National Aeronautics and Space Administration

NASA Sounding Rockets Annual Report 2019

Message from the Chief

Giovanni Rosanova
Chief, Sounding Rockets Program Office

The Sounding Rocket Program continued to reach for the heavens in 2019. We launched 17 missions, from 5 launch sites around the globe, using 6 vehicle configurations and covering five different science disciplines.

The first Astrophysics mission this year was a re-fly of the Dual-channel Extreme Ultraviolet Continuum Spectrograph (DEUCE) mission, flown from White Sands Missile Range, NM. DEUCE measured ionizing photons emitted by ε Canis Major. The mission was successful and DEUCE is slated for another flight in 2020 from a new launch site in Australia. A second astrophysics mission Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet host stars (SISTINE), also from White Sands, tested new technologies useable for future NASA science missions. SISTINE also aimed to study the UV environments of low mass stars and their effects on potential exoplanet atmospheres. The technology test portion of this mission was successfully executed; however, science data was not collected. SISTINE also is scheduled to fly from Australia in 2020.

Solar physics was supported with two flights from White Sands Missile Range. Chromospheric LAyer Spectro-Polarimeter (CLASP) 2 aimed to further our understanding of solar activity through measurement and modeling of solar magnetic fields. EUV Snapshot Imaging Spectrograph (ESIS) observed magnetic reconnection in the transition region of the Sun. Both missions successfully collected data, and early results are described on pages eight and nine of this report.

The Grand Challenge Initiative (GCI) is a series of large-scale international collaborative programs that will use in-situ observations and remote sensing to address fundamental issues in space and Earth science. The objective of CGI – Cusp, the first CGI project, is to determine the multi-scale physics of heating and charged particle precipitation that occurs in the ionospheric footprints of Earth's geomagnetic cusps. SRPO's participation in this international effort took us to two launch sites in the Arctic, Svalbard and Andøya Space Center, both in Norway. Four science missions encompassing six rockets, and one student mission, were flown and were successful in collecting the desired science data. Operationally, the first phase of the Grand Challenge campaign certainly lived up to its name. A tremendous amount of planning, logistics, technical expertise and long deployments in the field were critical to our success. Additionally, our success was due to the tireless efforts of our friends at NASA Headquarters who approved these missions as excepted activities during the partial government shutdown. The second phase of this campaign featured two rockets for the Auroral Zone Upwelling Rocket Experiment (AZURE) mission, which produced spectacular images from the neutral wind measurement tracers that were released and glowed in the northern sky. CGI-Cusp continues in Fiscal Year 2020 with two planned NASA missions; Cusp Region EXperiment (C-REX) 2 launching from Andoya Space Center, and Cusp Heating Investigation (CHI) launching from Svalbard.
For 2020 we are also continuing to work toward supporting southern hemisphere astrophysics missions from Australia. A new launch range, Equatorial Launch Australia (ELA), will be used for these missions supported by our mobile assets. The missions are currently manifested for a July 2020 launch window, and focus on UV and X-ray research.

We heard from some of the hundreds of students we inspire every year:
"RockSat-X was a great opportunity for me to get experience building a sounding rocket payload. Getting to learn from and network with engineers here at Wallops is an opportunity I will forever be grateful for." Josh Loredo - Computer Science & Mathematics - University of Kentucky

"Ever since I was a child I knew that my purpose was within the engineering field. I participated in many programs with the hope of gaining the experience to participate with NASA. After attending the Community College of Aurora, I had the opportunity of being part of RockSat-X which was an eye-opener. Diversity, inclusivity, and a wide range of experiences were seen not only in our team but in all the teams. The feeling of "belonging" was something that was felt throughout the project which helped keep me motivated to continue in my career path." Ruby Martinez Gomez - Aerospace Engineering - University of Colorado - Boulder

Those few lines are the best recognition of the value of our outreach and STEM engagement efforts. These students, among hundreds of others, participated in one of our flagship student flight opportunities, RockSat-X. This is the most advanced opportunity and enables student teams to design, build, test, and integrate, their own experiment. From idea to flight! Together with RockOn, a beginners workshop, and RockSat-C, intermediate experiment level, our student flight programs cover the spectrum of learning opportunities. These programs are a collaborative effort between SRPO, Colorado Space Grant and Virginia Space Grant Consortia.

Additional STEM engagement activities include the Wallops Rocket Academy for Teacher and Student (WRATS). The WRATS annual workshop was held in August to coincide with the RockSat-X launch. Nineteen teachers from six states came to Wallops and learned how to use model rockets as educational tools in the classroom. Both SRPO and NSROC staff conduct numerous outreach activities at local schools throughout the year, and serve as guides for facility tours for audiences as diverse as kindergarten students to congressional delegations.

I look back at the past year with gratefulness for the many missions and projects successfully completed by the program, but most of all, I am grateful for the outstanding team that supports the Sounding Rockets Program. At all levels of our organization, I see excellence. The willingness to tackle the hard tasks, as well as, focus on the details, makes the program world class. Thank you for your continued dedication and passion!

Giovanni Rosanova/Chief Sounding Rockets Program Office

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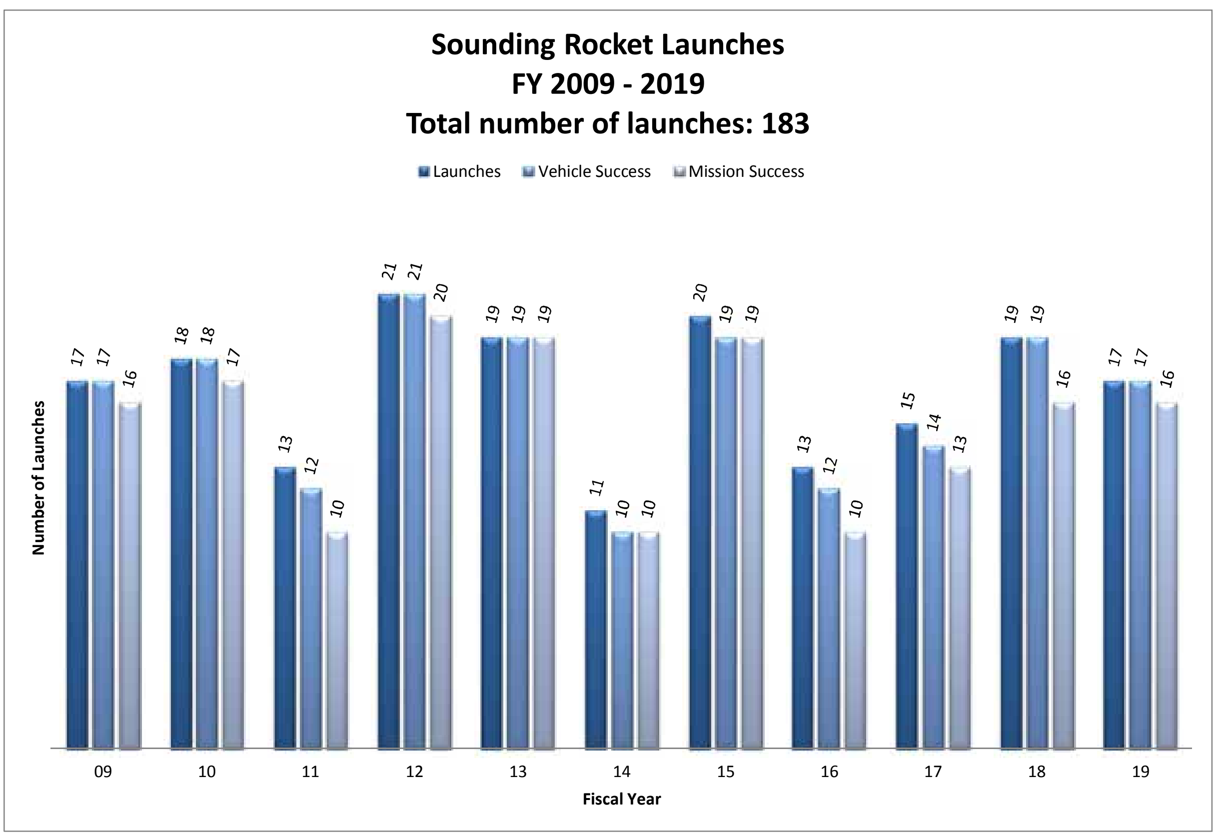
Cover photo: TRICE-2 launches from Andoya Space Center, Norway

Credit: Jamie Adkins/Wallops Imaging Lab

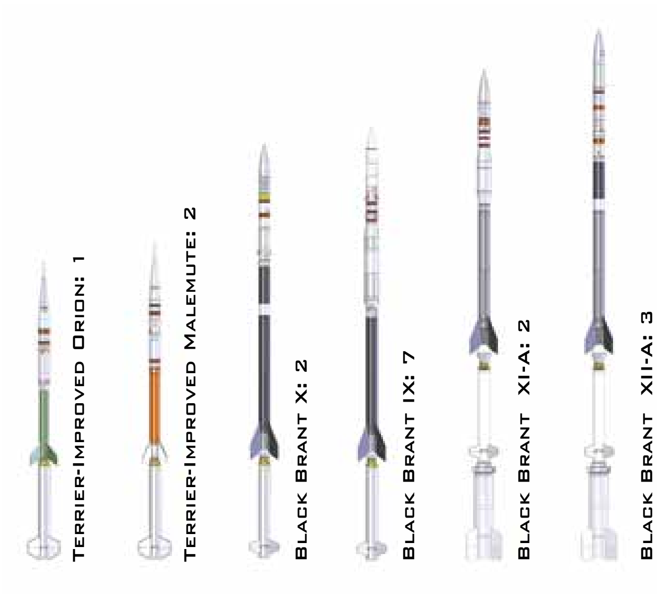
Sounding Rockets Overview

The Sounding Rockets Program Office (SRPO) and the NASA Sounding Rocket Operations Contract (NSROC) carry out NASA's sub-orbital rocket program. A fleet of vehicles acquired from military surplus or purchased commercially are used to carry scientific and technology payloads to altitudes between 50 and 1,500 kilometers. All payload support systems, such as Telemetry, Attitude Control, and Recovery are designed and fabricated by NSROC machinists, technicians and engineers. Launch operations are conducted worldwide to facilitate science requirements, for example Geospace research is often conducted in the arctic from launch sites in Norway and Alaska. Increasing mission complexities are addressed through continuous improvement in systems design and development.

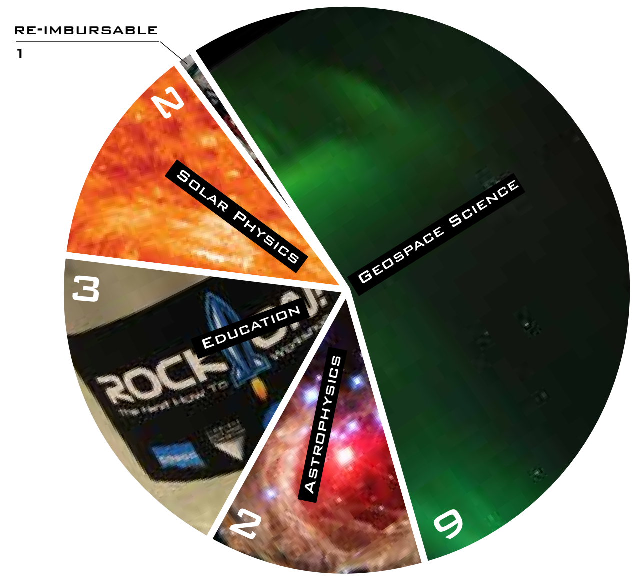
Launch History



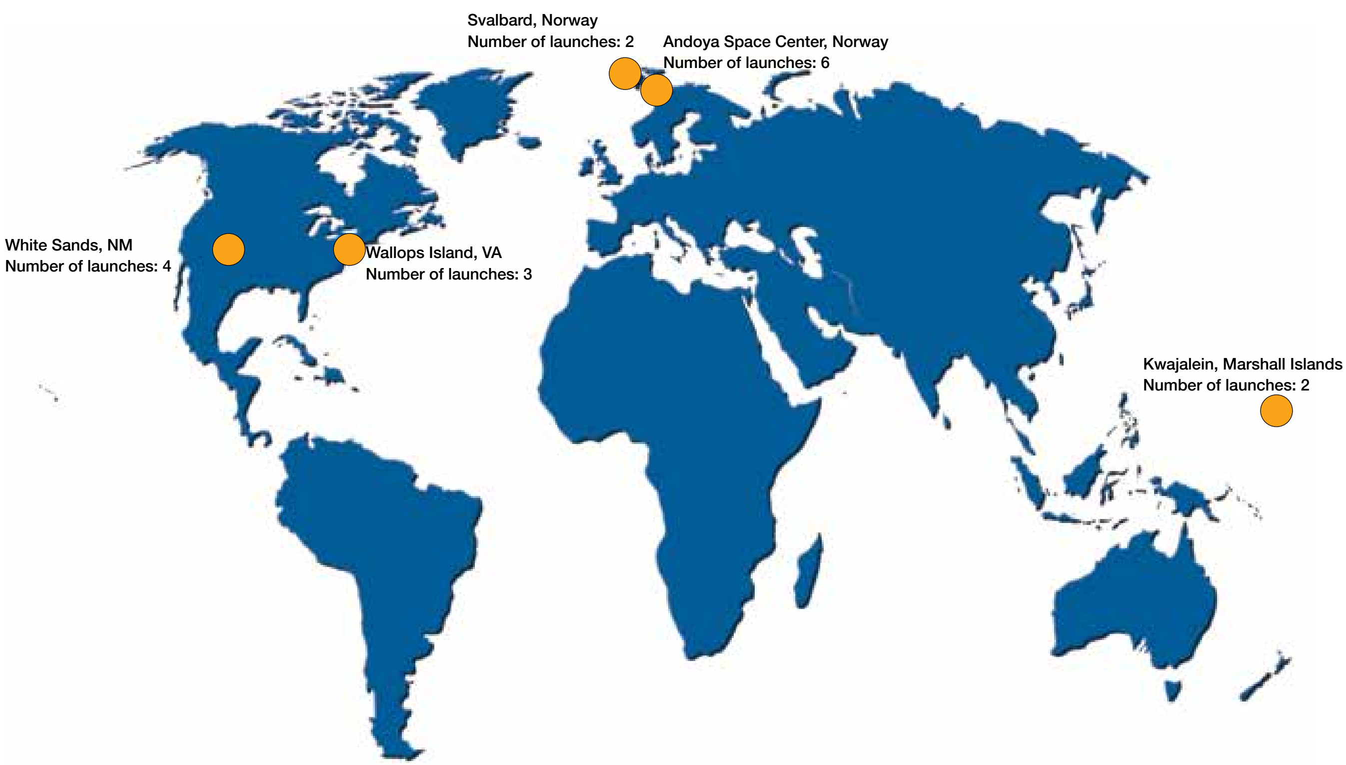
Vehicles Launched 2019



Missions by Discipline 2019



Launch Sites Used in 2019



This graphic, created from Solar Dynamics Observatory (SDO) and other orbital observatories, describes the relationship between, atoms, temperature and spectral wavelengths.

Sounding rocket instruments gather information about solar spectra in a similar way. This year, two missions, CLASP-2 and ESIS studied the Sun in several wavelengths. CLASP-2 gathered data on the solar chromosphere at 279.9 nm (2799 Å), and ESIS studied the transition region at 62.9 nm (629 Å), 46.5 nm (465 Å), and 30.4 nm (304 Å). Some of these observations are in the same wavelengths as orbital observatories and are conducted in conjunction with satellite over passes to correlate data.

4 - 20 keV
~2 mil K

Hard X-rays with energies of 4 - 20 keV emitted by accelerated electrons. Background image slices shows a composite of Hinode, NuSTAR, and SDO data.

1600 Å
10,000 K

1600 Å: Emitted by carbon-4 (C IV) at around 10,000 Kelvin. C IV at these temperatures is present in the upper photosphere and what's called the transition region. The transition region is where the temperature rapidly rises.

335 Å
~2.2 mil K

335 Å: Emitted by iron-16 (Fe XVI) at temperatures of 2,500,000 Kelvin. These images also show hotter, magnetically active regions in the corona.

304 Å
50,000 K

304 Å: Emitted by helium-2 (He II) at around 50,000 Kelvin. This light is emitted from the chromosphere and transition region.

211 Å
2 mil K

211 Å: Emitted by iron-14 (Fe XIV) at temperatures of 2,000,000 Kelvin. These images show hotter, magnetically active regions in the Sun's corona.

193 Å
1.6 mil K

193 Å: Emitted by iron-12 (Fe XII) at 1,000,000 Kelvin (hotter region of the corona) and iron 24 (Fe XXIV) at 20,000,000 Kelvin (hotter material in a flare).

171 Å
~600,000 K

171 Å: Emitted by iron-9 (Fe IX) at around 600,000 Kelvin. This wavelength shows the quiet corona and coronal loops.

131 Å
10 mil K

131 Å: Emitted by iron-20 (Fe XX) and iron-23 (Fe XXIII) at temperatures greater than 10,000,000 Kelvin, representing the material in flares.

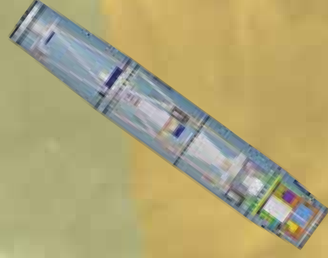
094 Å
6 mil K

94 Å: Emitted by iron-18 (Fe XVIII) at temperatures of 6,000,000 Kelvin. Temperatures like this represent regions of the corona during a solar flare.

Two Solar Physics mission, Chromospheric LAyer Spectro-Polarimeter (CLASP) 2 and EUV Snapshot Imaging Spectrograph (ESIS) were flown in 2019.

Chromospheric LAyer Spectro-Polarimeter (CLASP) 2

The aim of CLASP-2 was the detection of linear polarization (Hanle effect) of the Mg II h & k lines from the solar chromosphere.

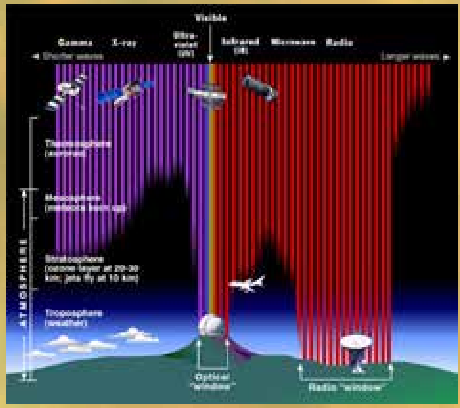


EUV Snapshot Imaging Spectrograph (ESIS)

The new ESIS instrument mapped Doppler shifts and line widths, which correspond with bulk and turbulent velocities, in the transition region at a two second cadence.

Credit: Multispectral background image NASA/SDO/GSFC Visualization Studio
X-ray background slice from NuSTAR, Hinode and SDO.

Electromagnetic Radiation



Most of the radiation emitted by the Sun is blocked by the Earth's atmosphere. In order to study the Sun at these wavelengths, instruments have to be placed in space. Spacecraft such as the SDO and Interface Region Imaging Spectrograph (IRIS) include multispectral instruments and have mission durations of several years. Sounding rockets are used for both fundamental science exploration and development of future technologies for spacecraft. Additionally an instrument can be launched at predetermined times and locations, to coordinate observations with orbital platforms. This type of coordination can augment and/or calibrate satellite research. With short mission lead times and lower cost, sounding rockets enable world class science discovery.

Instruments for Solar Physics

Spectrographs are commonly used instruments for solar physics. A spectrograph measures radiation intensity as a function of wavelength. All elements in the periodic table have associated characteristic spectra. When energy is added to an element, i.e., when electrons in an atom are excited and then transition back from this excited state to their ground energy levels, they emit radiation at specific wavelengths. Scientists have cataloged spectral wavelengths of the elements and use that information to determine the presence of these elements in the Sun and other stars. Elements found on the Sun, using spectroscopy, include hydrogen and helium with smaller amounts of other elements such as carbon, nitrogen, oxygen, neon, magnesium, silicone, sulfur, and iron.

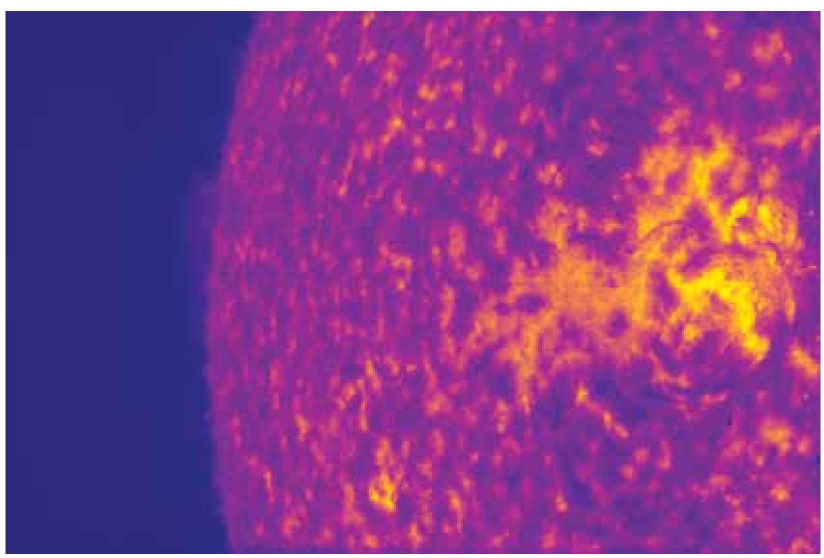
Knowing which elements are present, and their ionization temperatures, allows scientists to determine the temperature of the various regions of the Sun. To ionize an atom enough energy has to be added to free electron(s) from the atom. For example iron, which in its neutral state has 26 electrons (Fe I), temperatures around 600,000 Kelvin create ions of Fe IX where eight electrons are freed. This process emits EUV radiation at a wavelength of 171 Å.

Chromospheric LAyer Spectro-Polarimeter (CLASP) 2

Critical to understanding and predicting solar activity is the measurement and modeling of solar magnetic fields, which can only be quantified via measurement of the slight polarization and/or de-polarization that magnetism imparts to the Sun's light. The Chromospheric LAyer Spectro-Polarimeter (CLASP 2) mission successfully measured linear polarization of ultraviolet (UV) emission formed in the solar chromosphere, sensitive to a relatively wide range of magnetic fields through the Hanle and magneto-optical effects, and sensitive to anisotropic scattering of light from the Sun's atmosphere. CLASP 2 also, and for the first time, measured the circular polarization in UV emission lines formed in the chromosphere, a vital diagnostic of magnetic field strength via the Zeeman effect. By measuring both the linear and circular polarizations in a wavelength range of 279.9nm +/- 0.45 nm, CLASP 2 enables measurement of all 4 Stokes parameters in chromospheric UV emission for the first time. Coupled with sophisticated numerical modeling of scattering and magnetic effects, CLASP 2 is a pathfinder for future missions to routinely determine vector magnetic field in a portion of the Sun's atmosphere that is crucial for determining the flow of energy into the corona and solar wind, and the magnetic forces that power solar flares.

CLASP 2 payload team.

This mission was highly successful and excellent science was obtained. CLASP 2 targeted two regions on the Sun – an aging active region plage, and quiet Sun near the solar limb – to sample a wide range of magnetic field strengths and photon scattering angles.



CLASP 2 observed two targets with its spectrograph and its slitjaw context imager. This composite image combines the two fields of view to demonstrate the variety of conditions sampled by CLASP 2. The thin dark lines near the center of the image are the spectrograph slit at the two target locations. Image credit: Dr. Genevieve Vigil (NASA MSFC) and the CLASP 2 team.

Principal Investigator: *Dr. David McKenzie/NASA MSFC* • ***Mission Number(s):*** *36.332 NS*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *April 11, 2019*

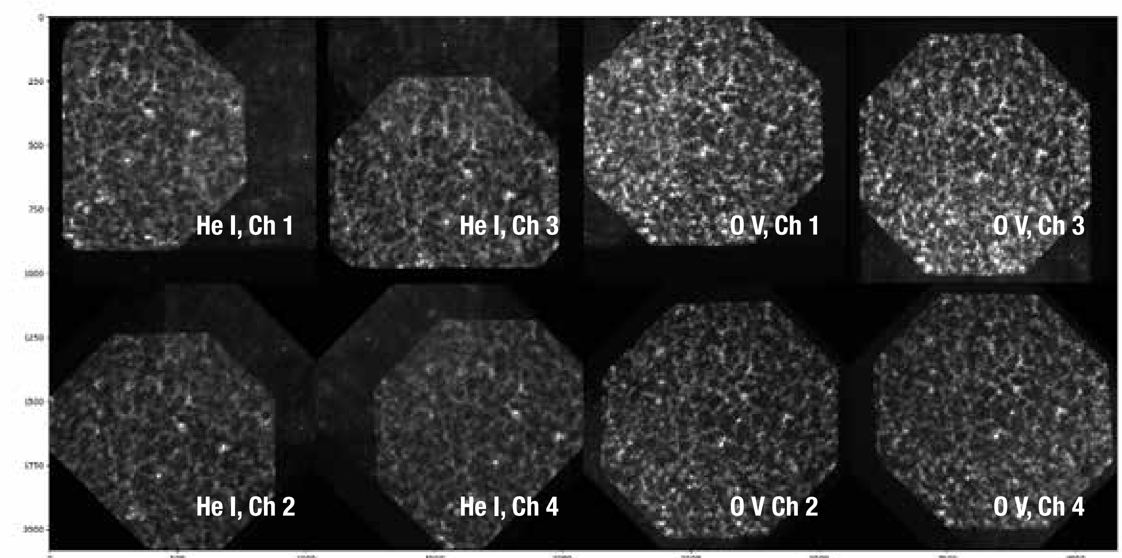
EUV Snapshot Imaging Spectrograph (ESIS)

ESIS was successfully launched from White Sands Missile Range, NM on September 30, 2019, and collected data on the transistion region on the Sun. The transition region is part of the Sun's atmosphere, and is located between the relatively cool chromosphere below, and the superheated corona above.

Every few seconds, a small (approximately Earth sized) explosion occurs somewhere on the solar disk. These transition region explosive events are an example of magnetic reconnection, the same mechanism that is responsible for the much larger release of energy in solar flares. The purpose of ESIS mission was to observe these events in enough detail to characterize the triggering of and release of magnetic energy.

The new ESIS instrument mapped Doppler shifts and line widths, which correspond with bulk and turbulent velocities, in the transition region at a two second cadence in the 62.9 nm (O V) spectral line. ESIS was augmented by the Multi-Order Solar EUV Spectrograph (MOSES), which can be configured for either 46.5 nm (Ne VII) or 30.4 nm (He II). For this flight MOSES was configured for 46.5 nm, but did not collect data due to a malfunctioning shutter.

ESIS payload team.



A low resolution, first look, at ESIS data. Labels indicate element and channel.

Principal Investigator: *Dr. Charles Kankelborg/Montana State University* • ***Mission Number(s):*** *36.320 US*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *September 30, 2019*

Astrophysics Missions 2019

Astrophysics seeks to understand the universe and our place in it and aims to discover how the universe works, explore how it began and evolved, and search for life on planets around other stars. In 2019 two Astrophysics missions, studying various aspects of our Galaxy in the Ultraviolet part of the spectrum, were flown.

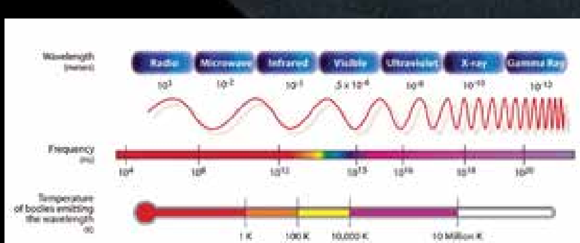
Spectrometers and telescopes are frequently flown onboard sounding rockets for Astrophysics research. Telescopes focus the incoming radiation from a target object and spectrometers spread light out into specific wavelengths creating a spectra.

All atoms and molecules have characteristic spectra that produce absorption or emission lines at specific wavelengths. This allows scientists to extract information about composition, temperature, and other variables of the astronomical target of their study. Emission line spectra are created when an electron drops down to a lower orbit around the nucleus of an atom and loses energy. Absorption line spectra occur when electrons move to a higher orbit by absorbing energy.

Visible light is what we are most familiar with on Earth. Visible light ranges in wavelength from 400 nm to 700 nm, with violet being the shortest wavelength and red the longest. Absorption and emission spectra of objects in the Universe reveal information about the elements present, the temperature, and density of those elements and the presence of a magnetic field and many other variables.

High energy and high temperature processes in the Universe radiate in the *Ultraviolet (UV)* part of the spectrum. Knowledge of star formation and evolution, growth of structure in the Universe, physics of jet phenomena on many scales, aurora on and atmospheric composition of the gas giant planets, and of the physics of protoplanetary disks, has been expanded through UV observations.

To emit *X-rays,* gas must be under extreme conditions, such as temperatures of millions of degrees, superstrong magnetic fields, or electrons must be moving at nearly the speed of light. Extreme conditions can be found in disks of matter orbiting black holes or in supernova remnants. X-rays are classified into two types: soft X-rays and hard X-rays. Soft X-rays fall in the range of the EM spectrum between UV light and Gamma Rays. Hard X-rays are very close to gamma-rays. The only difference between them is their source: hard X-rays are produced by accelerating electrons, while Gamma Rays are produced by atomic nuclei.



Electromagnetic Radiation

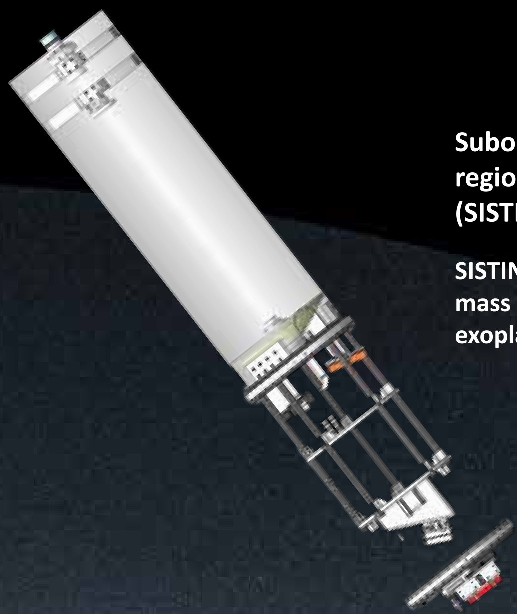
Continuos spectra are created by hot opaque objects.

Hydrogen absorption spectra in visible wavelengths.

An absorption spectrum is created when energy from a hot opaque object travels through cooler transparent gas.

Hydrogen emission spectra in visible wavelengths.

Hot transparent gas, such as gaseous nebulae, create emission spectra.



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

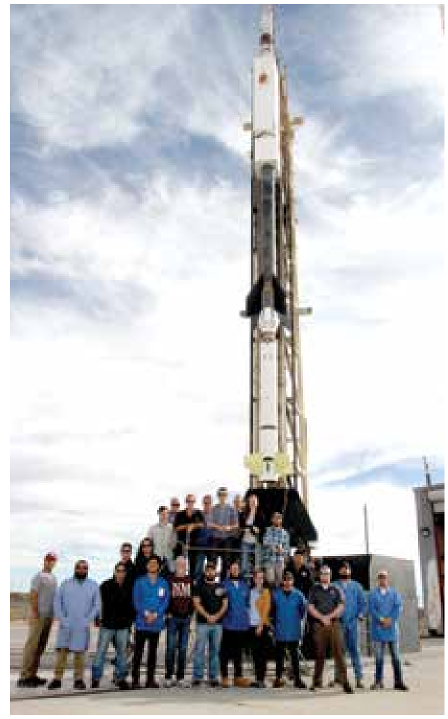
SISTINE is designed to allow the investigation of low-mass star UV environments and their effects on potential exoplanet atmospheres.

Dual-channel Extreme Ultraviolet Continuum Spectrograph (DEUCE)

DEUCE is a spectrograph operating from 650 – 1100Å. DEUCE is designed to measure how much ionizing photons B stars, such as the target star for the 2019 mission ε Canis Major, produce.

Dual-channel Extreme Ultraviolet Continuum Spectrograph (DEUCE)

The Dual-channel Extreme Ultraviolet Continuum Experiment (DEUCE) is a spectrograph operating from 650 – 1100 Å. DEUCE was designed to measure how many ionizing photons B stars, such as the target star for this mission ε Canis Major, produce.


DEUCE payload team.

DEUCE has two modes; a low resolution, high throughput mode operating from 700 – 890 Å, and a high resolution, low throughput channel from 700 – 1100 Å. The stellar brightness changes dramatically above 912 Å and below 912 Å necessitating the two modes. The change in intensity was unknown, and could range from 10/1 to 10,000/1. DEUCE was designed to measure the flux of local, early-type hot stars that have very little intervening absorbing material in the interstellar medium. Only two such stars exist, β and ε Canis Major.

There were 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 that regime.


Recovery of the DEUCE payload.

This mission, in addition to providing scientific data, tested the largest ever flown microchannel plate detector for future large-scale space missions.

DEUCE launched on December 18, 2018. The flight was a success and recorded a high-quality spectrum in both channels. Significant flux was recorded from 700 – 890 Å, representing the first measurement of an early type star in the wavelength region. Analysis is ongoing, and presentation of the data is planned for the AAS meeting in January 2020.

Principal Investigator: *Dr. James Green/University of Colorado* • ***Mission Number(s):*** *36.331*
UG ***Launch site:*** *White Sands Missile Range, NM* • ***Launch date:*** *December 18, 2018*

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


SISTINE payload team.

NASA and the University of Colorado at Boulder collaborated to launch an astrophysics experiment into Earth's near-space environment in order to study the ultraviolet radiation environment around low-mass stars and the effects of that UV on potential exoplanet atmospheres. The NASA/CU 36.346 UG – France mission launched from White Sands Missile Range, NM, on August 11, 2019.

This celestial payload was the first flight of the Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet host stars (SISTINE). This new 22" telescope payload utilizes heritage detector control systems and acts as a technology testbed for enhanced lithium fluoride (eLiF) coatings on large optics and large format detectors.


Recovery of the SISTINE payload.

Characterization of exoplanet atmospheres, including the potential for habitability, requires an understanding of the interaction with the host star's ultraviolet (UV) radiation environment. Nearby solar-type stars and red dwarfs host our best opportunities to characterize potentially inhabited worlds, and many of these systems will be searched for biomarkers by NASA's future flagship missions. Far-ultraviolet (FUV) radiation impacts chemicals such as H_2O, CO_2, and CH_4. The host star's HI Ly α is a significant contributor to these effects and can also be used as a proxy for the extreme-ultraviolet (EUV) flux from the host star. EUV flux is likely to have a significant effect on atmospheric mass loss on exoplanets but is difficult to measure directly due to attenuation by the interstellar medium (ISM). Additionally, flare activity in the FUV can be correlated to large ejections of charged particles that can heavily affect O_3 quantity in an atmosphere. SISTINE's imaging capability and spectral resolution allow the investigation of low-mass star UV environments and their effects on potential exoplanet atmospheres. SISTINE provides spectral coverage from 100 - 160nm, a range not covered by, at moderate spectral resolution, any current orbital asset; this range spans strong atomic emission lines tracing various formation temperatures in the stellar atmosphere: 10^4 K (Ly-α, 121 nm), 10^5 K (C IV, 155 nm), and $10^{5.5}$ K (O VI, 103 nm).

For this mission, SISTINE aimed to characterize the instrument performance and demonstrate the advanced optical coatings and detectors for future NASA missions. All technology was successfully demonstrated in flight on 36.346 UG. This calibration mission was also designed to study how the outer envelopes of stars are disperesed back into the interstellar medium by observing the space target NGC 6828, a planetary nebula, however, science data was not successfully collected.

Principal Investigator: *Dr. Kevin France/University of Colorado* • ***Mission Number(s):*** *36.346 UG*
Launch site: *White Sands Missile Range, NM* • ***Launch date:*** *August 11, 2019*

Twin Rockets to Investigate Cusp Electrodynamics (TRICE) 2

The TRICE-2 main objective was to investigate whether the magnetic reconnection at the magnetopause is steady or pulsed. As magnetic reconnection is the major external driver for vertical dynamics in the auroral zone atmosphere, this is a key Earth system science question.

VISualizing Ion Outflow via Neutral atom imaging during a Substorm (VISIONS) 2

VISIONS-2's main objective was to investigate upward acceleration of ions along the magnetic field lines in order to understand the wave-particle interaction that accelerates oxygen ions above 10eV to escape the Earth gravitation.

Cusp Alfven and Plasma Electrodynamics Rocket (CAPER) 2

CAPER-2 explored the physical nature of magnetosphere-ionosphere (MI) coupling in terms of waves and acceleration processes.

Auroral Zone Upwelling Rocket Experiment (AZURE)

The AZURE mission was designed to make measurements of the atmospheric density and temperature with instruments on the rockets and deploying visible gas tracers, trimethyl aluminum (TMA) and a barium/strontium mixture, which ionizes when exposed to sunlight.

Geospace Missions 2019

Geospace Science missions in 2019 focused on the Grand Challenge Initiative (GCI) – Cusp, a series of international sounding rocket missions from Norway. Four of the NASA sounding rocket science missions were launched in FY 2019; VISIONS 2, TRICE 2, CAPER 2 and AZURE. Two additional NASA science missions, Cusp Heating Investigation (CHI) and Cusp-Region EXperiment (C-REX 2), as well as, two international missions will be launched in FY 2020.

On the other side of the globe, in the Marshall Islands, the Waves and Instabilities from a Neutral Dynamo (Too WINDY) 2, investigated a phenomenon called Equatorial Spread F (ESF). Two sounding rockets were launched to investigate the origins and evolution of ESF.

Waves and Instabilities from a Neutral Dynamo (Too Windy) 2

Data from Too-WINDY will aid in answering questions about the origin of Equatorial Spread F (ESF) by measuring the influence of horizontal thermospheric winds on the formation of ESF, as well as, taking measurements of ionospheric densities and electric and magnetic fields.

Background image: Earth's Magnetosphere/Trond Abrahamsen/Andoya Space Center

VISualizing Ion Outflow via Neutral atom imaging during a Substorm (VISIONS) 2

VISIONS-2's main objective is to investigate upward acceleration of ions along the magnetic field lines in order to understand the wave-particle interaction that accelerates oxygen ions above 10eV to escape the Earth gravitation.

VISIONS-1, launched from Poker Flat Research Range in 2013, observed the ion outflow at night from the polar auroral zones. VISIONS-2, observed the phenomenon during the day from Earth's magnetic cusp. The two VISIONS-2 payloads were launched from Ny-Ålesund, Norway, on December 7, 2018, through the magnetic cusp, to apogees near 600 (low flyer) and 800 (high flyer) km. During flight, the two payloads remotely sensed ion outflow and its drivers over a region approximately 1000 km in diameter, providing critical information about the patchiness and burstiness of cusp ion outflow, as well as, detailed information about the mechanisms that drive this outflow, leading to a new understanding of the mechanisms that couple the magnetosphere:

One of the VISIONS–2 being prepared for deployment testing.

1) What is the total low-altitude (<1000 km) ion outflow at energies > 10 eV from the cusp under typical Bz south conditions?
2) How spatially and temporally variable is this outflow?
3) How is the outflow tied in detail to drivers and sources of free energy (e.g. auroral electron precipitation, convection, Joule heating)?

The cusps are regions near the Earth's poles where the magnetic field lines dip down toward the ground. These regions are the strongest source of outflowing ions. When the ions are present, which is not all the time, they have dramatic effects on near-Earth space. Among other things, they can affect the rate at which solar-wind energy is transferred to the magnetosphere, and the rate and details of how this stored energy is released to produce aurora. In addition, a better understanding of the outflow could shed light on why Mars, which has a very weak magnetic field, is losing its atmosphere, while Venus, which has no magnetic field at all, remains enshrouded in a thick atmosphere.

NASA Goddard Space Flight Center provided the principal instrument, the Miniaturized Imager for Low-Energy Neutral Atoms (MILENA). It traces its heritage to an instrument that flew on the U.S. Air Force-sponsored FASTSAT mission in 2011. Goddard also provided the Fields and Thermal Plasma package, which consisted of a double-probe electric field instrument. The Aerospace Corp. provided the Rocket-borne Auroral Imager, the Energetic Ion Analyzer, and the Energetic Electron Analyzer.

Data from VISIONS-2 will aid in the understanding of the physics that influence Earth's magnetosphere.

Principal Investigator: *Dr. Douglas Rowland/NASA GSFC* • ***Mission Number(s):*** *35.039 & 040 GE*
Launch site: *Ny Alesund, Svalbard, Norway* • ***Launch date:*** *December 7, 2018*

Twin Rockets to Investigate Cusp Electrodynamics (TRICE) 2

Two four-stage Black Brant XII-A rockets were flown from Andoya Space Center, Norway in support of the TRICE-2 mission. The main objective of TRICE-2 was to investigate whether the magnetic reconnection at the magnetopause is steady or pulsed. As magnetic reconnection is the major external driver for vertical dynamics in the auroral zone atmosphere, this is a key Earth system science question. Magnetic reconnection is anticipated to modulate the thermosphere as well as the ionosphere.

One of the TRICE payloads mounted on the MOI test table.

With a single rocket or satellite it is not possible to unambiguously distinguish between steady state reconnection from multiple reconnection sites and pulsed reconnection. The TRICE-2 approach was to fly two sounding rockets simultaneously from Andøya Space Center, Norway over Svalbard, Norway, one high-flying and one low-flying, both at the same magnetic coordinates. Except when they are on the top of each other, there will always be one lagging behind the other, allowing assessment of whether the magnetic reconnection process is a steady state or time varying.

Data from the TRICE-2 mission is being analyzed.

Principal Investigator: *Dr. Craig Kletzing/University of Iowa* • ***Mission Number(s):*** *52.003 & 004 UE*
Launch site: *Andoya Space Center, Norway* • ***Launch date:*** *December 8, 2018*

Cusp Alfven and Plasma Electrodynamics Rocket (CAPER) 2


CAPER–2 in the Electromagnetic Interference (EMI) testing facility.

CAPER-2 explored the physical nature of magnetosphere-ionosphere (MI) coupling in terms of waves and acceleration processes. There are at least two separate electron acceleration processes of broad significance to space plasma physics: acceleration in electrostatic electric fields and in time-varying electromagnetic fields associated with Alfvén waves. In addition, a host of microscopic wave modes play a role in redistributing energy from the resulting electron beams to the thermal plasma, including most ubiquitously Langmuir waves. While many previous rocket experiments have probed nightside processes such as polar substorms, the data from CAPER-2 will make significant advances in understanding electrodynamics associated with MI coupling in the cusp.

CAPER-2 flew somewhat low and to the east of nominal trajectory, but it still achieved mission success by spending several minutes in the cusp at altitudes above 600 km. Significant Alfvén wave power and hundreds of Langmuir wave bursts were observed, which will allow the principal CAPER-2 science objective, assessment of wave-particle interactions in the cusp, to be achieved. An unexpected discovery was very low frequency waves emanating from the cusp and observed by CAPER-2 in the minutes preceding its encounter with the cusp. These waves show distinctive features which may allow the locations and physical processes of cusp electron precipitation to be detected remotely from up to 100 km away.

Principal Investigator: *Dr. James Labelle/Dartmouth College* • ***Mission Number(s):*** *52.005 UE*
Launch site: *Andoya Space Center, Norway* • ***Launch date:*** *January 4, 2019*

Auroral Zone Upwelling Rocket Experiment (AZURE)

The AZURE mission was designed to make measurements of the atmospheric density and temperature with instruments on the rockets and winds by deploying the visible gas tracers, trimethyl aluminum (TMA) and a barium/strontium mixture, which ionizes when exposed to sunlight. Two three-stage Black Brant XI-A, were launched two minutes apart, from Andoya Space Center in Norway The vapors were released over the Norwegian Sea at 71 to 150 miles altitude. By tracking the movement of these tracers, using groundbased photography and triangulating, their moment-by-moment position in three dimensions were obtained. AZURE provided valuable data on the vertical and horizontal flow of particles in two key regions of the ionosphere, the E and F regions. The results will be key to a better understanding of the effects of auroral forcing on the atmosphere, including how and where the auroral energy is deposited.

The ionosphere is the electrically charged layer of the atmosphere that acts as Earth's interface to space. The ionosphere has two regions, E and F. The E region — so-named by early radio pioneers who discovered the region was electrically charged, and could reflect radio waves — lies between 56 to 93 miles above Earth's surface. The F region resides just above it, between 93 and 310 miles altitude. Both regions contain free electrons that have been ejected from their atoms by the energizing input of the Sun's rays, a process called photoionization. After nightfall, without the energizing input of the Sun to keep them separated, electrons recombine with the positively charged ions they left behind, lowering the regions' overall electron density. The daily cycle of ionization and recombination makes the E and F regions especially turbulent and complex.

Vapor tracers released by AZURE.

Principal Investigator: *Dr. Miguel Larsen/Clemson University* • ***Mission Number(s):*** *51.001 & 002 UE*
Launch site: *Andoya Space Center, Norway* • ***Launch date:*** *April 5, 2019*

Using vapor tracers and instruments, AZURE focused specifically on measuring the vertical winds in these regions, which re-distribute the energy, momentum and chemical constituents of the atmosphere. Existing wind measurements from ground-based instruments show evidence of significant structure at horizontal scales between 6 miles and 60 miles wide in both the charged particle drifts and the neutral winds. But so far, the in-situ scientific measurements of winds have been limited to a narrow set of altitudes — and those measurements do not fit predictions. AZURE extends the range of measurements by using distributed vapor tracer deployments.

Dr. Miguel Larsen received the NASA Distinguished Public Service Medal in 2019.

Citation: In recognition of pioneering research to measure vertical profiles of the Earth's upper atmospheric winds & leading over 100 NASA sounding rockets during 40 years of research.

From the award nomination: *Dr. Larsen is the undisputed world leader of wind profiles in the upper atmosphere. He has designed and built experiments that were subsequently flown on over 100 NASA sounding rockets, launched at high, mid, and low latitudes. Accordingly, he is frequently sought by researchers throughout our nation whether from academia, NASA, or DoD research organizations. He has also participated in many international research projects, most notably with Japanese and European research scientists. The contributions from Dr. Larsen's fundamental research cannot be overstated. Having provided fundamental knowledge of our planet's upper atmosphere and having secured a solid foundation for future explorations, Dr. Larsen's distinguished abilities and vision have left an indelible impact on NASA's mission and our Nation's atmospheric research community.*

Waves and Instabilities from a Neutral Dynamo (Too Windy) 2

Two rockets were part of the Too-WINDY mission. The first Black Brant IX sounding rocket was successfully launched at 11:28 UTC June 19, 2019 and was followed five minutes later by a second Black Brant IX rocket. The first rocket flew to approximately 375 km altitude and released vapor trails of tri-methyl aluminum (TMA) and lithium, to allow scientists to measure winds and energetic particles in the upper atmosphere. The second rocket, carrying an instrumented payload, reached an altitude of approximately 414 km.

The ionosphere is defined as the layer of the Earth's atmosphere that is ionized by solar and cosmic radiation. Ionization occurs when incoming energetic radiation strips electrons from atoms and molecules, creating temporarily charged particles. The nighttime ionosphere has two layers, E and F. Disturbances in the F layer, the layer studied by Too-WINDY, degrade radio and radar signals at low magnetic latitudes. Predicting when these disturbances will occur would improve the reliability of space-borne and ground-based communication systems. Data from Too-WINDY will aid in answering questions about the origin of ESF by measuring the influence of horizontal thermospheric winds on the formation of ESF, as well as, taking measurements of ionospheric densities and electric and magnetic fields.

An important element of these experiments involved measurements of the atmospheric winds at high altitudes. Just as on the ground, winds at very high altitudes carry a tremendous amount of energy and are known to

Too WINDY payload teams with rockets on Roi Namur.

Principal Investigator: *Dr. David Hysell/Cornell University* • ***Mission Number(s):*** *36.344 & 345 UE*
Launch site: *Kwajalein Atoll, Marshall Islands* • ***Launch date:*** *June 19, 2019*

have a direct effect on the ionospheric disruptions that are the focus of Too-WINDY. Wind measurements at these altitudes are difficult because of the very low atmospheric density. Over the past five decades, several tracer techniques have been perfected to accomplish this by optical tracking of visible gases released from the rockets. Lithium vapor and trimethyl aluminum (TMA) gas have been particularly effective. TMA reacts spontaneously on contact with oxygen to produce a pale white glow visible from the ground. For the Too-WINDY mission, sunlight reflected by the Moon will illuminate the lithium, producing an emission that can be detected with cameras equipped with narrow-band filters. The lithium under these illumination conditions, rather than twilight conditions, is not visible to the naked eye and is harder to track. Using moonlight for illumination allows the launches to occur later in the evening, when the critical ESF conditions occur. Both gases, which are harmless when released at these altitudes, move with the background atmosphere and can therefore be used to determine the wind speeds and direction over the height ranges where the releases occur.

The two rockets, both Terrier-Black Brant sounding rockets, were launched nearly simultaneously into a ESF event. The TMA tracers were deployed both on the upleg and downleg parts of the trajectory and occurred between 80 and 180 km, in the Mesosphere and Lower Thermosphere region (MLT). The Lithium deployments occurred on the upleg of the trajectory between 250 - 350 km, in the thermosphere.

Data from the ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR) was used to monitor the state of the upper atmosphere/ionosphere in order to determine when the large-scale disruptions occurred and thus when to launch the rockets. ALTAIR was also be used to monitor the evolution of the ESF after the launches.

TooWINDY ready to launch from Roi Namur

Education Missions 2019

Level 1
RockOn!

Level 2
RockSat-C

Level 3
RockSat-X

RockSat-XN

The international cooperative effort - Grand Challenge Initiative - Cusp, a collaboration and data sharing effort between Norway, Japan and the United States, was augumented with an international student mission with participants from the same countries. RockSat-XN utilizes the well established RockSat-X mission architecture (see page 28) and allows students to design and build experiments that are exposed to the space environment. This mission differs from the historical RockSat-X architecture in two major ways: it was launched from Norway, and it incorporated foreign national participation. Unlike previous RockSat-X payloads, RockSat-XN was not recovered.

The following student experiments flew on this mission:

University of Norway – Tromso (UiT)

Detected and measured distribution of neutral Mesospheric Smoke Particles (MSP) in the winter Mesosphere.

University of Oslo (UiO)

Released six sub-payload modules (daughters) and established communication and measured small-scale electron density using Langmuir probe systems deployed on the daughters.

University of Tokyo (PARM)

Observed the incoming Pulsating Aurora (PsA) electrons in a wide energy range from a few tens of keV to a few MeV with onboard particle detectors. Observed the temporal/spatial variations of PsA with an onboard optical instrument.

Principal Investigator: *Mr. Chris Koehler/Colorado Space Grant Consortium*• ***Mission Number(s):*** *46.018 UO*

Launch site: *Andoya Space Center, Norway* • ***Launch date:*** *January 13, 2019*

Pennsylvania State University (PSU)

Contributed to the understanding of cause(s) of Polar Mesosphere Winter Echoes (PMWEs) by using instruments to collect measurements and compare data to a ground radar devoted to measuring PMWEs during the experiment.

Capital Technology University (CTU)

Identified atmospheric composition through spectral analysis and/or capture, as well as, verified functionality of modified Aerogel thermal insulation.

University of New Hampshire (UNH)

Observed directly (Nitric Oxide) NO air afterglow emissions vs. altitude. Calculated NO densities and enhancements vs. typical background values.

University of Puerto Rico (UPR)

The experiment consisted of the collection and analysis of organic compounds located inside the aurora borealis trail.

RockOn & RockSat-C

The RockOn! workshop was held at NASA Wallops Flight Facility, June 16 - 21, 2019. Eighty nine students and faculty members participated in this year's workshop, which was the 12th 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. Eighty-nine students participated in the RockOn workshop and 95 in the RockSat-C flight opportunity.

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 week, 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.

RockOn website: https://spacegrant.colorado.edu/rockon-home/rockon-2019-home

RockSat-C website: https://spacegrant.colorado.edu/rs-c-home/previous-experiments/rs-c-2019-home

Principal Investigator: *Mr. Chris Koehler/Colorado Space Grant Consortium* • ***Mission Number(s):*** *41.126 UO*
Launch site: *Wallops Island, VA* • ***Launch date:*** *June 20, 2019*

RockSat-X

RockSat-X was successfully launched from Wallops Island, VA on August 12, 2019. 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 2019:

Community Colleges of Colorado

The Debris Orbital Tumbler and Thermal Sensor (DOTTS) 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.

College of the Canyons

The goal of the Mesospheric Autorotational Payload Lander Experiment (MAPLE) was to create a versatile reentry system that uses autorotation to reduce velocity while gathering kinematic and environmental data to determine the concept's efficiency and reliability.

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.

University of Maryland

The Space Characterization and Assessment of Manipulator Performance (SCAMP) II project was a continuation of the experiment, first flown in 2018, and consisted of a functional robotic manipulator component in a microgravity environment to test contact stability on both hard and soft contacts.

Principal Investigator: *Mr. Chris Koehler/Colorado Space Grant Consortium*• ***Mission Number(s):*** *46.022 UO*
Launch site: *Wallops Island, VA* • ***Launch date:*** *August 12, 2019*

University of Nebraska Lincoln

The University of Nebraska Lincoln's mission looked to further develop and streamline the mechanism for a deployable boom system started by NASA Langley Research Center. The boom is designed to be easily deployed and retracted for application in various space-based experiments.

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 payload used polyimide aerogels stored in a sealable container to collect samples of micrometeorites and organic molecules.

West Virginia Collaboration

The West Virginia Space Flight Design Challenge is a collaboration between colleges in West Virginia, New York, and NASA IV&V. Each school had its own experiment which were integrated together with an additional system that provides power and telemetry. The Hobart and William Smith Colleges were attempting to measure the temperature and vibration of the payload throughout the flight. West Virginia State University flew radiation, optical, and particle detectors to provide hands-on experience with designing and building space related experiments and prepare for potential future CubeSat missions by comparing component designs. West Virginia University flew an antenna that is capable of changing shape during flight. West Virginia Wesleyan College flew a Geiger counter to measure the cosmic ray incident on Earth to compare with previous NASA studies. Finally, Blue Ridge Community and Technical College aimed to record an accurate vibration of the rocket to provide vibrational data to future RockSat teams.

https://spacegrant.colorado.edu/rs-x-home/rs-x-2019-home

RockSat-X team with Payload.

RockSat-X team on Wallops Island after launch.

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 Wallops Rocketry Academy for Teachers and Students (WRATS) workshop is hosted by the Sounding Rockets Program Office and NSROC with support from the Wallops Education Office. 2019 was the 9th year of the workshop with 19 teachers selected from over 60 applicants. Participating educators teach STEM topics at the High School or Middle School level.

In 2019 the WRATS workshop started with a viewing of the RockSat-X launch, which set the stage for the rest of the week.

WRATS offers a unique, in-depth, learning experience where teachers get hands-on practice building 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.

Internships

NSROC Attitude Control System intern participates in the RockSat–X sequence testing.

Over 200 students have participated in the internship program managed for the Sounding Rockets Program Office by NSROC. The program, now in its 18th 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 2019, NSROC provided opportunities for 14 internships involving all engineering disciplines.

Outreach

Tour of the Testing and Evaluation Lab.

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

NSROC and SRPO staff supported the NASA Community College Aerospace Scholars (NCAS) with mentors, presentations and facility tours. NCAS is a national STEM focused program where community college students interested in NASA related careers participate in a five-week online learning experience. Top scoring scholars are invited to participate in a 3-day workshop. The workshop was held in September and led by the Education Office.

Technology Development

The SRPO and NSROC are actively engaged in upgrading and developing new technologies for the program. New emerging technologies include Distributed Payload Communications. Additionally, component level improvements are developed continuously and flown on either dedicated missions or on a space available basis on manifested flights.

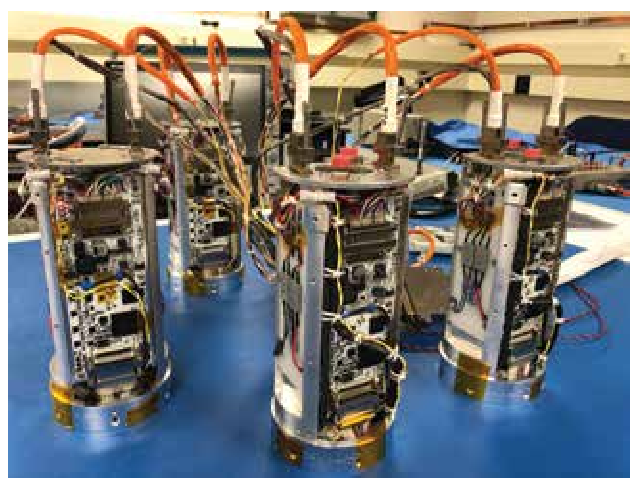
The NASA Sounding Rocket Program (NSRP) continues to assess new technologies in order to expand the capabilities for our science and technology customers, address obsolescence, and to improve efficiency. The major initiatives of the NSRP technology roadmap continue to focus on (1) providing increased scientific observation time for Solar and Astrophysics missions, (2) increasing the telemetry data rates from the current capability of 10 to 20 Mbps to systems with rates ranging from 40 to ~400 Mbps, and (3) developing free-flying sub-payload technologies. 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.

In 2019 the NSRP continued preparing experiments for the 46.020 Hesh (SubTEC 8) technology demonstration mission that launched early in Fiscal Year (FY) 2020. The mission featured several experiments from NASA and NSROC, designed to test sounding rocket development components and subsystems. The mission objectives included: (1) demonstrate distributed sub-payload to main payload telemetry communication, (2) provide an observation opportunity for one prototype star tracker (3) demonstrate a 40 Mbps telemetry encoder; and (4) provide a test flight opportunity for several sounding rocket development components and subsystems. Experiments from NASA ETD included: distributed measurement communication, low cost star tracker, airborne power supply unit (APSU), autonomous rocket tracker (ART), and solid state altimeter. Experiments from NSROC included: 40 Mbps high data rate encoder, wideband S-band/GPS high temperature combo antenna, GNC integrated power system, and the NIACS with Tern Inertial Navigation System (INS) controlling.

Sub–TEC 8 Payload

Distributed Payload Communication

Distributed Payload Communication is a NASA Sounding Rockets Program (NSRP) development effort using matrixed NASA Engineering and Technology Directorate (ETD) engineers to design a system that telemeters data from multiple deploying sub-payloads to the main payload. The ETD design effort encompasses a sub-payload transmitting antenna, a sub-payload command and control board with embedded encoder, a main payload receive software defined radio, and a main payload receive antenna system with filter and low noise amplifier. The SubTEC 8 payload deployed four sub-payloads – two via high velocity springs and two via Commercial-off-the-Shelf (COTS) rocket motors. The data from the sub-payloads was telemetered to the main payload via S-band frequencies at speeds of up to 1 Mbps and separation distances up to 20 km.



Sub–payloads for SubTEC 8.

Low Cost Star Tracker (LCST)

The LCST is designed to provide arcsecond level pointing accuracy using COTS components. The first flight of the LCST was in 2017 on SubTEC 7, and while the flight was a success, several improvements have been incorporated and were tested on SubTEC-8 in FY 2020.

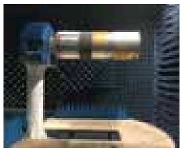
High Data Rate Telemetry Encoder

NSROC has selected Curtiss-Wright's Axon system for the high data rate telemetry encoder. Curtiss Wright currently offers a wide variety of data modules including but not limited to, analog and asynchronous with output accommodations for PCM and Ethernet with a roadmap to add additional capabilities every quarter for the foreseeable future. Curtiss Wright also offers options for development of custom modules at a rate of 1 deck per year for required sounding rocket specific data types. The Axon encoder also allows the use of satellite stacks that can be scattered throughout the payload. A prototype unit was configured and flown on SubTEC 8 mission in FY 2020 with a dedicated 40 Mbps telemetry downlink.

LCST setup for alignment checks.

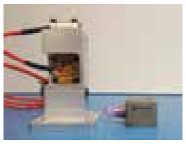
Other technolgies under development

Several other technologies under development by SRPO were flown on SubTEC 8.



High Temp GPS/S-Band Combo Antenna: New GPS/S-Band combo antenna design with a two layer design improves manufacturing yield over older three layer design

New Spin Motors; Redesign of the M37 legacy spin motor. New spin motor will maintain the legacy motor performance with new propellant expected to achieve DOT Class 1.3C certification



New Accelerometers: Intended to replace the legacy equipment with smaller footprint & all 3 sensing axes in one package. Equal/better accuracy to legacy sensor

Tern Inertial Navigation System (INS): Replacement to the legacy GLN-MAC devices with better manufacturability and enhanced attitude solution and capabilities

Airborne Power Supply Unit (APSU): Programmable DC/DC converter than can supply dual constant voltage or constant current outputs in a small enclosure, enabling power conditioning from a single bus to multiple outputs with differing requirements

Autonomous Rocket Tracker (ART): External nacelle designed to relay GPS coordinates to a remote user via the Iridium satellite network. Design is completely independent from the payload and mounts to the outer payload skin via straps

Solid State Altimeter: Replacement for legacy plenum chambers. Smaller footprint and more reliable altitude detection

Autonomous Flight Termination System (AFTS): NASA AFTS to acquire and/or develop capabilities, procedures, and tools needed to satisfy WFF responsibilities associated with certifying and processing an AFTS as the primary safety system

Results from the SubTEC 8 mission will be reported in the FY 2020 Annual Report.

New opportunities to conduct science missions in the Southern Hemisphere are being developed by SRPO. In 2020 sounding rockets are planning to return to Australia with three Astrophysics payloads.

FY 2019 saw several flights from launch sites in Norway as part of the Grand Challenge Initiative - Cusp. The missions involve US, Norwegian, and Japanese scientists and an international student mission. Two additional NASA missions are scheduled for flight in FY 2020 as part of the initiative.

On the Horizon

New and repeat opportunities to conduct science missions in remote locations abound within the SRPO in FY 2020 and beyond. A new Australian launch range, Equatorial Launch Australia (ELA) is set to be an operational site by mid-year 2020. Operations will continue from regularly used launch sites, Wallops Island, White Sands Missile Range, and Poker Flat Research Range. Approximately twenty missions are manifested for flight in FY 2020. The Grand Challenge Initiative - Cusp will continue through the year with launches from both Andoya Space Center (ASC) and Ny-Ålesund, both in Norway.

Grand Challenge

The first segment of the Grand Challenge Initiative - Cusp was completed in FY 2019. Two NASA launches, and one international launch supported by SRPO, remain on the scheuled for FY 2020. In November 2019, Cusp-Region Experiment (C-REX) 2 and Cusp Heating Investigation (CHI) will launch from Andoya Space Center and Ny-Ålesund, respectively. Additionally, a Norwegian mission, ICI-5 will launch from Svalbard. ICI-5 is supported by SRPO with rocket motors. More information on the Grand Challenge Initiative can be found here: http://www.grandchallenge.no/

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. Equatorial Range Australia (ELA), near Nhulunbuy, Northern Territory has been selected as the launch site for three astrophysics mission scheduled for FY 2020. This will be NASA's first ever use of a foreign commercial launch range which, while exciting for program also introduces unique challenges. The SRPO has worked closely with the NASA Office of International and Interagency Relations (OIIR) to resolve these challenges in order to bring this new approach to fruition. Relatively new mobile assets, sucha as the Liquid Nitrogen Plant and one Medium Mobile Launcher (MML) will be used to facilitate the campaign. Additionally, the Wallops Flight Facility (WFF) mobile range assets will be used to support this campaign.

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 Spectrograph (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.

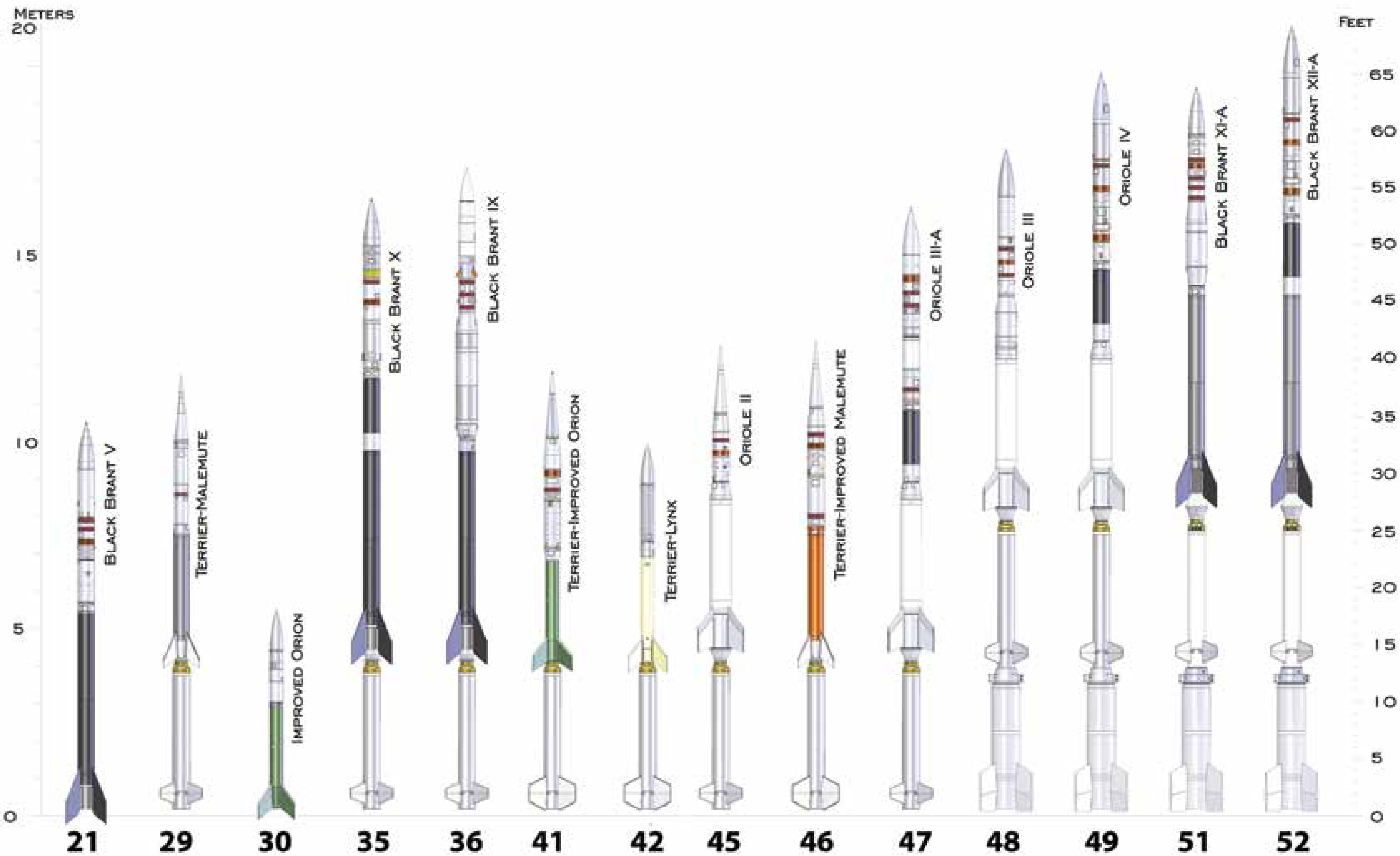
X-ray Quantum Calorimeter (XQC)

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.

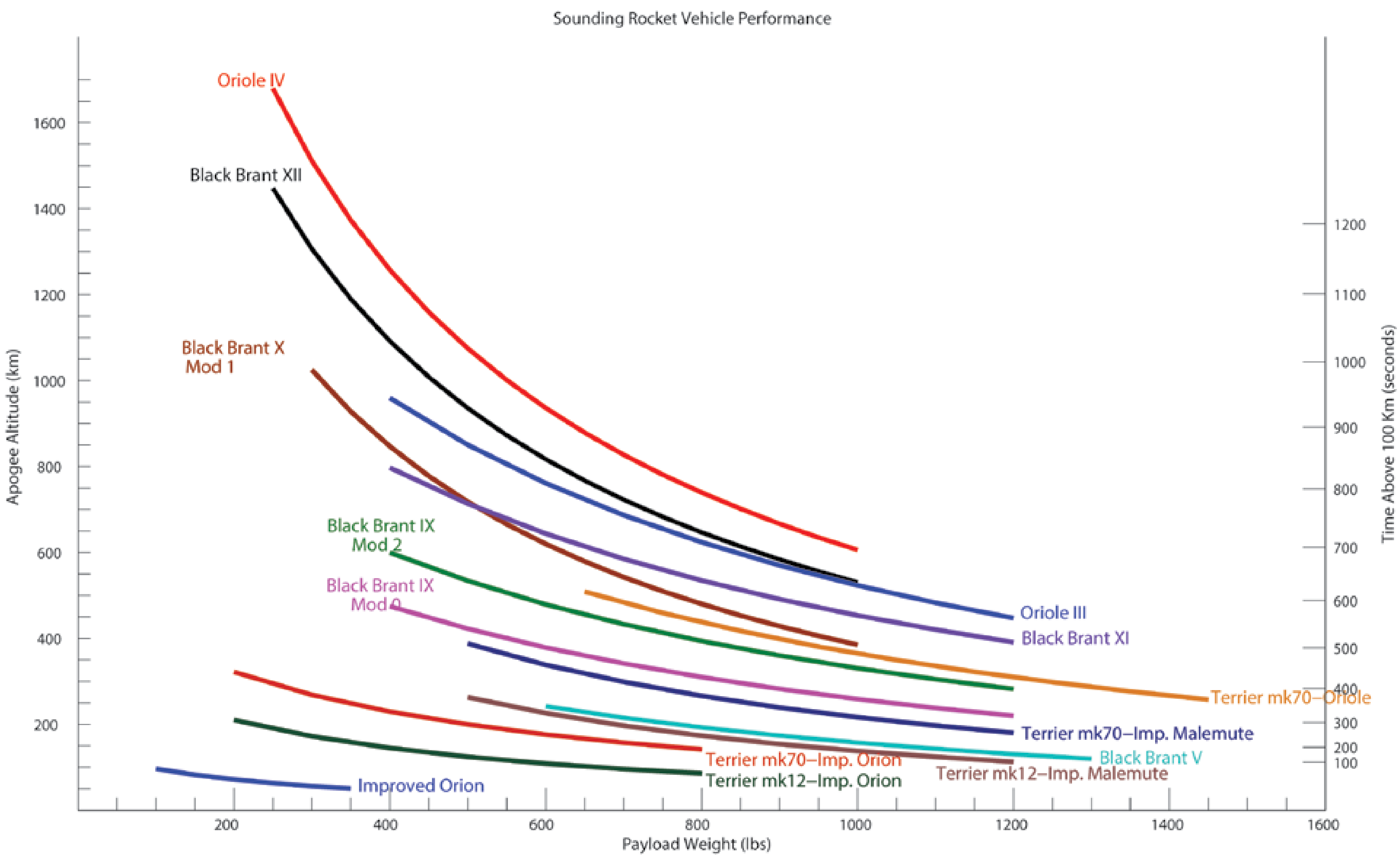
Kwajalein

In June 2019, the SRPO returned to Reagan Test Site (RTS) at Kwajalein Atoll, Marshall Islands, to launch two rockets for Dr. Hysell, Cornell University as part of the TooWINDY mission (see page 21). The next Kwajalein deployment is scheduled for June 2021 for Dr. Barjatya, Embry Riddle. The goal of the Sporadic E Electrodynamics (SEED) mission is to collect the first simultaneous multipoint spatial and temporal observations of low-latitude Sporadic-E layers and their associated electrodynamics and neutral dynamics. Two Terrier-Improved Malemute vehicles will be launched in support of SEED.

Sounding Rocket Vehicles



Sounding Rocket Vehicle Performance



Sounding Rocket Launch Sites

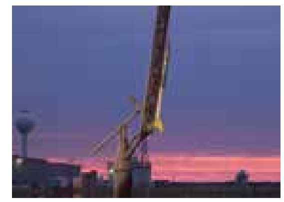
Poker Flat, Alaska

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

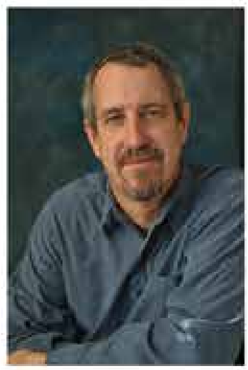
Sounding Rockets Program Office personnel

John Hickman
Assistant Chief

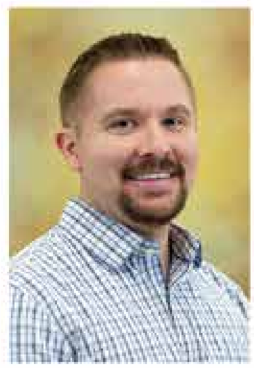
Giovanni Rosanova
Chief

Scott Bissett
Operations Manager

Julie Bloxom
Business/Grants Manager



Chuck Brodell
Vehicle Systems Manager



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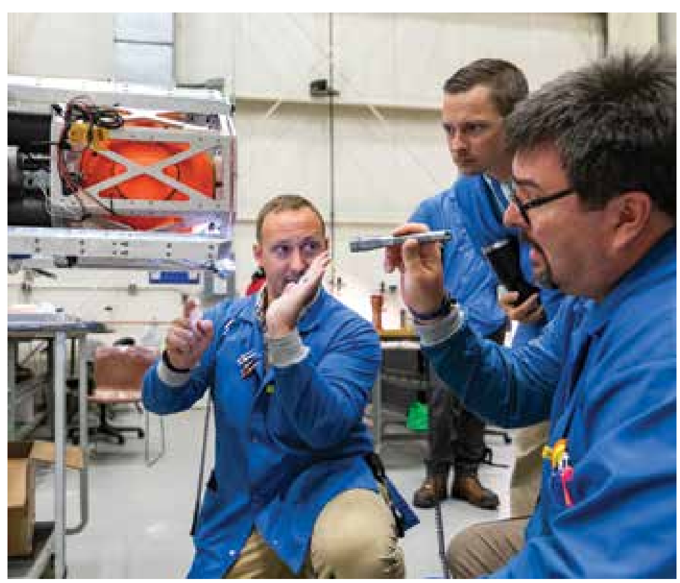
Science mission information submitted by Principal Investigators.

VISIONS–2 payload teams in Svalbard, Norway. Credit: Allison Stancil–Ervin/Wallops Imaging Lab.

AZURE integration.

AZURE deployment testing.

TooWINDY payload testing.



RockSat–X integration.


VISIONS–2 launches from Svalbard. Credit: Allison Stancil–Ervin/Wallops Imaging Lab.


VISIONS–2 deployment testing.


VISIONS–2 integration.


Machine shop.

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NP-2019-11-421-GSFC