Missile Range, NM.
Photo by: Visual Information Branch/WSMR

Principal Investigator: *Dr. Gilbert/NASA Engineering Safety Center* • ***Mission Number(s):*** *12.088 NR*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *March 30, 2021*

High Operational Tempo (HOTShot)

The HOTShot payload was successfully launched on a NASA sounding rocket on September 11, 2021 from Wallops Island, VA.

This flight was part of the HOTShot program, which collects scientific data that benefits aerospace research and informs future weapon designs for the U.S. nuclear enterprise. Its non-nuclear scientific experiments evaluate prototypes and help develop high-fidelity computer models and mechanical flight simulators.

HOTShot payload during integration at Wallops.
Photo by: Berit Bland/NSROC

Principal Investigator: *Dr. Leathe/Sandia* • ***Mission Number(s):*** *46.033 AR*
Launch site: *Wallops Island, VA* • ***Launch date:*** *September 11, 2021*

Education Missions 2021

Level 1 RockOn!

Level 2 RockSat-C

Level 3 RockSat-X

RockOn & RockSat-C

The RockOn! workshop was conducted virtually in 2021. Hundred and two students and faculty members participated in the virtual workshop, which was the 13th 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. Thirty-two RockOn experiments and eight RockSat-C experiments were flown on this mission.

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.

Photos by: Berit Bland/NSROC

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.

RockOn website: https://spacegrant.colorado.edu/national-programs/rockon-home

RockSat-C website: https://spacegrant.colorado.edu/rs-c-home/previous-experiments/rs-c-2020-home

Principal Investigator: *Mr. Chris Koehler/Colorado Space Grant Consortium*• ***Mission Number(s):*** *41.130 UO*
Launch site: *Wallops Island, VA* • ***Launch date:*** *June 25, 2021*

RockSat-X

RockSat-X was successfully launched from Wallops Island, VA on August 19, 2021. 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 2021:

Community Colleges of Colorado

The experiment involved create a virtual reality camera assembly that fits into a payload, enabling a 360° video of the rocket outside of the Earth's atmosphere, and assess the effects of microgravity and radiation exposure on the bacterial species Serratia marcescens. The project is a collaboration between three community colleges in Colorado: Arapahoe Community College, Community College of Aurora, and Red Rocks Community College. Their primary experiment was to develop a cost-effective method to alter the trajectory of space debris in suborbital flight.

Photos by: Berit Bland/NSROC

College of the Canyons

The goal was to design a drop capsule that utilizes the properties of auto rotation to provide the necessary lift for the capsule to slow and successfully splashdown with the vehicle and test cargo intact

University of Kentucky

The University of Kentucky improved upon an experiment flown in 2017 that tested data acquisition, communication, and thermal protection of a small reentry capsule. This year's experiment is one of the last stages of the development which aims to increase the technology readiness level (TRL) of the capsule to TRL 7.

Colorado School of the Mines

The experiment tested various space debris remediation techniques to deorbit space debris less than 1 cm. Also included was testing of a communication system from a ground-based system.

Principal Investigator: *Mr. Chris Koehler/Colorado Space Grant Consortium*• ***Mission Number(s):*** *46.030 UO*
Launch site: *Wallops Island, VA* • ***Launch date:*** *August 19, 2021*

University of Colorado

The experiment was designed to design and test a rigid panel deployment sequencing mechanism and demonstrate the device's feasibility in a microgravity environment. The objectives were to demonstrate a successful boom deployment using folded strain technology, collect data on shock, deployment rate, temperature, humidity and video footage of deployment, and demonstrate the application of a strain deployed boom for use of extending a wireless transmission module.

Virginia Tech

The primary objective of the experiment was to test a deployable solar array for future CubeSat or other small satellite energy production applications. The goals included the successful deployment of a solar array from a sounding rocket payload deck, successful retraction of the array and recovery of the intact experiment after re-entry and splashdown, and the successful use power generated by the solar array to run at least one onboard sensor.

University of Puerto Rico

The University of Puerto Rico's mission was to collect micrometeorites in the Meteor Trail at altitudes of 50-68 miles (80-110 km) in order to gather organic molecules for complete Nucleic Acids sequencing of DNA and RNA. The experiment uses polymer aerogels to gather samples of micrometeorites and organic molecules. An additional objective was to continue the MinION™ trade study and incorporate the Oxford Nanopore Voltrax™ device and certify it to Technical Readiness Level (TRL) 9.

Northwest Nazarene University (NNU) & Kaua'I Community College (KCC)

This University team tested RFID devices in space and aimed to create a high quality 360-degree VR experience. Education focused objectives include bringing together students from NNU and KCC to construct a low-cost space-ready payload employing RFID and Virtual Reality technologies in order to develop students' real-world engineering skills and provide opportunity to share the results with a broader community.

West Virginia Collaboration

The West Virginia Space Flight Design Challenge is a collaboration between several colleges and include West-Virginia University (WVU), Morgantown; Blue Ridge Community and Technical College (BRCTC), Martinsburg; West Virginia State University (WVSU), Institute; and West Virginia Wesleyan College (WVWC), Buckhannon. Each school had its own experiment which were integrated together with an additional system that provides power and telemetry. The objectives of the WVSU experiment were to compare Geiger-Muller tube designs, determine orientation of radiation sources relative rocket and improve the mounting mechanism to reduce noise obtained from vibration throughout the mission, detect orientation of the rocket relative to the Sun, and measure flight dynamics (acceleration and rotation rates), magnetic fields, and temperature. WVU's experimemt used a Raspberry Pi, two speakers and a microphone to measure the transmission of pressure waves. The WVWC experiment used two Inertial Measurement Units (IMU) to study rocket motion during a multi-stage parabolic space flight. BRCTC provided an experiment to record an accurate vibration profile (Power Spectral Density) of the canister in the rocket to provide vital hertz data to future RockSat teams.

University of Colorado RockSat-X Team taking flight.
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 in 2022. 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 Deploying and Retracting Tubular (DaRT) boom system with 360º cameras
- 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

Deploying and Retracting Tubular (DaRT) boom system (ETD)

The SubTEC-9 payload includes the first flight test of the DaRT boom system. For this flight cameras are mounted on the booms, which are then deployed and retracted. The boom systems are mounted in an opposing pair configuration, resulting in a tip-to-tip span of 5 meters.

Opposing pair configuration

DaRT interior view.

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

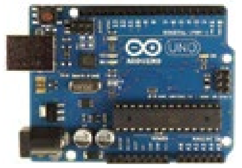
– Power for the PARSEC experiment

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.

Sounding Rockets Program Technology Roadmap

* Acronyms

INS – Inertial Navigation System

GIPS – Guidance, Naviation & Control Integrated Power System

MUTAS – Multi–threaded Universal Telemetry Analysis Suite

SPARCS – Solar Pointing Attitude Rocket Control System

FTS – Flight Termination System

Goals

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 and modern–ization of payload systems
- Minimize weight and volume of support systems

High altitude vehicle with re–entry and recovery
- Allows longer science ob–servation times while still allowing re–flight of science instruments and payload systems

Mesospheric vehicle and pay–load
- Leverage sub–payload sys–tems to develop miniature yet capable payloads for meso–spheric science

Core Technologies

Sub–Payloads

- 1 Mbps telemetry
- Single main receiver
- Sub–payload sensor suite

- Dual main receiver
- GPS receiver
- Larger battery packs

- GPS sub–payload antenna upgrade
- Increased RF range (~40 km) with lower–rate data

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

Telemetry

- High data rate encoder
- 40 Mbps S–band telemetry
- Ethernet via telemetry (EVTM) development

- 40 Mbps C–band telemetry devel–opment
- Ethernet payload bus communica–tion development

- Ground station upgrades for C–band telemetry
- High rate (1 Gbps) onboard data recorder development

- 300–400 Mbps C–band telemetry development

Miniaturization & Modernization

- Tern INS and GIPS *
- Tern NIACS
- TM over IP data distribution
- Telemetry analysis suite (MUTAS)*
- Deployable ground station

- Tern SPARCS* development
- High energy density battery development

- Wallops Integrated Star Tracker (WalST)

- New ignition system
- New power system
- Payload lightweight concepts

- Integrated power system devel–opment
- Versatile Linear Shape Charge (FTS)*

- Consolidated ordnance system development

- Low–cost flight computer

New Capability

- Swarm Communication

- Deploying and Retracting Tubular (DaRT) Boom

- Nested skin for high altitude reentry

- Mesospheric payload

- Large diameter payload (>32")
- Mesospheric vehicle
- High altitude vehicle

- High altitude vehicle recovery

2019 2020 2021 2022 2023 2024 2025

SubTEC–8
Launched: October 24, 2019

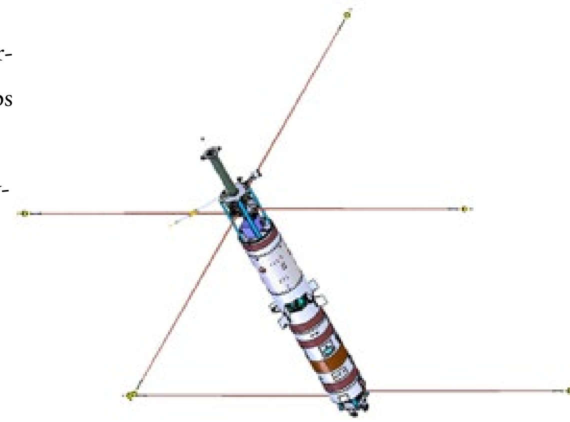
SubTEC–9

SubTEC–10

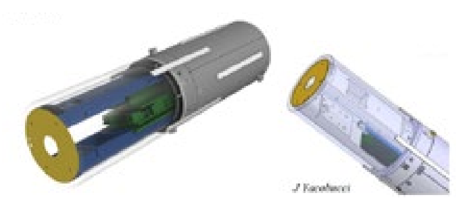
Additional Technology Development

In addition to the dedicated technology development missions, such as the upcoming Sub-TEC 9, the SRPO provides enhancements to new technologies for science missions. For the Kinetic-scale Energy and momentum Transport eXperiment (KiNET-X, see page 20) mission several upgrades were made to the Distributed Payload Communication sub-payload system. KiNET-X was designed to enhance our understanding of a key aspect of heliophysics; the energy and momentum coupling between spatially separate but magnetically linked plasma regimes. With known energy and momentum input, KiNET-X is designed to test the understanding of kinetic-scale transport. In particular, these questions are addressed: 1) how momentum transport is affected by ion kinetic-scale physics, 2) how electromagnetic energy is converted into plasma kinetic and thermal energy, 3) the interplay between fluid- and kinetic-scale processes.

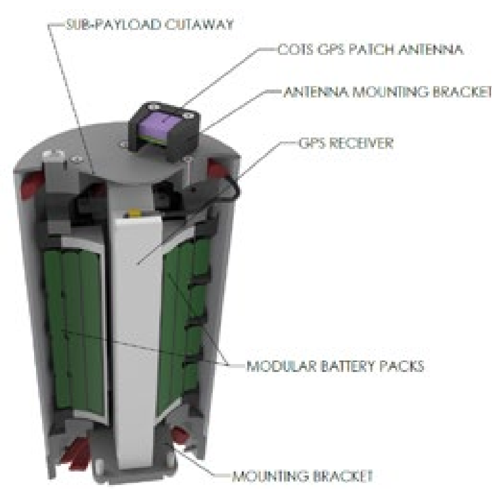
KiNET-X was a multi-instrument payload with participation from several science institutions and organizations, and was launched from Wallops Island, VA on May 7, 2021. The Principal Investigator was Dr. Peter Delamere from University of Alaska, Fairbanks. The deployable sub-payloads, developed by SRPO and ETD, contained instruments provided by Co-Investigator Dr. Kristina Lynch from Dartmouth College.


KiNET–X payload

Several modifications were made to the sub-payloads for this mission. A modular battery package, for longer data collection times on the sub-payloads, and a miniature GPS package, for improved location information during flight, were added. Additionally, a dual-channel "Marko" receiver for the main payload was developed. This was designed to enable one receiver to track two ejectables, or two receivers to track four ejectables. The prior design used one receiver to track four ejectables that exited the payload at different times. That configuration led to signal loss from the first set of deployables, due to the second set, still inside the main payload, overpowering the weaker signal from the deployed sub-payload.


Deployable sub–payloads.

Ovearall the results from the improved sub-payloads were positive.



Modified deployable.
3D model by Josh Yaccobucci/NASA ETD


Scott Hesh integrating deployables for the KiNET-X mission.
Photo by: Berit Bland/NSROC

STEM Engagement

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

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

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

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

The CoVid-19 pandemic hampered on-site, in person outreach activities. These will resume when safety allows.

The Wallops Rocketry Academy for Teachers and Students (WRATS) is a week long workshop hosted by the Sounding Rockets Program Office and NSROC with support from the Wallops Education Office. The first WRATS workshop was held in 2011. Participating educators teach STEM topics at the High School or Middle School level. The 2021 workshop was postponed due to the CoVid-19 pandemic.

WRATS offers a unique, in-depth, learning experience where teachers get hands-on practice building model rockets and payloads, Presentation topics such as aerodynamics, propulsion, recovery system design, and trajectory simulations are covered.

WRATS starts with overviews of the Sounding Rockets Program and model rocketry, followed by construction of an E-powered model rocket. Tours of sounding rocket Testing and Evaluation facilities and machine shop are also included. By the end of the first day, all teachers have a flyable model rocket.

On the second day, teachers build an electronic payload to measure acceleration, temperature. and pressure during flight. The payload is based on the Arduino microprocessor and inexpensive sensors. Recovery system design and construction are also completed. Once all the construction activities are completed, the models are launched and recovered at Wallops Flight Facility. Flight data is then plotted and analyzed.

The participants also get an opportunity to watch a sounding rocket launch from Wallops Island.

Internships

Over 200 students have participated in the internship program managed for the Sounding Rockets Program Office by NSROC. The program, now in its 19th year, provides internships and co-op opportunities for students studying engineering, computer science, electrical or mechanical technology, as well as business disciplines. Students work side-by-side with experienced engineers and managers to perform significant, valuable tasks, leading to a better understanding of the work in a highly technical environment. Almost 90 percent of undergraduate students who intern or participate in the co-op program return for additional employment. Several participants in the program have gone on to pursue higher education in the engineering and science fields.

In 2021 five internships were offered. Disciplines included Aerospace, Mechanical and Electrical engineering.

Outreach

Before facility restrictions due to CoVid-19 SRPO and NSROC personnel supported local schools by providing speakers, judging science fairs, and conducting special programs. Additionally, speakers were provided upon request to local civic organizations through the NASA Office of Communications.

NSROC and SRPO staff supported the virtual NASA Community College Aerospace Scholars (NCAS) with mentors and presentations. NCAS is a national STEM focused program where community college students interested in NASA related careers participate in a five-week online learning experience. Top scoring scholars are invited to participate in a 2-week virtual workshop. Three workshop were held in 2021 and led by the Education Office.

Tour of the Testing and Evaluation Lab.

New opportunities to conduct science missions in the Southern Hemisphere are being developed by SRPO. The planned return to Australia, originally scheduled for 2021, has been delayed due to CoVid-19 impacts on travel restrictions and quarantine requirements. Range setup was started in 2021, and launch operations are currently planned for 2022.

Several other missions are in development, and include flight tests for the Mars Ascent Vehicle (MAV) for a team from NASA JPL and Marshall Space Flight Center, as well as, flight tests of a Mars parachute for the NASA Langley Research Center.

Additionally, a solar physics campaign is planned for Poker Flat Research Range, AK in 2024.

On the Horizon

New and repeat opportunities to conduct science missions in remote locations abound within the SRPO. The new Australian launch range, Equatorial Launch Australia (ELA), was originally set to be operational by mid-year 2021. Due to CoVid-19 impacts the sounding rocket launches planned from ELA are being delayed and are currently planned for mid-year 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 2022.

Australia

The SRPO has been working for a number of years to solidify plans that would enable the astrophysics science community to have access to a launch range in the southern hemisphere that also offers up some of the capabilities of our routine launch range in White Sands, New Mexico – primarily telescope recovery. ELA, near Nhulunbuy, Northern Territory, has been selected as the launch site for three astrophysics mission, now scheduled for FY 2022. Site setup began in late summer 2021.

Aerial view of the ELA launch site.

The southern hemisphere science missions include:

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

SISTINE will investigate low-mass star UV environments and their effects on potential exoplanet atmospheres. The astrophysical target for SISTINE is the α Centauri A + B System. SISTINE made its first flight in 2019 from White Sands Missile Range, NM.

Dual-channel Extreme Ultraviolet Continuum Experiment (DEUCE-ELA)

DEUCE-ELA is designed to measure the first EUV spectrum, 500 – 900 Å, of the most accessible potential exoplanetary system, the α Centauri A + B System. No other star, except the Sun, has been observed in this spectral range. The high-energy (XUV and FUV; 5 – 911 Å and 912 – 1800 Å, respectively) stellar spectrum is required to understand habitable atmospheres as this emission both drives and regulates atmospheric heating and chemistry on Earth-like planets; and is critical to the long-term stability of terrestrial atmospheres. These observations will provide a crucial, and unique, input for models of planets orbiting G- and K-type stars.

X-ray Quantum Calorimeter (XQC)

The objective of the XQC mission is to measure high resolution spectra of the diffuse X-ray background at 0.1-3 keV. Observations in this energy range have shown that the interstellar medium (ISM) in our Galaxy contains large amounts of previous unsuspected hot gas in the 1 million to 3 million degree temperature range. This gas can have profound effects on the structure and evolution of galaxies, and plays a key role in the distribution and life cycle of the elements produced deep in the interiors of stars. Despite its importance, this hot component of the ISM is still poorly understood. Better understanding requires high spectral resolution observations of the atomic spectral lines that make up the bulk of the X-ray emission. These "plasma diagnostics" convey a rich variety of information about the composition, temperature, motion, and history of the hot gas.

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:

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 Principal Investigator for FOXSI-4 is Dr. Glesener/University of Minnesota.

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.

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.

Mars landing and ascent missions, FY 24 & 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. Several sounding rocket missions will be flown FY 24 and 25 to test systems for the Mars Ascent Vehicle (MAV) and parachutes for the Sample Retrieval Lander (SRL).

Sounding Rocket Launch Sites

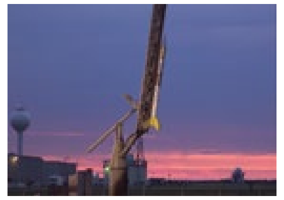

Poker Flat, Alaska


Esrange, Sweden


Kwajalein, Marshall Is.


Andøya, Norway


Woomera, Australia

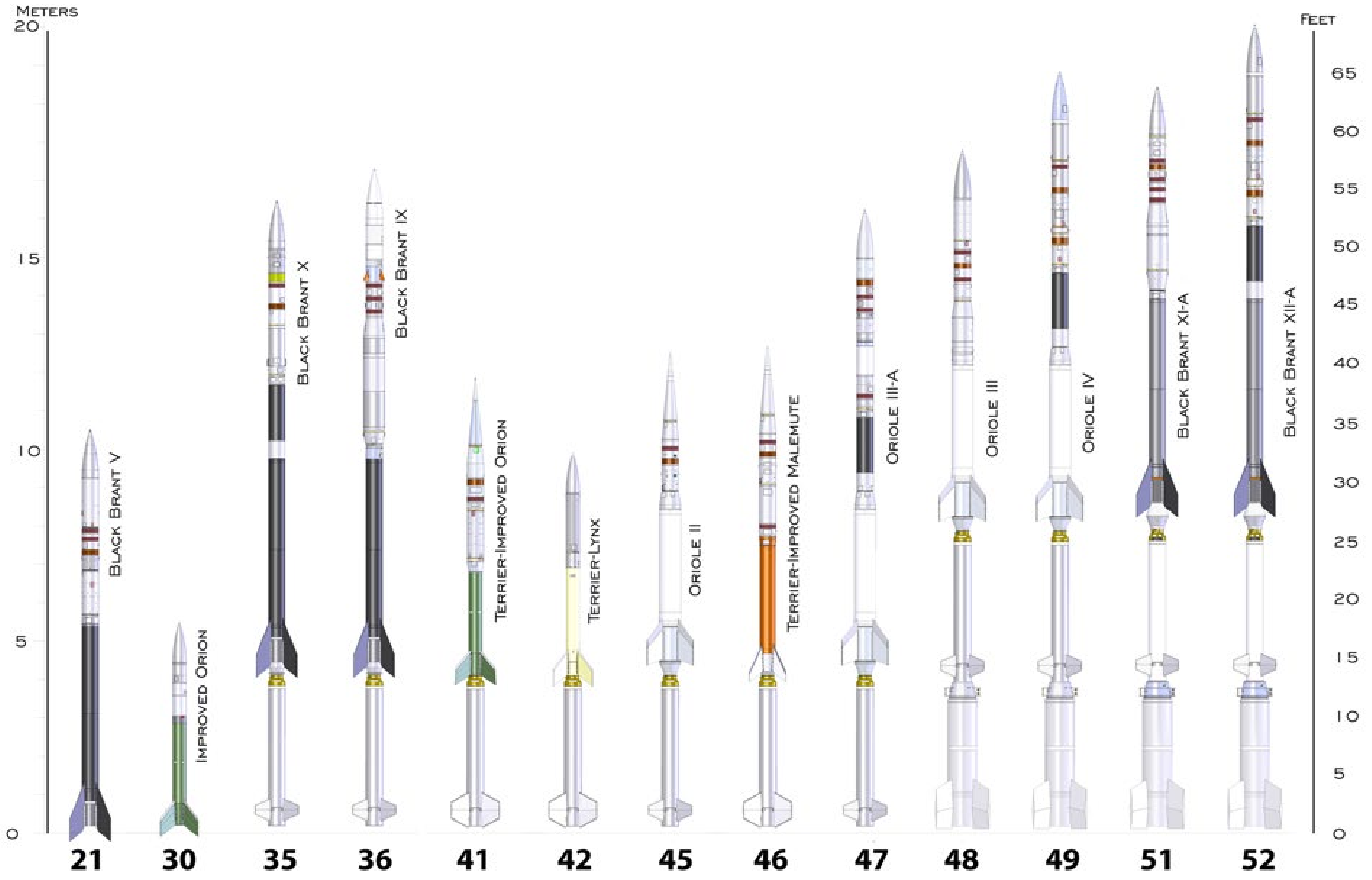

Wallops Island, Virginia

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

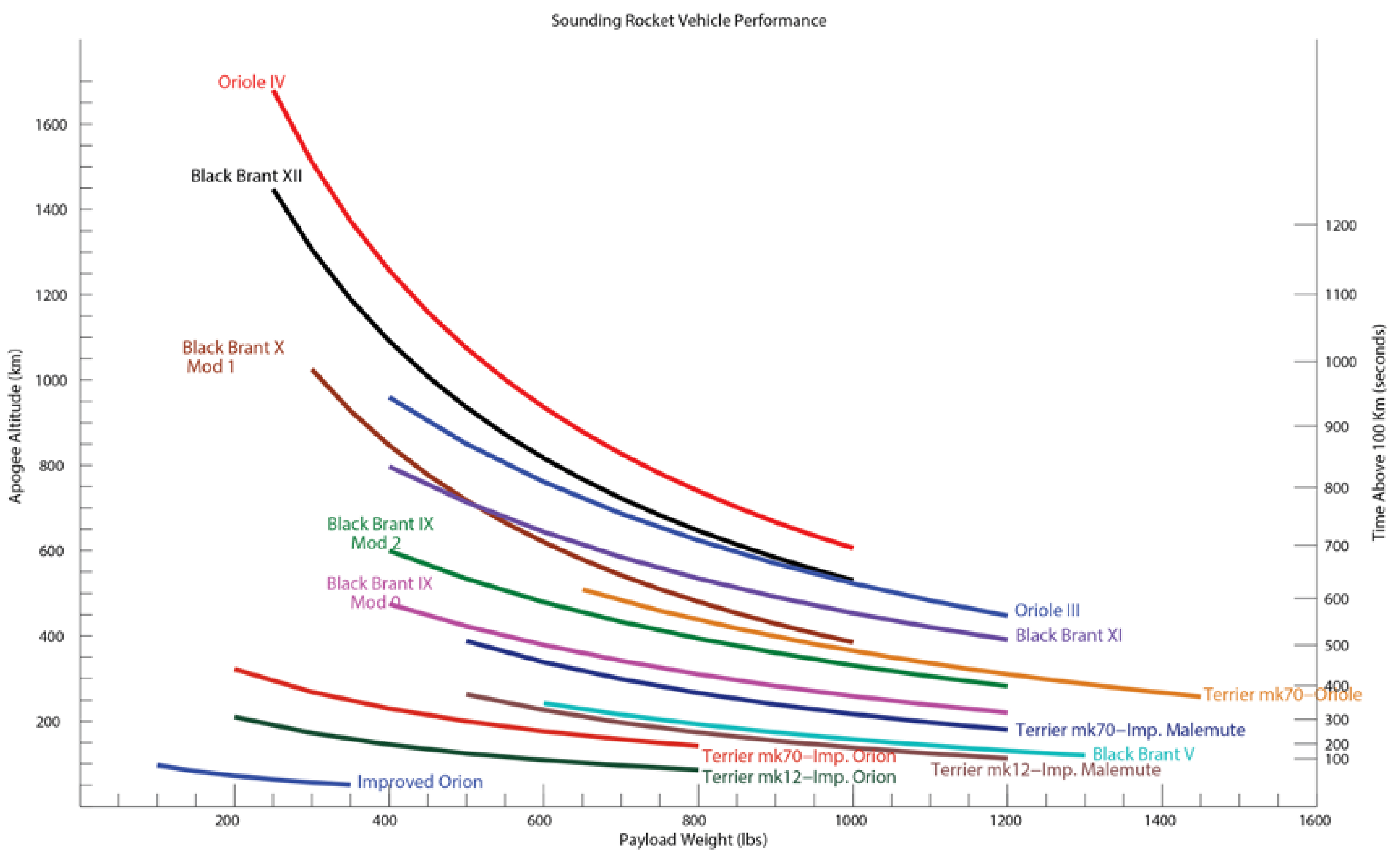
1. Kwajalein Atoll, Marshall Islands
2. Barking Sands, HI
3. Poker Flat, AK
4. White Sands, NM
5. Punta Lobos, Peru *
6. Alcantara, Brazil *
7. Camp Tortuguero, Puerto Rico *
8. Wallops Island, VA
9. Fort Churchill, Canada *
10. Greenland (Thule & Sondre Stromfjord) *
11. Andøya, Norway
12. Esrange,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

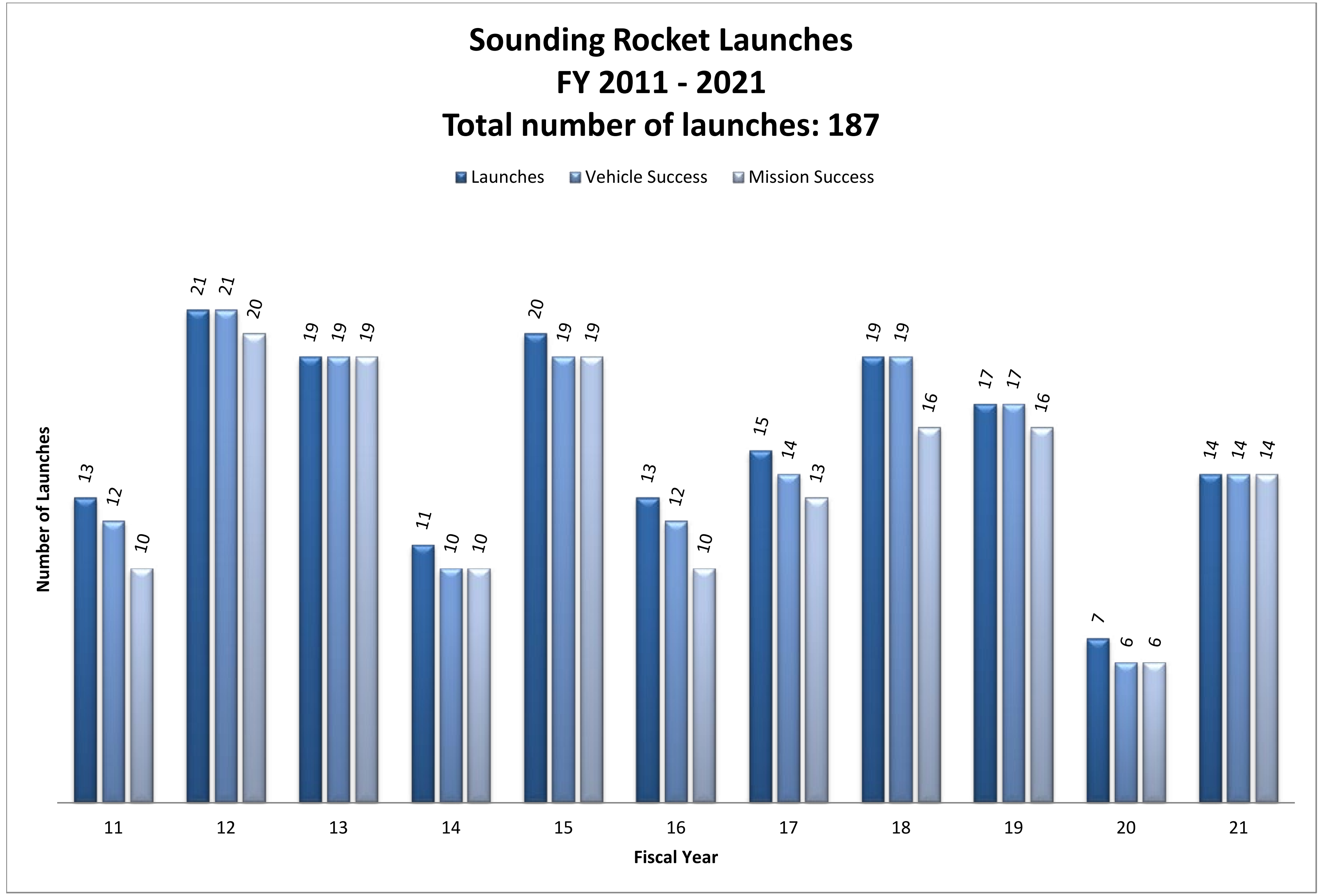
* Inactive launch sites

Sounding Rocket Vehicles



Sounding Rocket Vehicle Performance

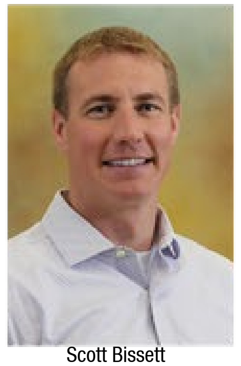




Sounding Rockets Program Office personnel

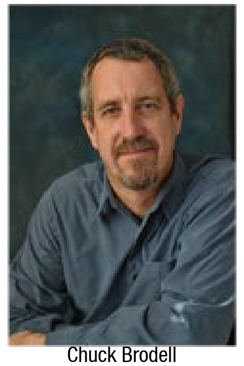

Giovanni Rosanova
Chief


John Hickman
Assistant Chief


Scott Bissett
Operations Manager

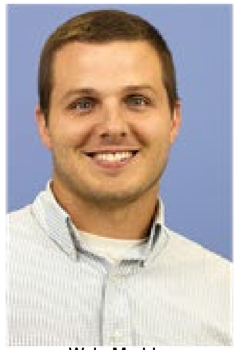

Julie Bloxom
Business/Grants Manager

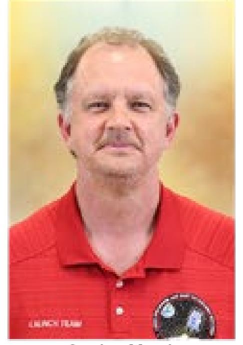

Daniel Bowden
Operations Manager


Chuck Brodell
Vehicle Systems Manager

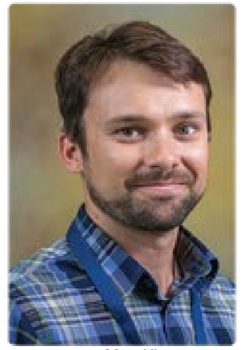

Catherine Hesh
Technology Manager


Scott Hesh
Electrical Engineering


Wyle Maddox
Resources Analyst


Gordon Marsh
Projects Manager

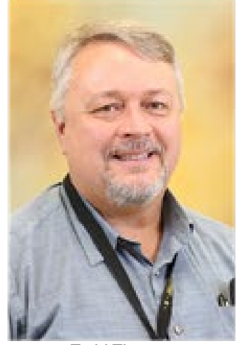

Jennifer McIntyre
Resources Analyst


Max King
Operations Manager

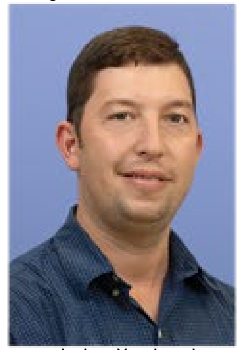

Carsell Milliner
Technical Manager


Sarah Ross
Grants & Project Support


Shane Thompson
Payload Systems Manager


Todd Thornes
Safety & Mission Assurance Manager


Libby West
Projects Manager


Joshua Yacobucci
Mechanical Engineering

Contact Information

Giovanni Rosanova
Chief
Ph: 757-824-2202
Email: Giovanni.Rosanova@nasa.gov

John Hickman
Assistant Chief
Ph: 757-824-2374
Email: John.C.Hickman@nasa.gov

Scott Bissett
Operations Manager
Ph: 757-824-2083
Email: Scott.A.Bissett@nasa.gov

Julie Bloxom
Business Manager/Grants Manager
Ph: 757-824-1119
Email: Julie.B.Bloxom@nasa.gov

Daniel Bowden
Operations Manager
Ph: 757-824-1435
Email: Daniel.C.Bowden@nasa.gov

Chuck Brodell
Vehicle Systems Manager
Ph: 757-824-1827
Email: Charles.L.Brodell@nasa.gov

Catherine Hesh
Technology Manager
Ph: 757-824-1408
Email: Catherine.L.Hesh@nasa.gov

Scott Hesh
Electrical Engineering
Ph: 757-824-2102
Email: Scott.V.Hesh@nasa.gov

Max King
Operations Manager
Ph: 757-824-1505
Email: Maxim.C.King@nasa.gov

Wyle Maddox
Resources Analyst
Ph: 757-824-2453
Email: Wyle.W.Maddox@nasa.gov

Gordon Marsh
Projects Manager
Ph: 757-824-1166
Email: Gordon.D.Marsh@nasa.gov

Jennifer McIntyre
Resources Analyst
Ph: 757-854-2231
Email: Jennifer.L.McIntyre@nasa.gov

Carsell Milliner
Technical Manager
Ph: 757-857-4665
Email: Carsell.A.Milliner@nasa.gov

Sarah Ross
Grants & Project Support
Ph: 757-824-1804
Email: Sarah.C.Ross@nasa.gov

Shane Thompson
Payload Systems Manager
Ph: 757-824-2217
Email: Shane.A.Thompson@nasa.gov

Todd Thornes
Safety and Mission Assurance Mgr.
Ph: 757-824-1557
Email: Todd.L.Thornes@nasa.gov

Libby West
Projects Manager
Ph: 757-824-2440
Email: Libby.West@nasa.gov

Joshua Yacobucci
Mechanical Engineering
Ph: 757-824-1940
Email: Joshua.T.Yacobucci@nasa.gov

National Aeronautics and Space Administration

Goddard Space Flight Center
Wallops Flight Facility
34200 Fulton Street
Wallops Island, VA 23337
www.nasa.gov/centers/wallops

www.nasa.gov