National Aeronautics and Space Administration

NASA Sounding Rockets 2009 Annual Report


Sounding

Sounding Rockets Program – Annual Report 2009

The NASA Sounding Rockets Program has completed another active and successful year. It supported a wide variety of scientific teams on missions studying plasma, solar and cosmic physics, and deep space objects. The program also supported development efforts that will enable new suborbital, orbital, and planetary missions in the future. The program's unique mobile ability facilitates worldwide launches, anytime, anywhere; and takes full advantage of specialized scientific instruments, developed to capture phenomena that occur at a specific time and place in space. Many of the 2009 missions featured increased payload complexity and expanded flight operations. Future missions being planned and designed for the coming year promise even more exciting challenges and significant rewards for the scientific community. This annual report offers some brief insights into the scientific missions, development efforts, and the educational and workforce development projects supported by the NASA Sounding Rockets Program, as well as a forecast of challenges "on the horizon."

Phil Eberspeaker

Chief, Sounding Rockets Program Office

36.226 UG payload being prepared for deployment testing.

Introduction

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 stimulate innovation and technology maturation and enables rapid response to scientific events.

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

Telescopes and spectrometers to study Solar Physics and Astrophysics are flown on sounding rockets to collect unique science data and to test prototype instruments for future satellite missions. An important aspect of most satellite missions is calibration of the space-based sensors. Sounding rockets offer calibration and validation flights for many space missions, particularly solar observatories such as the Thermosphere-Ionosphere-Mesosphere-Energetics-Dynamics (TIMED) satellite, the Solar Heliospheric Observer, and the future Solar Dynamics Observatory (SDO).

The Inflatable Reentry Vehicle (IRVE) launches from Wallops Island, Virginia.

Executive Summary

Science with Sounding Rockets

Since their first use for space and atmospheric research in the 1950's, sounding rockets have continued to provide valuable data for scientists in several fields of study. Astrophysics, Heliophysics, and Geospace Sciences all use sounding rockets for relevant research.

Missions 2009

Sixteen rocket missions supported science and technology disciplines including geospace physics, astrophysics, and aeronautics and education. Specific studies accomplished spectral measurements of the white dwarf Feige 24 in the Extreme Ultraviolet wavelengths, measurements of auroral currents in the magnetosphere-ionosphere-thermosphere, wind measurements in the turbopause, investigations of motions and structure of the aurora, and measurements of the cosmic infrared background. Additionally, two planetary reentry experiments were flown, as well as two education missions.

Mission Support Upgrades

In preparation of upcoming missions several payloads were integrated and tested including two payloads to be launched during the winter campaign in Poker Flat, Alaska, February - March 2010. Upgrades to the Sounding Rockets Program included several new machines in the fabrication shop and new test equipment in the Testing and Evaluation Lab.

Technology

New technologies to enhance the Sounding Rockets Program are continuously under development. Currently, high data rate telemetry and a new flight termination system are at the forefront of the technology development effort. Sub-TEC missons support testing of new technologies, both for the Sounding Rockets Program and external customers. Two Sub-TEC missions are scheduled for flight in 2010.

Education

The NASA Sounding Rockets Operations Contract (NSROC) continued the highly successful internship program whereby university engineering interns participated in the various aspects of the Sounding Rockets Program. Two education payloads were flown in 2009, one on a single stage Orion from Poker Flat Research Range, Alaska and the other on a two-stage Terrier-Orion from Wallops Island, Virginia. The Sounding Rockets Program Office (SRPO) supports NASA's workforce development objectives with the Hands-On Project Experience (HOPE) mission, scheduled for flight in 2010. Vehicle systems engineer, Dustin Herold, hired in 2009, shares his background leading to employment as a rocket engineer.

Extensions

The NASA Sounding Rockets Program is a national resource, supporting government agencies such as the Missile Defense Agency (MDA), US Air Force, the Naval Research Laboratory (NRL) and the US Army with launch vehicles, as well as payload manufacturing and testing services. The NASA Max Launch Abort System (MLAS) was flown from Wallops Island in 2009. Sounding rockets provided manufacturing support and four Terrier motors for this successful mission. Two hypersonics test flights were performed using sounding rockets.

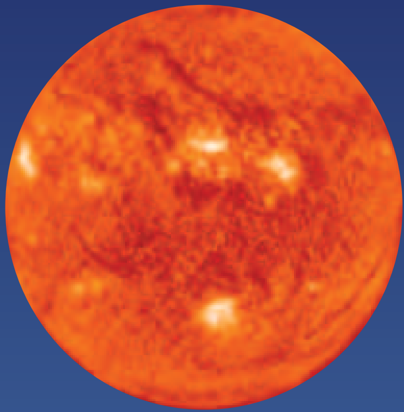
Future

Worldwide operations are one of the Sounding Rockets Program's unique features. In response to the science community's interest, proposals are solicited for a campaign from Woomera, Australia, planned for 2012. Launch opportunities are also planned for Kwajalein, Marshall Islands. Additionally, CubeSats will be flown on sounding rockets in 2010.

Program Statistics

Charts, graphs and metric analyses quantify the progress and success of the Sounding Rockets Program and include launch history, launch sites, and vehicle and mission success statistics.

Science



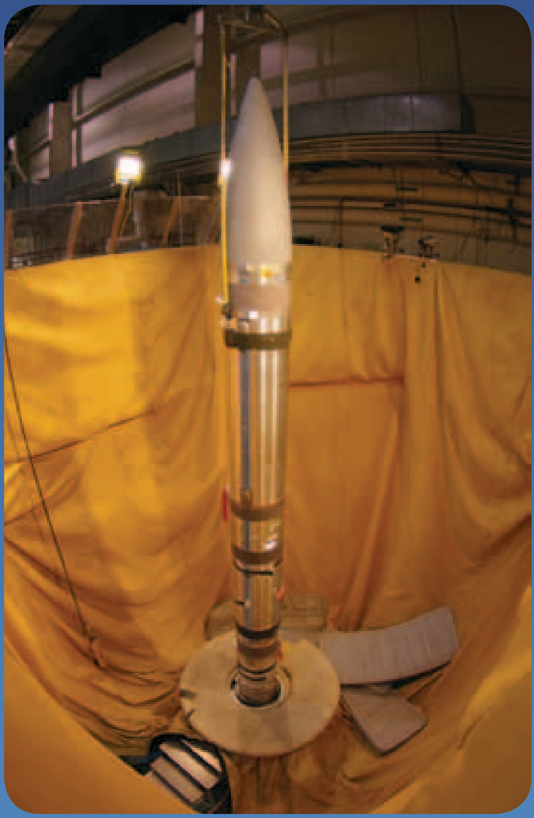
Science Highlight

Changing Aurora: in-situ and Camera Analyses of Dynamic Electron Precipitation Structure (CASCADES) 2
by Dr. Kristina Lynch, Dartmouth College, Principal Investigator

Changing Aurora: in-situ and Camera Analyses of Dynamic Electron Precipitation Structure (CASCADES) 2 was launched on March 20, 2009, at 11:04 UT (roughly 30 minutes pre-midnight magnetic local time.) The 12 minute 43 second flight reached an apogee of 564 km over the northern coast of Alaska at 11:11:11 UT, and entered the polar cap at 11:14:40 UT before atmospheric reentry at 11:16:42 UT. The experiment array included a 5-payload suite of in-situ instrumentation, ground cameras of various fields of view at three different points under the trajectory, various ground magnetometers, the PFISR radar at the launch site, and the THEMIS spacecraft in the magnetotail.

Dr. Kristina Lynch preparing a Particle Free Flyer for testing.

The array design was chosen to address questions about (1) shears in ionospheric electric fields and their ability to drive waves; (2) proper motion of auroral structures with respect to the ambient ionosphere; and (3) quantifying parameters of dispersive Alfven wave phenomena and their effects on auroral fluxtubes.



40.023 payload ready for deployment testing.

The CASCADES 2 trajectory passed through several parts of a poleward boundary intensification event, with both inverted-V type aurora and sustained Alfvenic activity seen.

The CASCADES 2 mission is designed to address the following questions:

- Does dynamic aurora move with respect to the background ionosphere? How much? Does it matter?
- What is the spatial (as opposed to temporal) variation of auroral parameters like B and E? What does this mean for theories of energy transfer?
- Alfven waves carry disturbances and changes down to and through the auroral zone, giving us structured and dancing aurora. They are pretty: do they matter? Are these structures significant for magnetosphere/ionosphere coupling? Do direct observations of these motions validate theories and models?

The following graphics detail some of the findings from the mission.

Initial Results of the CASCADES-II Sounding Rocket:
A Series of Poleward Boundary Intensifications


Photo by Mike Nicolls

Meghan Mella, Kristina Lynch
Dartmouth College
Contact: Meghan.Mella@Dartmouth.edu

Paul Kintner, Erik Lundberg
Cornell University

Marc Lessard
University of New Hampshire

Hans Stenbaek-Nielsen
University of Alaska Fairbanks

Nickolay Ivchenko, Hanna Dahlgren
KTH

Robert Michell
SWRI

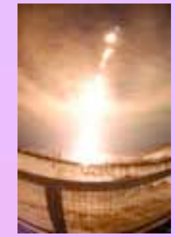


Photo by Robert Michell

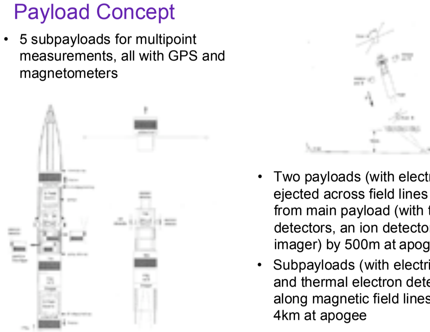
Abstract
CASCADES-II was launched on 20 March 2009 at 11:04:00UT from the Poker Flat Research Range. The payload had five sub-payloads for multipoint measurements of auroral dynamics and structure. The signatures in the keograms at the time of flight can be described as a series of Poleward Boundary Intensifications, which are repeated brightenings along the poleward edge of the auroral oval that may move equatorward. There have been theories suggesting that these repeated poleward brightenings are related to Alfvénic activity at the Plasma Sheet Boundary Layer (PSBL)[Liu, et al. 1995]. The launch of CASCADES-II into this dynamic Alfvénic structure will provide a rich case study of this less-studied type of event.

Initial analysis of the optical data indicates the payloads cross through the equatorward edge of a PBI at the beginning of flight, followed by a period of unstructured aurora, until reaching the onset of the next PBI at a higher latitude. During these two PBIs we observe increased activity in all particle detectors. The field aligned electrons on multiple payloads show impressive dispersion signatures. Also we see Alfvén waves with amplitudes of over 200mV/m in both electric field instruments at the end of the flight, together with strong perturbations of the magnetic field. In this Alfvénic region we observe very structured ion precipitation. The in situ data for this event will be a good case study for various theories and models of Alfvénic aurora. In this poster I will present a brief overview of the rocket design and launch, along with initial in situ data as well as PFISR and THEMIS data during the time of flight, focusing in particular on what this case study can tell us about PBIs.

mission, although much data remains to be analyzed

Payload Concept

- 5 subpayloads for multipoint measurements, all with GPS and magnetometers

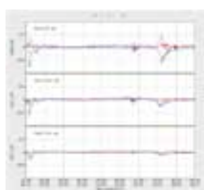


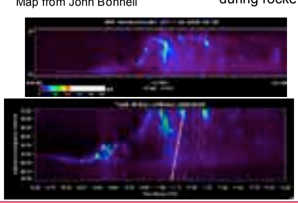
- Two payloads (with electron detectors) ejected across field lines separated from main payload (with two electron detectors, an ion detector, and an imager) by 500m at apogee
- Subpayloads (with electric field booms and thermal electron detectors) ejected along magnetic field lines separated by 4km at apogee

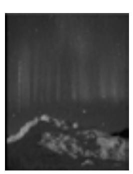
Launch Conditions


Map from John Bonnell

- Launched 20 March 2009 at 1104:00 UT
- Apogee of 564km
- Negative bay in H seen by ground magnetometers
- PBI signatures seen in keograms
- Tall rays imaged during rocket flight

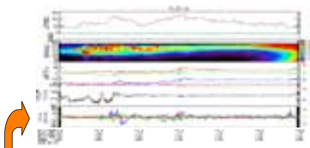




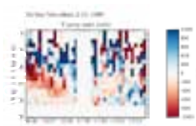


Satellite and Radar Data

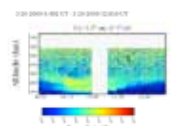
Bursty Bulk Flows (BBFs) are often seen in the tail and are connected to flows observed in the ionosphere. Many studies have been done connecting BBFs to PBIs using satellite and radar data from events similar to our event.

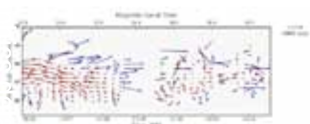


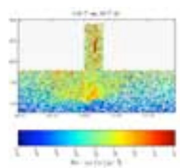
At the time of launch, earthward flows are seen in the tail by THEMIS.



Before launch, PFISR observes westward flows pulling equatorward. The electron density is enhanced both before and during launch.

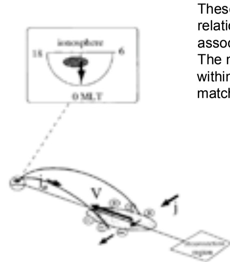






Connection of BBF to PBI

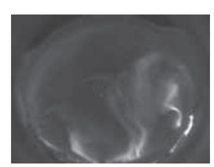
These figures from Nakamura et al. show the spatial relationship between the BBF footpoint and the associated ionospheric auroral signature.
The map to the left shows the THEMIS footpoint to be within one hour east of the rocket trajectory, which matches this picture.



Since the event during the time of launch can be classified as a PBI, what can this case study say about the correlation among flows in the magnetotail, auroral intensifications detected on ground-based instruments, and Alfvén waves on the rocket?

CASCADES-II Location

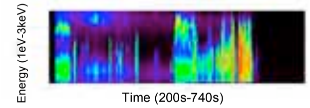
	L-Shell	MLT
Launch	5.7RE	23:34
Apogee	8.7RE	23:41
Onset of Alfvénic Aurora	9.7RE	23:44
LOS	14.6RE	23:46



North-South aligned auroral arcs seen just prior to launch, a common signature of PBIs.

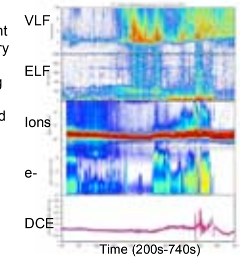
In Situ Data

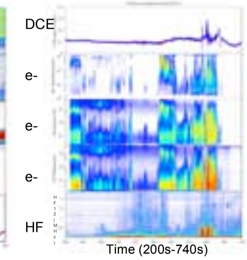
The in situ data gives us a detailed look at the ionospheric signatures seen in conjunction with the BBFs and PBIs.

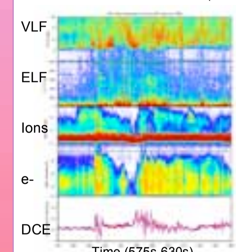


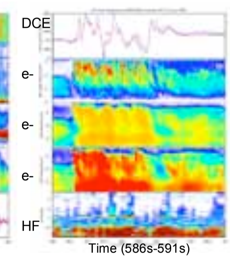
The electron spectrogram for the full flight shows inverted-V type aurora at the equatorward edge of a PBI, and Alfvénic aurora near the end of flight, at the onset of the next PBI.

Full flight summary plots showing particle data and electric field data.





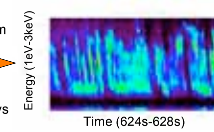




Zoomed data showing detailed data toward the end of flight during Alfvénic aurora.

In situ electron dispersion signatures during Alfvénic aurora give a source region of 429 km above payload with a frequency of 10 Hz.

Electron structure width can be approximated from in situ data as well as camera data to be 2-5 km at 600s time of flight, when the tall rays are seen.



- We observe a dispersive Alfvén wave at 1000km with a frequency of 10Hz
- From the camera we get a perpendicular phase velocity which gives a $k_\perp$ of $2^*\pi/2$km
- From the e^- or the camera data we get $k_\perp$ which gives a $v_\perp$, which is consistent with above
- From the delay between in situ particle and electric field measurements we get a $v_\parallel$ which is consistent with Chris Chaston's model and also gives a $k_\parallel$
- The 2 payload DCE should give a direct observation of the parallel phase velocity
- A five point magnetic field measurement will allow us to calculate ∇xB to get the current.

References and Acknowledgements

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Liu, W. W., B.-L. Xu, J. C. Samson, and G. Rostoker, Theory and observation of auroral substorms: A magnetohydrodynamic approach, J. Geophys. Res.,100, 79, 1995.
Lyons, L., T. Nagai, G. Blanchard, J. Samson, T. Yamamoto, T. Mukai, A. Nishida, and S. Kokubun (1999), Association between Geotail plasma flows and auroral poleward boundary intensifications observed by CANOPUS photometers, J. Geophys. Res., 104(A3), 4485-4500.

DARTMOUTH

GEM, 25 June 2009

Ground-based optical observations during the Cascades-2 rocket

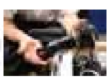
H. Dahlgren (1), N. Ivchenko (1), K. Lynch (2), M. Lessard (3), H. Nielsen (4), S. Jones (3), T. Aslaksen (5), M. Mella (2), P. Kintner (6), E. Lundberg (6)

Introduction

The Cascades-2 (The Changing Aurora: In Situ and Camera Analysis of Dynamic Electron Precipitation Structures) sounding rocket was successfully launched into dynamic and rayed aurora over Alaska on 20 March 2009. Ground-based observations of the aurora were carried out with optical instruments located in Kaktovik, in Toolik Lake and at Poker Flat. The instrumentation consisted of all-sky cameras as well as narrow field imagers. Thin, tall auroral rays are seen at the rocket footprint, and their properties are investigated further.

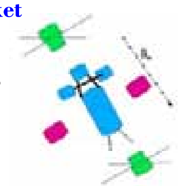
Ground-based instrumentation

All-sky cameras as well as narrow FOV imagers were positioned at Toolik Lake Field Station, Kaktovik and at Poker Flat.
Two AVT Guppy cameras, FOV: 24.4° × 31.6°, were tracking the rocket footprint from Toolik:
-Guppy1: Filter: 6300 Å, 4 s exposure times
-Guppy2: Filter: RG645 cutoff, 2 fps

Cascades-2 rocket

Sounding rocket with multi-point measurements
-Two free-flying subpayloads along B_0, with
* wire-boom E-field probes, magnetometers and GPS
-Two free-flying particle detectors across B_0 with
* electron detectors, magnetometers and GPS
-Main payload with
* ion detector, electron detectors, magnetometers, imager and GPS



Launched from Poker Flat into rayed aurora on 20 March 2009, through events of Polar Boundary Intensifications (PBIs).
Apogee: 564 km
PI: Kristina Lynch, Dartmouth
Collaborators: Dartmouth, Cornell, UNH, UAF, KTH, and UC Berkeley
For more information on the rocket and rocket data analysis, see presentation by P. Kintner!

Analysis of auroral rays

Height extent

During the rocket TOF auroral rays were observed from the side. The 100 km to 200 km footprint of the rocket is marked with white dots in Fig.1. The images indicate that there are two layers of rays, one layer (yellow arrow in Fig.1) closer to the camera and another layer further away (orange arrow in Fig.1). From the auroral features detected in the *in-situ* data we can assume that the rays seen at the footprint take place at the known distance of 580 km between Toolik Lake and the rocket footprint. Their height extent is then 130 km. Fig.3 shows a keogram made from cuts along the rocket footprint. The altitude extent of the rays is fairly constant with time.

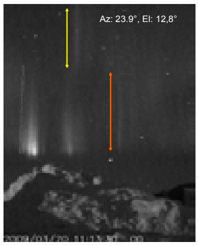


Fig.1: Guppy2 image showing two layers of rays, marked in yellow and orange. The rocket footprint (100 – 200 km extension) is shown as a dotted line.

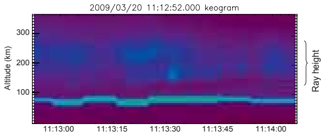


Fig.2: Keogram from vertical cut along rocket footprint, where the rays are seen as light blue. The green line shows the top of the snow pile. The jumps are due to the motion of the tracking camera.

Motion of rays

The time series of guppy images (Fig. 3) show the evolution of auroral rays during an interval of 1min 10s. The auroral drapery is characterized by dynamic and rapid rays moving in opposite directions, with a lower boundary at about 100 km altitude.

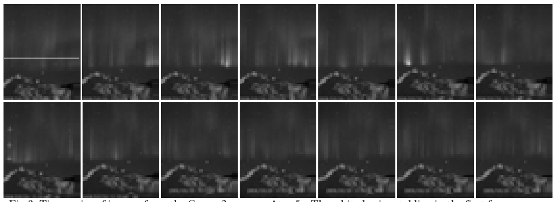


Fig.3: Time series of images from the Guppy2 camera. Δt = 5s. The white horizontal line in the first frame illustrates the position of the cut to create the keograms in Fig.4 and 5.

The motion of the rays can be seen from keograms made by a horizontal cut in the images (Fig. 4 and 5). From the slope of the structures the velocity is determined to 13 km/s both for westward and eastward moving rays.

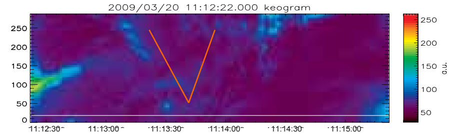
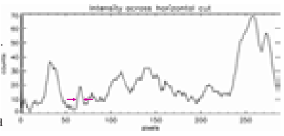


Fig.4: Keogram from a cut made at y=180 in the images. The motion of rays in different directions is seen as lines with positive and negative slopes for eastward and westward motion, respectively. Red lines are put on the keogram to mark typical velocities. The white line near the bottom shows the position of the rocket footprint.

The individual widths of the rays vary, with values down to 5.5 km as seen from the side (Fig. 6). The rays merge and split continuously, with a typical distance between the rays of 15 km, and about 10 individual rays observed simultaneously.



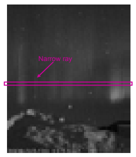


Fig.6: Left: Plot of the intensity through a horizontal cut of an image. The widths of the narrowest rays is determined, by fitting a Gaussian to the intensity peak. Right: Image with marked cut and narrowest ray.

The large scale picture

All-sky data from Kaktovik (Fig. 7) show the band of rays that the rocket passsed through. Fig. 8 is spectrograph data from Kaktovik. The rocket passed through the poleward onset of a PBI at the time of the observed rays.

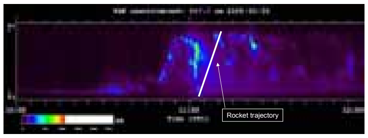


Fig. 8: Spectrograph data from Kaktovik: the rocket passed through poleward onset of PBI at time of the guppy observations.

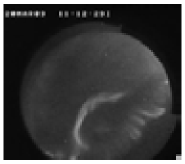


Fig. 7: Kaktovik All-sky camera data

Electron data (Fig. 9, 10) show that the rays are caused by mainly electrons with energies of less than 1 keV. The dispersion seen in electron data is a signature of Alfvén waves. Fig. 10 (top) shows the altitude variation in intensity, with maximum intensity measured at 150 km.

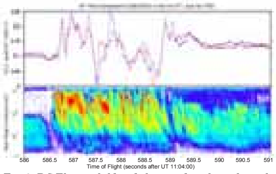


Fig. 9: DC Electric field and electron data from the rocket.

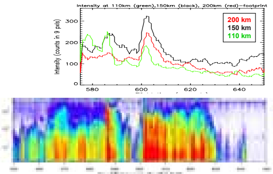


Fig. 10: The correlation between emission intensity in the footprint at 110 / 150 / 200 km altitude (top) and precipitating electron energy (bottom) indicates that the observed rays are the ones seen by the rocket.

Discussion and Conclusions

Auroral rays have been investigated during the flight of the Cascades-2 rocket. First preliminary results show widths of down to 5 km, height extension of 130 km with sharp lower border and motions of the rays in eastward and westward directions simultaneously, with velocities of up to 13 km/s. Rocket data indicates <1 keV electron precipitation and Alfvén wave signatures at the time of the rays. The rays are brightest at ~150 km altitude.

This study will continue by a more detailed analysis of the many data sets (ground based and *in-situ*) available.

(1) Royal Institute of Technology, (2) Dartmouth College, (3) U. of New Hampshire, (4) U. of Alaska , (5) University of Tromsø, (6) Cornell University

Missions

36.207 DG - Kowalski

Mission: 36.207 DG

PI: Dr. Michael Kowalski

Institution: Naval Research Laboratory

Vehicle: Black Brant IX

Launch Site: White Sands, New Mexico

Launch Date: October 20, 2008

The extreme ultraviolet (EUV) waveband provides critical spectral diagnostics on physical conditions within million degree plasmas. These are ubiquitous in the universe and examples include stellar coronae, white dwarf photospheres, accretion phenomena in cataclysmic variables (CVs) and active galactic nuclei (AGN), and the interstellar medium (ISM) of our own galaxy as well as of others. The 36.207 payload, Joint astrophysical Plasmadynamic Experiment (J-PEX), was a high-resolution EUV (220-250 Å) spectrometer. It contained multilayer-coated gratings, which were the culmination of basic, NRL and NASA-funded research spanning two decades, and a microchannel plate detector with both high quantum efficiency and high spatial resolution (cross strip anode).

J-PEX first flew successfully in 2001 (36.195) and produced the first high-resolution EUV spectrum of a non-solar object, the isolated white dwarf G191-B2B. Results included a measurement of the ISM He II column and an indirect detection of photospheric helium. Both are critical to models of stellar formation and evolution, as white dwarfs are the endpoints for most stars, including the Sun. Advances require both high sensitivity and high spectral resolution to disentangle source features from those in the ISM. J-PEX has now achieved the world's best resolving power (~4000) and effective area (~7 cm2) in an EUV astrophysics instrument.

The target for this second mission (36.207) was also a white dwarf, Feige 24, but it is located in a binary system, thus introducing exciting new aspects that are complementary to the first mission. J-PEX successfully recorded the target spectrum and analysis is in progress.

J-PEX launch White Sands, NM

The J-PEX team at White Sands Missile Range.

PI Website: http://xweb.nrl.navy.mil/jpex/index.html

30.073 UO - Thorsen

Mission: 30.073 UO
PI: Dr. Denise Thorsen
Institution: University of Alaska/Fairbanks
Vehicle: Orion
Launch Site: Poker Flat Research Range, Alaska
Launch Date: January 10, 2009

The 30.073 UO student payload was launched from Poker Flat Research Range, Alaska, on a single stage Orion sounding rocket. The primary science objective of Ionospheric Science and Inertial Sensing (Project ISIS) was to measure the plasma density structure of the high latitude D-region ionosphere above Poker Flat Research Range, using a plasma probe, radio receivers, and other sensors. Project ISIS will also study atmospheric attenuation of ultraviolet rays in collaboration with Tokai University of Japan.

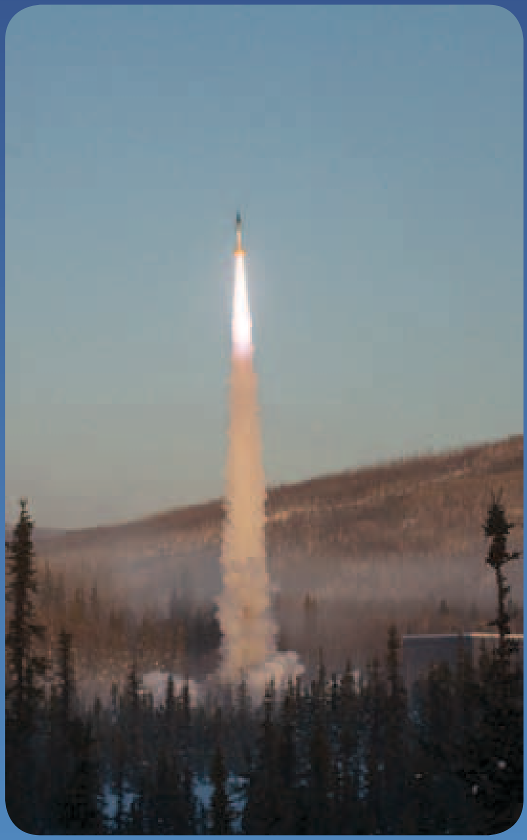
Goals of the Student Rocket Project
Student Training - Provide students with opportunities for hands-on experience with design, construction, testing and launch of sounding rocket payloads.

Scientific Research - Develop low-cost, student-designed rocket payloads to investigate high latitude geophysical phenomena.

Technology Transfer - Provide frequent launch opportunities to maintain the technology base and transfer specialized knowledge from practicing aerospace professionals to students.

Collaborations with Industry - Provide a low-cost test bed for verification of new flight hardware technology and development of internet tools for distributed project management.

University of Alaska students with their payload at Wallops.



30.073 lift-off from Poker Flat, Alaska

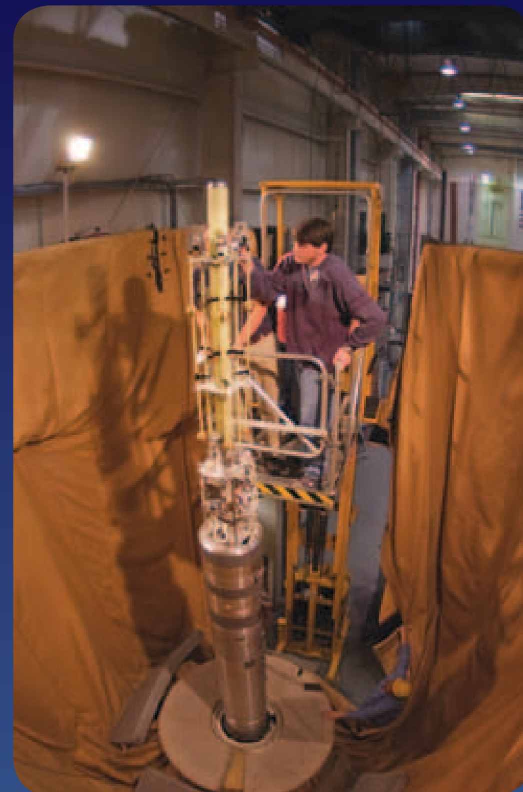
PI Website: http://www.uaf.edu/asgp/asrp/srp5/ssrp5_main.htm

21.139 & 36.242 UE - Bounds

Missions: 21.139 & 36.242 UE
PI: Dr. Scott Bounds
Institution: University of Iowa
Vehicle: Black Brant V & Black Brant IX
Launch Site: Poker Flat Research Range, Alaska
Launch Date: January 29, 2009

The Auroral Current and Electrodynamics Structure (ACES) rocket experiment uses two suborbital rockets plus ground-based measurements to make simultaneous measurements of the electrical currents associated with the aurora borealis or northern lights. This configuration allows the scientist and his team to understand where the auroral currents flow and how they are related to the magnetosphere above the aurora, the ionosphere where the auroras occur, and the upper atmosphere called the thermosphere.

The rocket experiments measure currents, auroral charged particles, and electric and magnetic fields in the auroras, directly, while ground-based measurements remotely image the auroras and record changes in the magnetic field as well as providing the variation in the density of the plasma (a thin gas of electrically charged particles) and its temperature over a range of altitudes.



PI Dr. Scott Bounds inspecting instrument prior to deployment testing.

Dr. Bounds (left) with payload team members Pat McPhail and Herbie Haugh during integration in Alaska.

PI Website: http://delta.physics.uiowa.edu/p/public_html/index.html

41.076 – 41.079 UE - Lehmacher

Missions: 41.076 – 41.079 UE
PI: Dr. Gerard Lehmacher
Institution: Clemson University
Vehicle: Terrier-Orions
Launch Site: Poker Flat Research Range, Alaska
Launch Date: February 18, 2009

41.076 on the vibration table in the Testing and Evaluation lab at Wallops.

In support of NASA's Geospace Science Program, four rockets were launched over Alaska to study turbulence in the upper atmosphere, with the strategic goal being to understand the Sun and its effects on Earth and the solar system. The launches took place at Poker Flat Research Range as part of the NASA 2009 sounding rocket campaign. Results from these flights are relevant to the Aeronomy in the Mesosphere (AIM) satellite mission, as well as the potential future Geospace Electrodynamic Connections (GEC) mission.

The two-stage Terrier-Orion rockets, flying to altitudes of approximately 140 km, released trimethyl aluminum, creating a glowing vapor trail. Sensitive cameras on the ground tracked the trails. Analysis of upper-atmospheric winds was conducted by tracking vapor trail formation, billowing, dispersion and diffusion. Two of the four rockets carried additional deployable payloads with instrumentation to measure electron density and neutral temperature and turbulence.

The instrumented sections were a collaboration of Clemson with Pennsylvania State University (Penn State) and the Leibniz-Institute for Atmospheric Physics in Germany. The University of Alaska assisted in the study with ground-based laser radar and other optical instruments.

Lehmacher launch and TMA trail.

PI Website: http://people.clemson.edu/~glehmac/atmospace/atmosspace.htm

36.226 UG - Bock

Mission: 36.226 UG
PI: Dr. Jamie Bock
Institution: Caltech
Vehicle: Black Brant IX
Launch Site: White Sands, New Mexico
Launch Date: February 25, 2009

The Cosmic Infrared Background ExpeRiment (CIBER) is a rocket-borne absolute photometry imaging and spectroscopy experiment optimized to detect signatures of first-light galaxies present during reionization in the unresolved IR background. CIBER-I consisted of a wide-field two-color camera for fluctuation measurements, a low-resolution absolute spectrometer for absolute EBL measurements, and a narrow-band imaging spectrometer to measure and correct scattered emission from the foreground zodiacal cloud. CIBER-I was successfully flown on February 25, 2009, and has one more planned flight in early 2010.

The payload being prepared for deployment testing. Nick Cranor working on payload with Bonnie Maxfield as ground safety inspector.

Ian Sullilvan with CIBER in the cleanroom at Wallops.

PI Website: http://science.jpl.nasa.gov/Astrophysics/AstronomicalInstrumentation/index.cfm

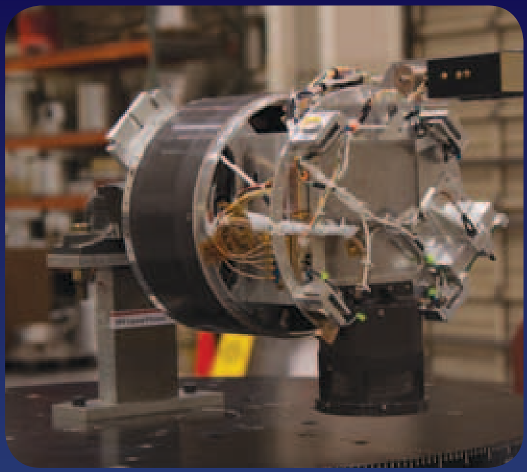
Mission: 40.023 UE
PI: Dr. Kristina Lynch
Institution: Dartmouth College
Vehicle: Black Brant XII
Launch Site: Poker Flat Research Range, Alaska
Launch Date: March 20, 2009

40.023 UE - Lynch

The purpose of the Changing Aurora: in-situ and Camera Analyses of Dynamic Electron Precipitation Structure (CASCADES) 2 sounding rocket mission was the investigation of motions and structure of electron precipitation in pre-midnight poleward edge discrete aurora.

The rocket included a main payload and four sub-payloads. The four sub-payloads consisted of two identical wire-boom electric field sub-payloads with Global Positioning System (GPS) position and timing, as well as two free-flying particle detector sub-payloads with GPS position and timing.

There are many investigators from many different institutions who contributed to the CASCADES mission. Kristina A. Lynch of Dartmouth College was the principal investigator and was responsible for the overall mission. Dartmouth College, with support from the University of New Hampshire, was responsible for the overall system design, particle detectors, and the Particle Free Flyer (PFF) sub-payloads. The University of New Hampshire was responsible for the onboard camera to image the visible aurora. Cornell University was responsible for providing the electric field and plasma wave sub-payloads, and five GPSs.



Mass Properties measurement of the Particle Free Flyer.

Brian Creighton and Dr. Kristina Lynch (PI) testing boom release mechanism.

PI Website: http://www.dartmouth.edu/~aurora/cascades2.html

41.080 DR - Murbach

Mission: 41.080 DR
PI: Marc Murbach
Institution: NASA Ames Research Center
Vehicle: Terrier-Orion
Launch Site: Wallops Island, Virginia
Launch Date: May 28, 2009

A novel planetary reentry concept, the Slotted Compression Ramp, or SCRAMP, situates the payload in front of the heat shield. The concept originated with the Sub-Orbital Aerodynamic Reentry Experiments, or SOAREX.. SOAREX is a multi-year hypersonic flight test development project at NASA's Ames Research Center at Moffett Field, California.

The reentry body on SOAREX VII, Murbach 41.080 DR, was a modified version of a classic SCRAMP called a Tube-Deployed Reentry Vehicle (TDRV). The design still uses a blunt-nosed cylinder with a flare skirt. The flare in the TDRV is made of a combination of high-temperature flexible materials, some of which were developed during the Shuttle program. Higher temperature material combinations have been identified and were included during proposed orbital reentry tests. Instrumentation on the TDRV included pressure sensors, radiometers, thermocouples, rate gyros, accelerometers, and a video camera.

Preliminary analysis of the data showed the probe quickly orienting nose-down after deployment, validating the predicted stability and the high drag coefficient.

Payload being prepared for vibration testing in the T&E lab.

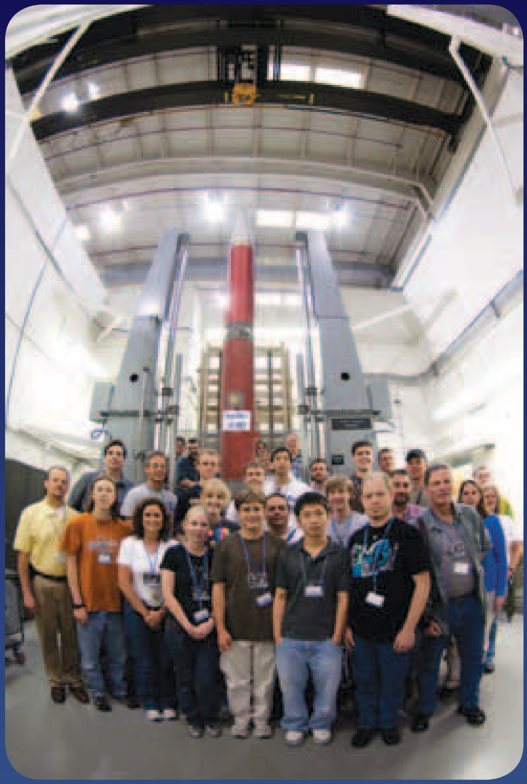
41.083 UO - Koehler

Mission: 41.083 UO
PI: Chris Koehler
Institution: University of Colorado
Vehicle: Terrier-Orion
Launch Site: Wallops Island, Virginia
Launch Date: June 26, 2009

Students and faculty from universities around the country participated in the 2009 RockOn! flight opportunity, June 21 - 26, 2009. Arranged jointly by the Colorado and Virginia Space Flight Consortia and supported by the NASA Space Grant Program and NASA Sounding Rockets Program Office, RockOn! is a hands-on workshop teaching participants how to create a spaceflight experiment, program a flight computer, and collect and analyze data. Additionally, in 2009, ten universities were selected to fly experiments of their own design by participating in the RockSat portion of the program.

The RockOn! workshop participants constructed, integrated and tested their experiment kits, and on the last day of the workshop, launched their experiments on a NASA two-stage Terrier-Orion sounding rocket.

RockSat participants integrated their completed experiments at Wallops the week of the launch and participated in pre- and post-launch activities.



RockOn! and RockSat participants with the payload.

PI Website: http://spacegrant.colorado.edu/rockon/

Mission: 36.244 UG
PI: Dr. James Green
Institution: University of Colorado
Vehicle: Black Brant IX
Launch Site: White Sands, New Mexico
Launch Date: June 27, 2009

36.244 UG - Green

The Green/36.244 UG mission contained the Diffuse Interstellar Cloud Experiment (DICE) telescope. The DICE mission was designed to obtain high resolution far ultraviolet spectra of gas inside the local bubble. DICE sampled the interface at the local cavity wall and determined whether the gas at the interface was flowing into the cavity or away from it. The current hot bubble model assumed a conductive heating interface.

Payload being prepared for vibration testing in the T&E lab.

PI Website:http://casa.colorado.edu/Employees/faculty_summaries/green_j.shtml

36.254 NR - Cheatwood

Mission: 36.254 NR
PI: Dr. Neil Cheatwood
Institution: NASA LRC
Vehicle: Black Brant IX
Launch Site: Wallops Island, Virginia
Launch Date: August 17, 2009

The Inflatable Reentry Vehicle Experiment II (IRVE-II) was the first fully successful flight demonstration of a hypersonic inflatable aerodynamic decelerator. It was launched August 17, 2009, from Wallops Island, Virginia, on a Black Brant IX sounding rocket. The reentry vehicle was successfully released from the launch vehicle shroud, inflated to its full 3-meter diameter, and survived reentry as intended, providing critical flight data for validation of analysis and design techniques. All onboard instrumentation functioned as planned, transmitting temperature, pressure, and other flight performance data to the ground station. The vehicle maintained inflation through reentry and also into the transonic and subsonic flight regimes, demonstrating stable flight throughout entry and descent.

Future mission plans include several follow-on demonstration flights, with higher reentry heating to match levels expected for interplanetary reentry missions, and larger diameter inflatable decelerators.

Inflated IRVE.

Stowed IRVE on the spin/balance table at Wallops.

PI Website: http://www.nasa.gov/topics/aeronautics/features/irve.html

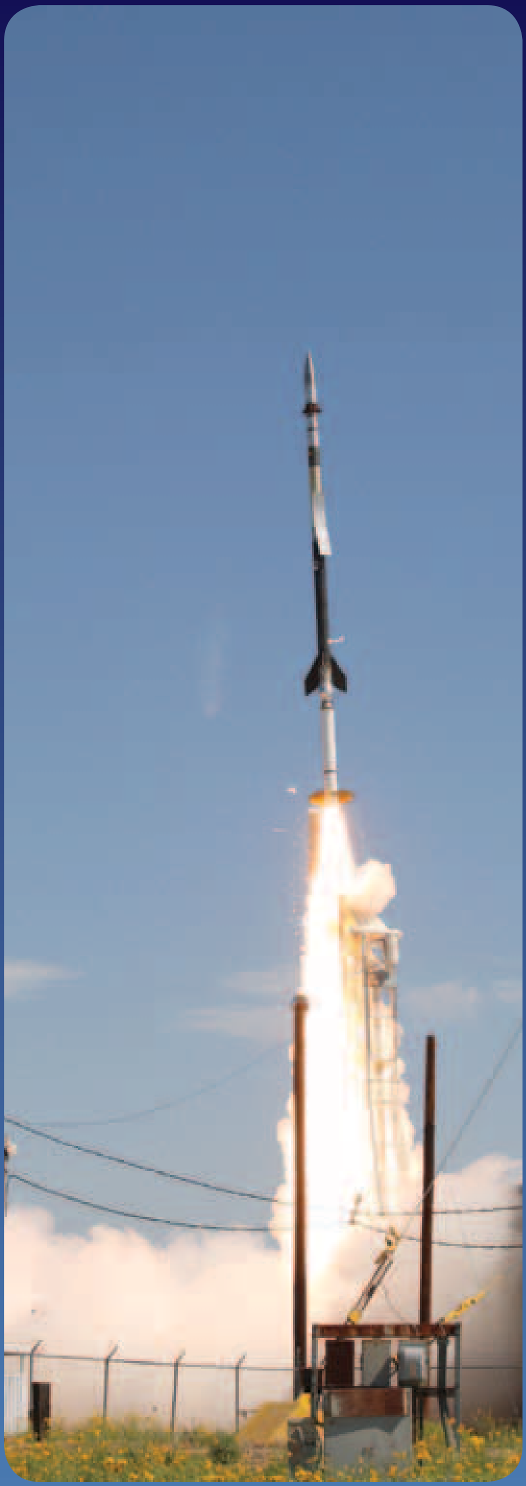
36.221 DS - Moses

Mission: 36.221 DS
PI: Dr. Dan Moses
Institution: Naval Research Laboratory
Vehicle: Black Brant IX
Launch Site: White Sands, New Mexico
Launch Date: September 14, 2009

The HERSCHEL (HElium Resonance Scatter in the Corona and HELiosphere) Suborbital Program is an international collaborative program between a consortium of Italian universities and observatories led by Dr. E. Antonucci (funded by the Italian Space Agency, ASI), the French Institut d'Astrophysique Spatiale, IAS (funded in part by Centre National d'Etudes Spatiales, French Space Agency), and the Solar Physics Branch of NRL (funded by NASA Sun Earth Connections and the Office of Naval Research). HERSCHEL investigated the slow and fast solar wind, determined the helium distribution and abundance in the corona, and tested solar wind acceleration models, all by obtaining simultaneous observations of the electron, proton and helium solar coronae. HERSCHEL also established proof-of-principle for the Ultra-Violet Coronagraph, which is in the European Space Agency Solar Orbiter Mission baseline.

HERSCHEL consists of the Sounding-rocket Coronagraphic Experiment (SCORE), and the HERSCHEL Extreme Ultraviolet Imaging Telescope (HEIT).

SCORE is the prototype of the coronagraph proposed for the Solar Orbiter mission. The test of SCORE in the suborbital flight is intended to prove multi-wavelength coronagraphy in view of space application.



36.221 DS lift-off from White Sands Missile Range, NM.

PI Website: http://wwwsolar.nrl.navy.mil/

Mission: 39.009 DR
PI: Dr. Paul Bernhardt
Institution: Naval Research Laboratory
Vehicle: Black Brant XI
Launch Site: Wallops Island, Virginia
Launch Date: September 19, 2009

39.009 DR - Bernhardt

The Charged Aerosol Release Experiment (CARE) was conducted by the Naval Research Laboratory (NRL) and the Department of Defense Space Test Program (DoD STP) using a NASA four-stage Black Brant XII suborbital sounding rocket. Using ground-based instruments and the STP/NRL STPSat-1 spacecraft, scientists studied an artificial noctilucent cloud formed by the exhaust particles of the rocket's fourth stage at about 173 miles altitude.

The Spatial Heterodyne IMager for MEsospheric Radicals (SHIMMER) instrument on the STPSat-1 spacecraft will track the CARE dust cloud for days or even months. The SHIMMER instrument has viewed natural noctilucent clouds for the past two years. The CARE will be the first space viewing of an artificial noctilucent cloud.

Data collected during the experiment provided insight into the formation, evolution, and properties of noctilucent clouds, which are typically observed naturally at high latitudes. In addition to the understanding of noctilucent clouds, scientists used the experiment to validate and develop simulation models that predict the distribution of dust particles from rocket motors in the upper atmosphere.

39.009 lift-off from Wallops Island, VA.

PI Website: http://wwwppd.nrl.navy.mil/

Upgrades

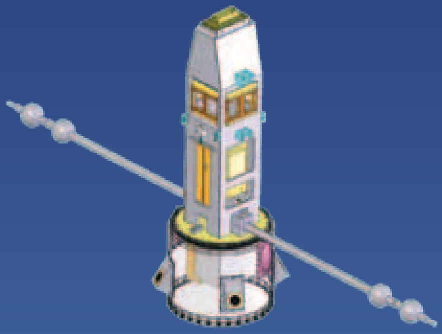
Mission Support

The NASA Sounding Rockets 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 led to streamlined processes and efficient design, manufacturing and assembly techniques. Management and technical support are provided for all facets of a mission and include engineering design, manufacturing, integration, and testing and evaluation. Periodic reviews are conducted to ensure mission requirements are being met on time and on budget.

Black Brant XII launch.

Launch Vehicles

The Sounding Rockets Program offers multiple proven launch vehicles to meet the needs of most researchers.



Solidworks model of payload.

Payload Design

All payload components, mechanical and electrical systems, telemetry, recovery and other subsystems are designed using state-of-the-art software, modeling and analysis tools. Three-dimensional (3-D) visualization tools facilitate the iterative design process by allowing flexibility in design updates and changes.

Manufacturing tools.

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 and processes to support the mechanical needs of the program.

Attitude Control System testing.

Subsystems

The Sounding Rockets Program provides standard subsystems such as recovery, attitude control systems, 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.

Testing and Evaluation

The launch and flight phases of a sounding rocket mission are violent and stressful events for the scientific payload. 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.

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. Temporary sites in Greenland, Marshall Islands, Puerto Rico and Brazil provide extensive access to phenomena of interest to the science community.

Mission Support Upgrades

Recent upgrades and new equipment in the machine shop include a HAAS 40-SL lathe with a maximum cutting length of 44 inches and 25.5-inch diameter. The lathe is equipped with live tooling, has a 7-inch bore and cuts at a maximum speed of 1,400 rpms. The tool probing feature allows quicker setup of jobs.

A fourth axis radial cutting feature has been added to the Leadwell V-40 vertical machine and is particularly useful for small parts.

The new OMAX Waterjet machine provides enhanced cutting capability and speed. Any material, except magnesium, up to 8-foot by 4-foot and 6 inches thick can be cut. All payloads have some parts made with the Waterjet. Additionally, the system cleans and recycles the water, leaving no waste.

The Mr Deburr vibratory finishing machine automates the deburring process.

Testing and Evaluation (T&E) Lab upgrades

Upgrades in the T&E lab equipment include a new vibration table, critical lift crane, and enhancements to the spin-balance test facility and mass properties measurement table.

Boom deployment testing.

Ready for launch in Norway.

HAAS 40-SL lathe

Tom Shockley with the deburring machine.

Technology

Rocket Boosted Sub-Payloads –
Dr. Marc Conde/University of Alaska, Fairbanks

The current standard way to measure thermospheric winds using a sounding rocket is to track the drift of rocket-released puffs of trimethyl aluminum (TMA) tracer gas. The TMA technique's accuracy and small measurement volume have spawned a number of missions that have attempted to measure wind gradients by using multiple rockets to release TMA puffs or trails at several different geographic locations.

Jeff Kaine with a Conde sub-payload and rocket motor.

A new technique to measure these wind gradients is under development by Dr. Marc Conde at the University of Alaska. This new method will deploy a constellation of TMA puffs from a single sounding rocket. The constellation deploys four puffs at each of at least 8 heights in the range of 120 km to 180 km altitude. The four puffs at each height are deployed in a square measuring approximately 100 km along each diagonal. Each puff is created by explosively shattering an ampule of 300 ml of liquid TMA carried in a sub-payload. To disperse the puffs throughout the required atmospheric volume, each ampule would be detonated by an autonomous sub-payload, ejected from the parent vehicle as it passed upward through 100 km altitude.

The objective of the first flight, scheduled for early 2010, is to deploy and detonate the sub-payloads along the single arc that is defined by the trajectory of one parent rocket vehicle, and to evaluate their ability to operate independently. Two ejection systems, mechanical springs and small rocket motors, are used to deploy the sub-payloads.

Flight Termination System (FTS)

NSROC is in the process of updating the FTS to be compliant with current range safety requirements. This task has been broken into three subtasks such that new FTS components can be integrated in three phases.

Hybrid I:

Continue to fly the Bristol Igniter Housing/FTS with a new receiver (Herley HFTR-60), NSROC manufactured control module (Circuit Card Assembly, CCA), and associated interface cables. These new components have been environmentally qualified to levels well in excess of flight levels per range safety requirements. Hybrid I is complete and the first flight of the Hybrid I system will be 36.252/Cash.

Hybrid II:

Replace the Bristol Igniter Housing with a NSROC manufactured ignition system, FTS, and skin. The FTS in this housing will meet Range Safety's redundancy requirements. For this update, the antenna system, batteries, and associated wiring harnesses will be environmentally qualified. Additionally, in order to meet Range Safety's FTS monitoring requirements without adding additional wiring to existing payloads, a multiplexing system will be added to the igniter housing. Furthermore, in the interest of minimizing the size and weight of the Hybrid II igniter housing, NSROC is investigating the use of a miniaturized capacitive discharge ignition system. The Hybrid II system will use the heritage ordnance package which consists of a SAFE/ARM, manifold, shape charges, and flexible confined detonating cords (FCDCs).

Flight Termination Systems are used on all launches from White Sands Missile Range, NM.

Final System: Replace the heritage SAFE/ARM, manifold, and FCDCs with a remotely controlled SAFE/ARM device and replacement FCDCs. Heritage shape charges will continue to be used.

Sub-TEC Program

The Sub-TEC technology initiative serves to improve technical capabilities of the Sounding Rockets Program and other users by providing a standardized carrier platform to flight demonstrate new technologies. Sub-TEC missions provide opportunities for multiple experiments and organizations to share the cost of a flight.

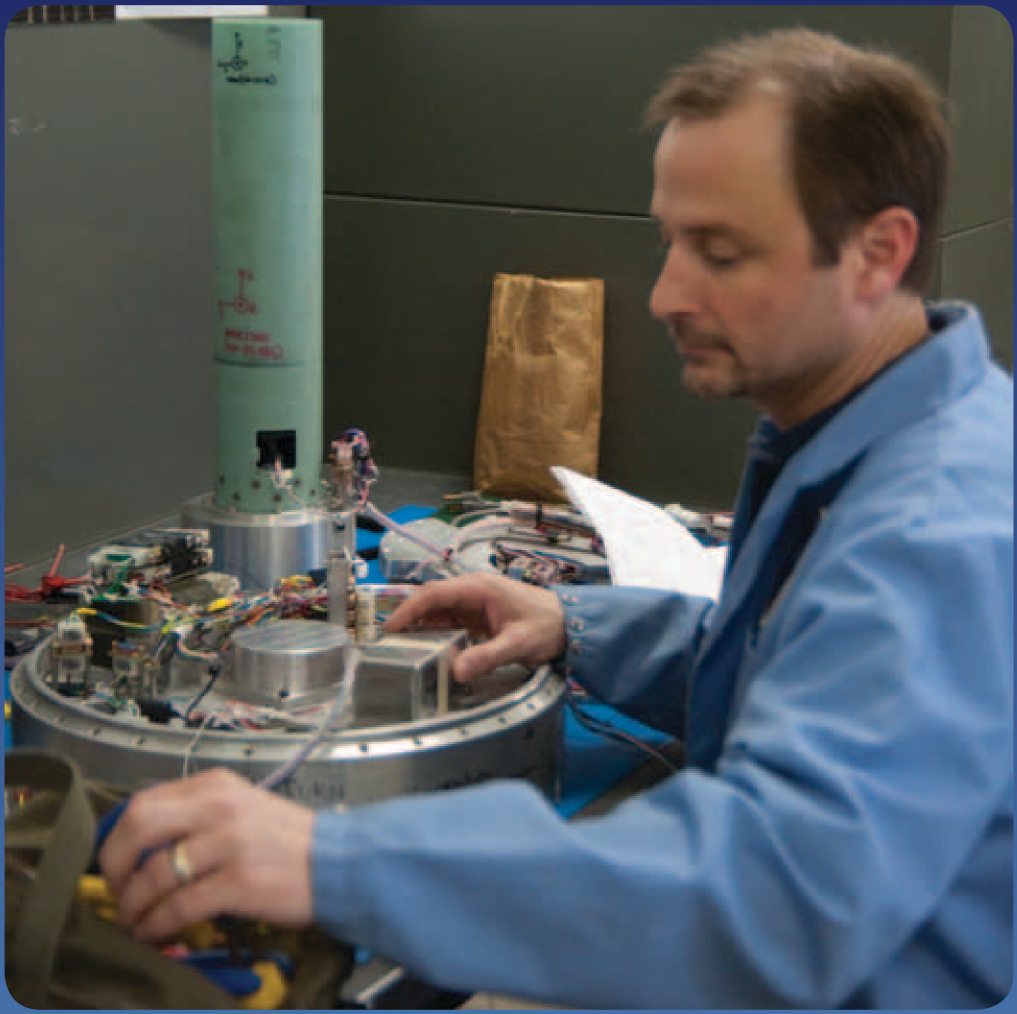
Sub-TEC III – Bull 41.082, scheduled for flight in 2010, carries the Autonomous Flight Safety System (AFSS) as the primary experiment. The AFSS is a non-traditional FTS. It is designed to replace the traditional ground command destruct systems and uses rules-based decision software and onboard sensors to terminate a flight autonomously.

Greg Waters and Bob Ray preparing the AFSS for vibration testing.

The AFSS project, a cooperative effort by Kennedy Space Center (KSC) and Goddard Space Flight Center (GSFC), will use GPS, modern Inertial Measurement Units (IMUs), and flight processors to monitor the progress of the launch vehicle with respect to multiple flight termination criteria and, if necessary, terminate the flight without relying on ground-based assets. In cooperation with the US Air Force and Defense Advanced Research Projects Agency (DARPA), the two Centers have worked together with limited budgets to develop complex algorithms, encode them in software, and deploy them on flight computers. Two successful launches of pathfinder systems (not connected to ordnance) have aroused great interest and support within

NASA and among potential users and collaborators in both the government and commercial space sectors. Test Article #3 is the third test prototype system of the overall AFSS program. It will be flown on a Terrier – Improved Orion sounding rocket at Wallops in FY10.

The project goal is to develop an autonomous expendable launch vehicle (ELV) termination system built around four test prototypes and incorporating heritage documented and undocumented range requirements. Additional requirements are being analyzed (for example, in software) to mitigate risks with a rules-based approach.



Dave Jennings working on the NSROC Sub-TEC experiments.

Other experiments on this mission include:

FAA Science Team -- ADS-B (Automatic Dependent Surveillance – Broadcast)
The ADS-B aids in air traffic control, improves aircraft-to-aircraft interaction, and it enhances pilot visual acquisition of approaching aircraft.

NSROC Experiments

- TM Gyro II, Miltech MINI IMU
- RTAS (Real Time Attitude Solution) – provides attitude solution in real time combining the solar sensor, magnetometer, Horizon Crossing Indicator (HCI), and angular rate sensor data.
- 2-WFF93 Command Uplink Receivers

- Lithium Ion Batteries/Opto-isolators
- FTS CCA (Circuit Card Assembly)
- PCB Piezotronics Vibrometer System
- JAVAD-100, Anti-vibration GPS Receiver (JAGR)

Sub-TEC IV – Hall 41.089, scheduled for flight in 2010, carries two primary experiments: high data rate telemetry and Small Rocket/Spacecraft Technology (SMART).

High Data Rate Module experiment is designed to accomplish the following:

- Push the envelope on both data rate transmission and data recording to the maximum feasible rates given current cost effective technical solutions, i.e. provide a telemetry system capable of transmitting ~400 Mbps data to the ground using existing X-band ground stations.
- System development will include the requirement to support direct downlink capability through existing telemetry stations for Geospace science missions.
- System development will include the requirement to support Astrophysics and/or Solar missions with high data rate onboard recording where utilization of high data rate telemetry systems are not feasible.

SMART contains basic components of a spacecraft prototype, including avionics, primary battery, optical sensors, thermal, pressure, inertial, and GPS-based position sensors. The main operational requirement for SMART is to be able to collect, record, and transmit subsystem (avionics primarily) performance data, including camera and sensor information. The system is based on the flight- ready SpaceCube avionics. SpaceCube is a reconfigurable, high-performance system designed for spaceflight applications requiring on-board processing. Space Cube, developed by engineers at the NASA Goddard Space Flight Center, is a next-generation command and data handling system.

High Data Rate Telemetry

Increased telemetry rates have the potential to enable significant advances in a number of experiment areas, including the detection of multiple component high frequency plasma waves, high speed auroral imaging, and high resolution spectrometry. The X-band downlink, currently under development, will lead to unprecedented data rates of 150 Mbps. This is over 10 times the traditional sounding rocket rate and well over what is provided by S-band telemetry systems.

The Correlations of High Frequencies and Auroral Roar Measurements (CHARM) II mission, with Principal Investigator Dr. James LaBelle, will be the first mission to test the new downlink.

Steve Bundick with the X-band telemetry system for CHARM II.

The X-band system on CHARM II will demonstrate a high rate 150 Mbps downlink using the X-band spectrum. The CHARM-II experiment baseband analog signal will be digitized at 10-M samples per second by a data encoder built by NSROC. The encoder formats the data samples into a telemetry frame. The telemetry frames are then clocked into an X-band modulator at a rate of 150 Mbps. The modulator unit (LCT2) was built by Wallops Applied Engineering and Technology Directorate (AETD), and outputs a SQPSK modulated signal at 8212 Megahertz (MHz). The low power output of the modulator is amplified to 30 watts (W) using a solid state amplifier provided by Aethercomm, Inc. The 30-W radio frequency (RF) signal is then routed to a Haigh-Farr 17.25-inch wraparound antenna and transmitted to the ground. Eleven-meter ground antennas at Poker Flat capable of receiving X-band frequencies will provide the gain needed to support the high rate downlink. X-band frequencies will provide the gain needed to support the high rate downlink.

Education

RockOn! and RockSat

Fifty-seven students and faculty, in 19 teams from universities around the country participated in the 2009 RockOn! flight opportunity. Arranged jointly by the Colorado and Virginia Space Flight Consortia and supported by the NASA Space Grant Program and NASA Sounding Rockets Program Office, RockOn! is a hands-on workshop teaching participants how to create a spaceflight experiment, program a flight computer, collect and analyze data, and participate in a launch of a Terrier-Orion two-stage sounding rocket.

RockOn! workshop participants with their experiment canisters.

In 2009, ten universities were selected to fly experiments of their own design by participating in the RockSat portion of the program. The RockSat program allows the previous year's workshop participants to apply their newly acquired knowledge to design, build, and fly a sounding rocket payload in less than one year's time.

RockOn! Workshop

The weeklong workshop started with an introduction to the program on June 21, 2009, by Chris Koehler, Director Colorado Space Grant Consortium and Mary Sandy, Director Virginia Space Grant Consortium. On the first day of instruction, the faculty/student teams were handed the experiment kits developed by the Colorado Space Grant Consortium. Each kit included all components required to build a space flight experiment: AVR microprocessor, accelerometer, pressure sensor, Geiger counter, and temperature sensor. The teams completed construction, programming and integration of the experiment by the third day of the workshop.

Students learned everything from soldering electronic components and mechanical assembly to writing code in C for the AVR microprocessor. The instructor, Chris Koehler, explained each step fully, and a team of student experts were available to help the teams complete the various steps in each project. The process was very systematic and ensured that all teams completed each step before proceeding.

The faculty/student team from Northwest Nazarene University, Idaho, led by Lawrence Miles, were first time participants in the RockOn! workshop. The team is actively involved with the Idaho Space Grant Consortium and has launched BalloonSats in the past. They plan to incorporate their RockOn! spaceflight experiment into future BalloonSat launches.

Peter Plumley, faculty member from Syracuse University, New York, was here for the second time. Last year he attended as part of a faculty team, and this year he brought along a student, Aaron Orbaker. Aaron appreciated the value of hands-on experience, particularly when added to a solid theoretical foundation.

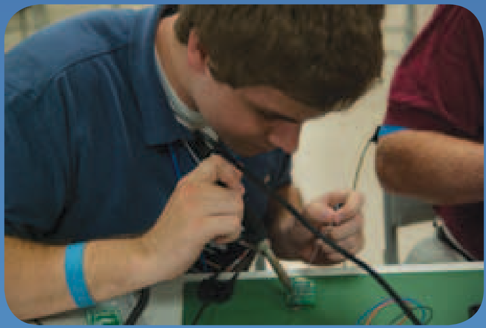
Jahnieka Griffin, a physics major and freshman from Hampton University in Virginia, is exploring her career options. “This workshop gives me an opportunity to explore space and spaceflight related careers,” she said, while inspecting the experiment board with her teammate Jayrik Hayes. Jayrik, a senior, also from Hampton University, will focus on Aerospace Engineering next year and is graduating in May 2010. “This is an awesome hands-on workshop and an invaluable learning experience,” Jayrik said enthusiastically.

Nazarene University team.

Syracuse University team with Chris Koehler/Colorado Space Grant.

Hampton University team.

Experiment stack assembly.



Soldering components.

At 4:00 a.m. on launch day, June 26th, the teams left their hotel on Chincoteague to arrive at Wallops Island in time for the 5:30 a.m. launch window opening. For most of the participants, this was their first sounding rocket launch, and they were clearly excited, as were the Wallops staff members out on the Island watching the launch. At T-10 seconds the audience helped with countdown, and at exactly 5:30 a.m. the Terrier-Orion rocket lifted off; the RockOn! and RockSat experiments were on their way to space. The rocket reached an altitude of 117 km and the payload started its descent. A parachute slowed the descent and softened the impact. Sealed sections kept the payload afloat in the ocean until a recovery boat picked it up.

41.083 launch.

When the payload was back at Wallops Flight Facility, approximately 4 hours after launch, the experiments were returned to the teams and the data analysis began. By the end of the day it was clear that all experiments worked as planned and all teams successfully downloaded their data.

Team members with their RockSat experiment.

RockSat

The RockSat flight opportunity provided educational institutions an option to fly experiments of their own design to space on board a NASA two-stage sounding rocket. The RockSat payload canister gave customers a design envelope to build around that allowed easy integration to a NASA sounding rocket. This standardized approach provided customers low cost access to space. To participate in RockSat, teams of students and faculty submitted proposals for review by the Space Grant Consortium and the NASA Sounding Rockets Program. The proposals were evaluated for compatibility with standard sounding rocket hardware and interfaces, and the payload had to fit in a standard RockSat canister. Teams could choose to collaborate and share space in one canister.

Team posing with full stack of RockSat experiments.

In 2009, the first four RockSat canisters, with 10 experiments, flew as part of the 41.083 Koehler mission.

The University of Puerto Rico team flew an experiment to collect and analyze gases and microorganisms in the near space environment. The students designed the experiment to collect samples of air at altitude and analyze gas composition and the presence of microorganisms.

The AirCore experiment from the University of Colorado was a collaborative effort with the National Oceanic and Atmospheric Administration (NOAA). The primary objective was to validate an AirCore sample with emphasis above 22 km to determine the change in the concentration of carbon dioxide and methane in the upper atmosphere in order to create an atmospheric profile.

AirCore canister integration.

The University of North Dakota's experiment was designed to investigate the capability of in-situ measurements of the concentrations of hydrogen (H2), oxygen (O2), methane (CH4) and ozone (O3) in the mesosphere.

Metro State College of Denver provided an experiment to gather data about the flight vehicle and recreate its behavior.

Team with RockSat canister.

Colorado State University's experiment objective was to develop a sounding rocket payload to act as a power bus, data logger, and mounting structure for future scientific payloads.

The University of Wyoming had two experiments: the Space Cowboys payload, which was designed to accurately measure internal canister environmental parameters; and the Good Vibrations payload, which investigated oscillator response under specific parameters unique to aerospace applications.

RockSat post-flight inspection.

The University of Minnesota with the MinnRock payload wanted to characterize the payload environment, measure the change in the Earth's magnetic field over the course of the flight, and sample GPS data throughout the flight.

Penn State University Mont Alto investigated mechanical stresses in an elastic deck plate simulating a sounding rocket payload section. Flight dynamic loads on a dummy mass attached to the center of the deck plate caused the deck plate to deflect; strain gauges measured deformation.

RockSat post-flight inspection

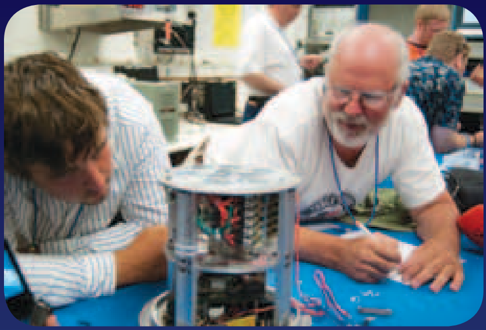
Boston University compared performance of Honeywell magneto-resistive and Aichi magneto-inductive magnetic sensors, and captured rocket dynamics via data analysis of fields. Students gained experience in electrical/mechanical design.

Virginia Tech flight-tested multiple sensors that will measure environmental conditions inside the canister, and studied the flight characteristics of the rocket. Students focused on gaining experience in electronics and sensor measurement.

A detailed RockSat Users Guide is available for download from the Colorado Space Grant Consortium website.

To find out more about this flight opportunity visit the Colorado Space Grant Consortium on the web at:
http://spacegrant.colorado.edu/rockon/
or the
Virginia Space Grant Consortium at: http://www.vsgc.odu.edu/

For information about the Space Grant program visit:
http://www.nasa.gov/offices/education/programs/national/spacegrant/home/index .html


RockSat post-flight inspection.


RockSat post-flight inspection.

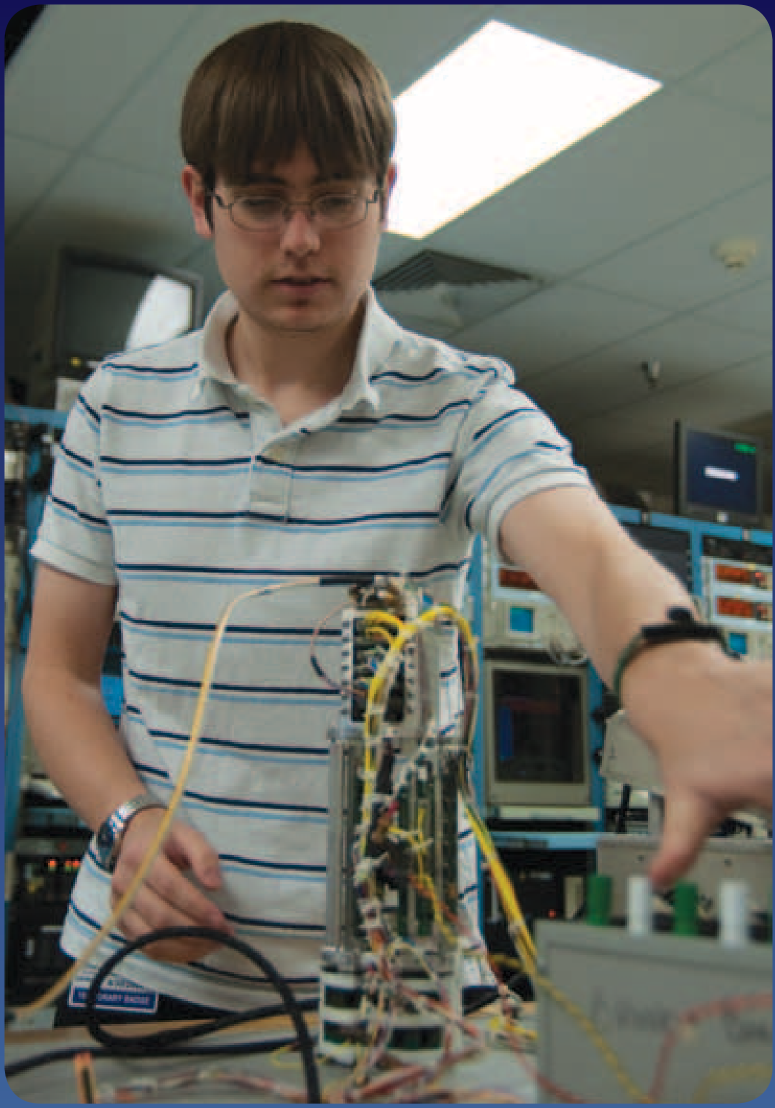

Colorado Space Grant team after the launch on Wallops Island.

Internship Program

Over 120 students have participated in the internship program managed for the Sounding Rockets Program Office by NSROC. The program, now in its 11th year, provides internships and co-op opportunities for students studying engineering, computer science and electrical or mechanical technology.

Students work side-by-side with experienced engineers and perform significant, valuable engineering tasks, leading to a better understanding of engineering, better grades and solid experience in a business environment.

Almost 90 percent of undergraduate students who intern or participate in the co-op program return for additional employment prior to graduation. Participants in the program have gone on to pursue higher education and careers in the engineering and science fields; three participants have doctorate degrees, 18 have or are pursuing master's degrees, and 14 are full-time employees in the Sounding Rockets Program.



NSROC intern with Mesquito avionics.

Hands-On Project Experience (HOPE)

In December 2008, NASA released the Hands-On Project Experience (HOPE) Training Opportunity (TO) to solicit NASA Center proposals to develop an in-house payload to be launched on a sounding rocket. The short mission completion times and many existing subsystems, such as telemetry, recovery, and attitude control, make sounding rockets an optimal carrier vehicle option for the first HOPE payload.

NSROC intern learning to balance payloads.

One goal of the TO is to provide hands-on flight project experience to enhance the technical, leadership and project skills for the selected NASA in-house project team. This opportunity includes experience in proposal development, and upon selection, development of a scientific investigation, payload integration and testing, integration of the payload with the launch vehicle, conducting flight operations (including data collection and analysis), and project management.

The first HOPE project selected for flight is the Terrain Relative Navigation and Employee Development (TRaiNED), Jet Propulsion Laboratory's response to the request for proposals. The TRaiNED project will advance Terrain-Relative Navigation (TRN) technology by collecting a set of correlated ground imagery, IMU and GPS data during a sounding rocket flight, and performing post-flight data analysis.

The project is based on the same design as a previously flown sounding rocket mission, 41.068. Modifications will be made only where necessary to meet the additional science objective of recording exo-atmospheric imagery and to improve the quality of the data set. The project team is comprised of early career hires supported by mentors who were part of the 41.068 team.

Employee Highlight - Dustin Herold, Vehicle Systems Group

Whereare you from?
I was born in Montrose, Colorado but grew up in Grand Junction, Colorado

How did you become interested in aerospace?
When I was five years old, my father brought home an Estes Rocket kit as a surprise for all the work I had been doing around the property. I was very excited because my uncle had been working for NASA and as a little kid I thought this was amazing and now I have my very own rocket! My father helped me put it together and we took it out and launched it. The parachute did not deploy correctly and it came down and broke. This upset me, so I saved my money and bought another kit. This cycle continued throughout the years until eventually I was launching rockets off of homemade propellant.

Dustin with the Improved Malemute motor (inert).

After I graduated high school I felt a call to serve my country so I enlisted in the USAF in 2001. I became a communications and survival expert where I spent most of my off time dreaming about rocketry and trying to figure out how to get back on the path toward my childhood dream. Four years and two children later, I was at work aggressing some students when a call from my commander came over the radio for me to immediately report to his office. As you can imagine I was very worried, trying to figure out what I had done wrong. When I got to his office and reported in, he began to give me a hard time asking me why I wanted to leave his unit and handed me my assignment to the Air Force Academy in Colorado Springs. I was so excited! Not only was I going back home, but the assignment was as Non Commissioned Officer in Charge of Rocket Research! I could not believe it and I can honestly say that this was one of the greatest moments in my life.

What rocket projects did you work on at the Air Force Academy?
The Air Force Academy lives by "learning space by doing space" and as we all know that is a lot to encompass. I worked on many projects to include liquid, hybrid, and solid rocket motors and topped it off with a sprinkling of small satellite research and development. My favorite project was the Falcon Launch Program where students got the chance to build a sounding rocket with DoD payloads and launch it once a year.


Computer design and analysis work.

In the spring of 2009, we built a rocket which closely resembled the Super Loki dart. We had a scientific payload called a fin tab that was designed to study, through telemetry, the effects of aeronautical loading on fins through Mach transition periods. The booster, designed to separate from the dart at 11,500 feet, worked perfectly, hurling the dart at Mach 7 to an altitude of 354,000 feet. This became the first intercollegiate rocket to ever make it to space.

Any recommendations for students considering aerospace as a career option?
Nothing can beat hard work and the belief in yourself that you can achieve. Aerospace is not a career that is by any means monotonous, and it takes incredible teamwork to accomplish what we do every day. With that said, a great mentor can give you the tools to achieve your goals and direct you on the right path. I would not be where I am today without the mentorship I was given.

Extension

Sounding Rockets Program as a National Resource

While remaining focused on aiding scientific exploration, the Sounding Rockets Program extends assistance to other government entities, such as the US Air Force, the Naval Research Laboratory, Missile Defense Agency, and others requiring launch vehicles, manufacturing, testing and launch support services.

Payload manufacturing, testing, launch vehicles and launch services are provided to the US Air Force for the AirBorne Laser (ABL) program. The primary objective of these launches is to provide a diagnostic target for the AirBorne Laser aircraft. NSROC staff are supporting launch operations on San Nicholas Island, California, for the six launches currently scheduled.

Reimbursable missions for NRL and MDA have included testing of new sensor technologies and the creation of artificial noctilucent clouds. Additionally, infrasound research is conducted by the Naval Air Warfare Center (NAWC) using single stage Orion sounding rockets.

Exploration Support - Max Launch Abort System (MLAS)

NASA's next generation of spacecraft will have the safest astronaut escape system, a modern-day version of the reliable Apollo system. Like Apollo, the Orion launch abort system will swiftly propel the crew capsule away from the nose of the Ares I rocket and out of harm's way in case of an emergency on the launch pad or during ascent to orbit.

The unpiloted test was part of an assessment by the NASA Engineering and Safety Center (NESC) of a potential alternate launch abort system concept which could be used for future piloted spacecraft.

MARTI payload on balancing table.

The MLAS demonstration vehicle consists of a full-scale composite fairing, a full-scale crew module simulator, and four solid rocket abort motors mounted in the boost skirt with motor mass simulators in the forward fairing.

SRPO provided critical assistance to the MLAS project, including the four Terrier solid rocket motors used to launch the capsule, some mechanical design and fabrication services, as well as component level environmental testing.

Hypersonics – Inflatable Reentry Vehicle Experiment (IRVE)
IRVE was designed to demonstrate that an inflatable structure can be used as a heat shield to safely slow a spacecraft moving at hypersonic speed (greater than Mach 5, or five times the speed of sound) through a planet's atmosphere. Inflatable heat shields may hold promise for future planetary missions.

MLAS team photo.

The purpose of a heat shield is to prevent a spacecraft from being damaged by high temperatures as it decelerates through a planet's atmosphere. The larger the total surface area of the heat shield, the greater the drag force generated. This increased drag can be used to deliver more mass to a given altitude or surface elevation, or a given mass to a higher altitude or surface elevation.

IRVE allows researchers to test a subscale model of a compact inflatable heat shield with the help of a two-stage Black Brant IX rocket. For the ascent, the 1,400-pound IRVE is packed into a single column and stowed within the 22-inch diameter payload section of the rocket. After apogee, during the downleg of the trajectory, IRVE is deployed from the payload section and begins the experiment phase of the flight.


IRVE in the Testing and Evaluation Lab.

Sounding rockets are a cost effective alternative for reentry testing experiments where hypersonic speeds are required. Exo-atmospheric altitudes are achievable with many vehicle configurations. Additionally, support systems, such as telemetry and deployment mechanisms, can be readily customized to facilitate the needs of the experiment.

Hypersonics - Sub-Orbital Aerodynamic Reentry Experiments (SOAREX)

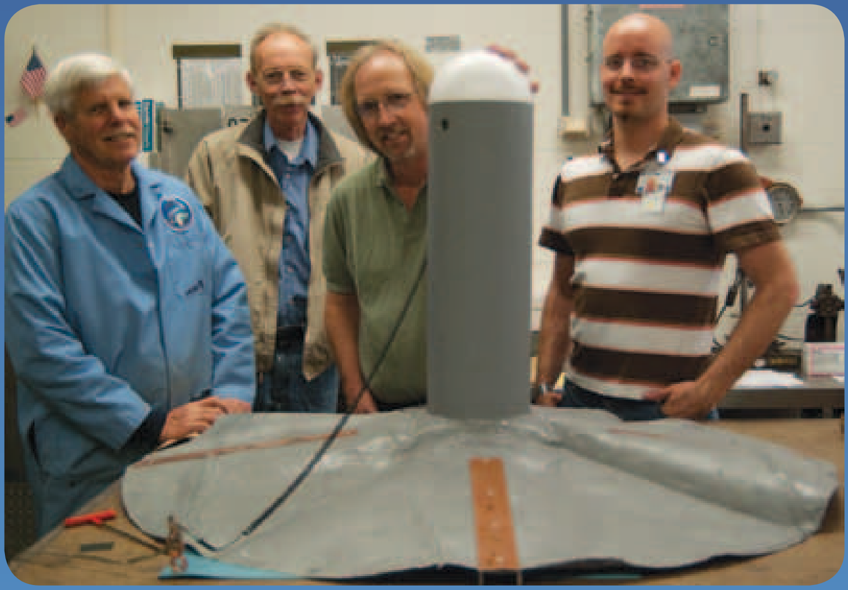
The Slotted Compression Ramp, or SCRAMP, is a unique design concept situating the payload in front of the heat shield. The concept originated with the SOAREX Project. SOAREX is a multi-year hypersonic flight test development project at NASA's Ames Research Center at Moffett Field, California. These experiments have a launch history beginning with a comprehensive success of SOAREX I, launched from White Sands Missile Range in 1998.


Classic SCRAMP.

The classic SCRAMP probe, flown in SOAREX I, IV and VI missions, is analogous in design to a badminton birdie, with a slotted flare skirt attached to a spherical or blunt-nosed cylinder. This serves to push the center of gravity forward, providing nose-forward stability. The diameter of the flare skirt is larger than the diameter of the cylinder nose. During reentry, both the flare skirt and the cylinder nose will produce shock waves. The bow wave produced by the cylinder nose will collide with a larger, stronger wave produced by the flare skirt. A slot around the inner circumference of the skirt will permit the thin layer of air next to the vehicle, the boundary layer, to be swallowed, leading to the interaction between the shock waves. This interaction and resulting redirection of energy creates sufficient drag to slow down and stabilize the vehicle during reentry.


TDRV skirt with Ed White (left) and PI Marc Murbach (right).

The Tube-Deployed Reentry Vehicle (TDRV) flown on SOAREX VII, Murbach 41.080, is somewhat different in design to the classic SCRAMP. While the design still uses a blunt-nosed cylinder with a flare skirt, there is no slot between the body and the skirt. The flare in the TDRV


TDRV team from left: Ed White, Herb Morgan, PI Marc Murbach and Bruce White.

is made of a combination of high-temperature flexible materials, some of which were developed during the Shuttle program. Higher temperature material combinations have been identified and would be included during proposed orbital reentry tests. Instrumentation on the TDRV included pressure sensors, radiometers, thermocouples, rate gyros, accelerometers, and a video camera.

Preliminary analyses of the data showed the probe quickly orienting nose-down after deployment, validating the predicted stability and the high drag coefficient. Sounding rockets, with short design and fabrication lead times and performance envelopes that can be tailored to mission requirements, are ideal launch vehicles for hypersonics experiments, decelerators and reentry experiments.

Future

On the Horizon

The SRPO is attempting to restart mobile operations, a historical hallmark of the program, in the next few years. Proposals have been submitted to NASA Headquarters to conduct research missions from Kwajalein Atoll, and we are awaiting word to see if they are successful. SRPO and NSROC employees are also investigating the possibility of a return to Woomera, Australia, with the added capability of launching Black Brant XIs. While these exciting new possibilities are currently in the planning stages, the campaigns would not likely begin before the 2012-2013 timeframe.

Ready for launch in Kwajalein 2004.

CubeSat Launches on Sounding Rockets

Two university CubeSats will be flown on mission 12.067 GT, the first test flight of a Terrier Improved Malemute vehicle. The University of Kentucky and California Polytechnic State University (Cal Poly) are supplying the CubeSats, 10 cm cubical experiments with a mass of up to 1 kilogram.

The Sub Orbital Cubesat Experimental Mission (SOCEM) includes University of Kentucky's Antenna Deployment and Monofilament Actuator Satellite (ADAMASat), consisting of a nichrome and monofilament actuator experiment. Cal Poly is also providing the Poly CubeSat Launcher (PCL), which is a stripped down Poly Picosatellite Orbital Deployer or P-POD. A skin door is deployed allowing the CubeSats to be ejected from the sounding rocket payload.

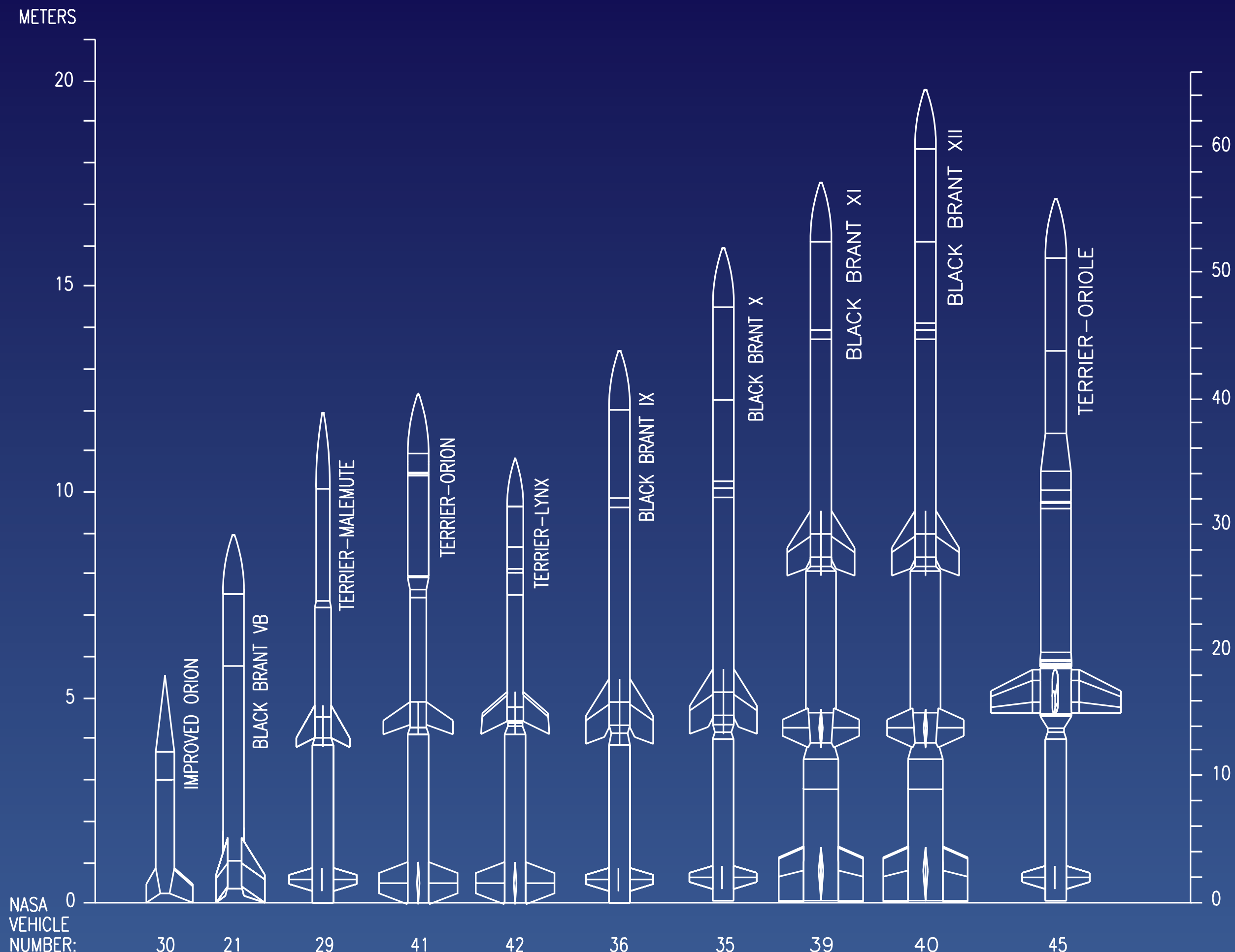
University of Kentucky student with CubeSat.

NSROC II Procurement Activities

Awarded in December 1998 with an original expiration date of January 31, 2009, the NSROC was tasked to integrate teams of engineers, technicians, managers and administrative staff with responsibility for all sounding rocket operations at Wallops Flight Facility, Wallops Island, Virginia. Approximately 170 people support the Sounding Rockets Program through this contract.

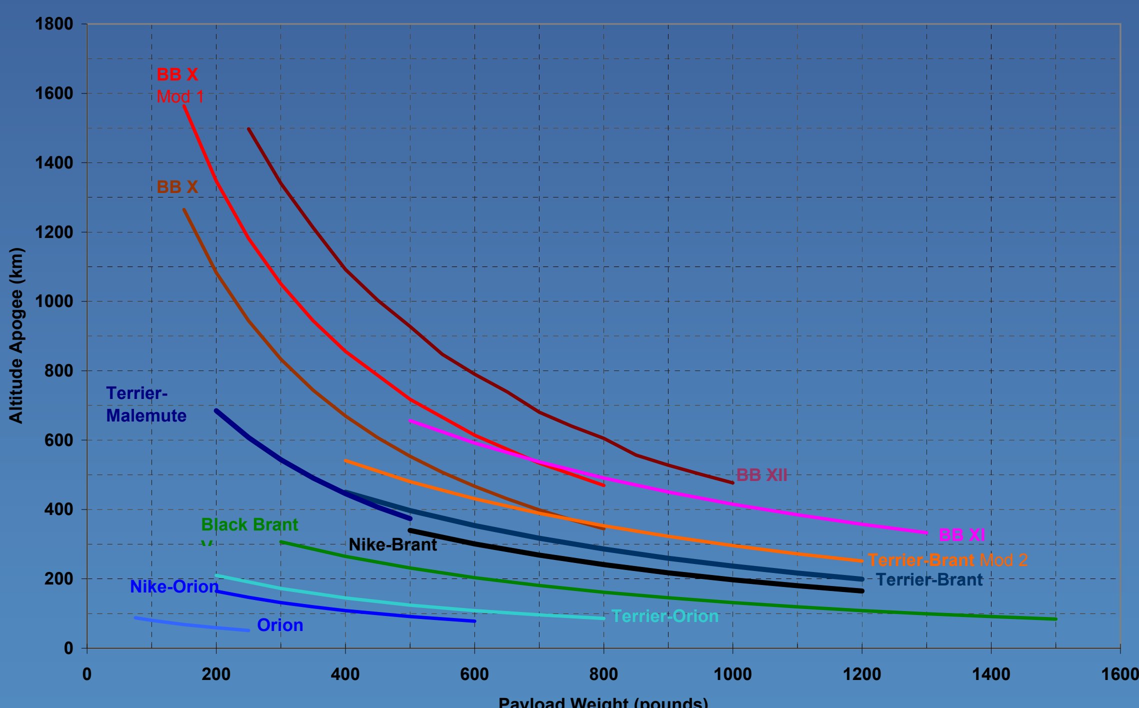
The NSROC Request for Proposals was released in the Spring of 2009 with a submission deadline in the Fall of 2009.The NASA Source Evaluation Board is evaluating the proposals and will make a recommendation in 2010.

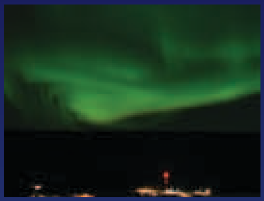
Statistics



Ten vehicles ranging from a single stage Orion to a four stage Black Brant XII make up the core of the Sounding Rockets Program. New vehicles, the MLRS–Dart and Terrier–Improved Malemute will be added in the near future. Above: relative scale of the currently available vehicles. Below: Vehicle performance altitude vs. payload weight.

Sounding Rocket Vehicle Performance





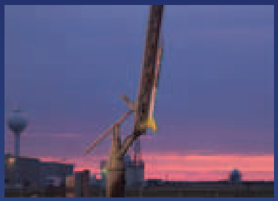
Poker Flat, Alaska

Esrange, Sweden

Kwajalein, Marshall Is.

Andoya, Norway

Woomera, Australia

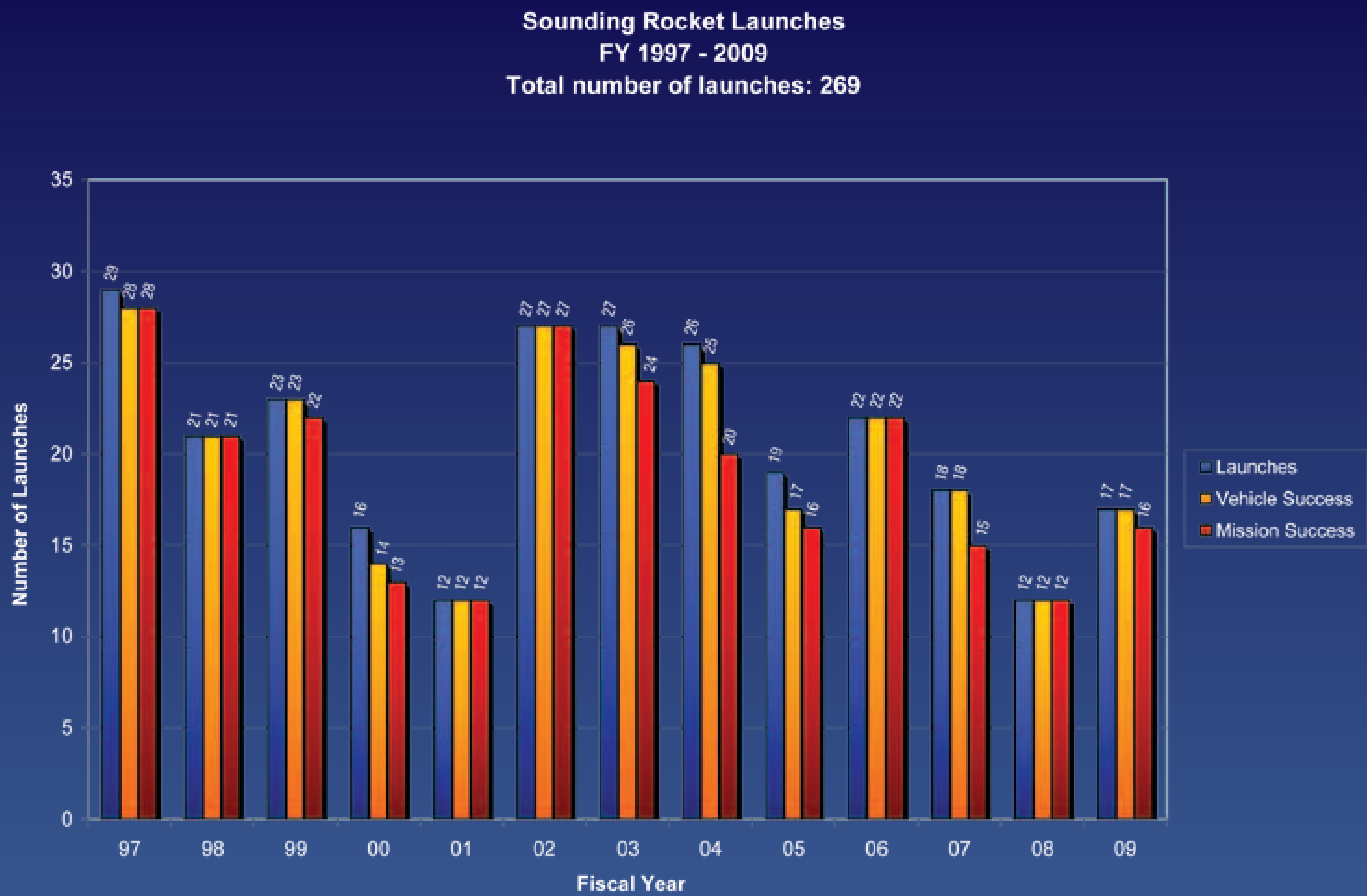


Wallops Island, VA

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

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

* Inactive launch sites



Sounding Rocket Launches
FY 1997 - 2009
Total number of launches: 269
Number of Launches
Fiscal Year
Launches
Vehicle Success
Mission Success
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02
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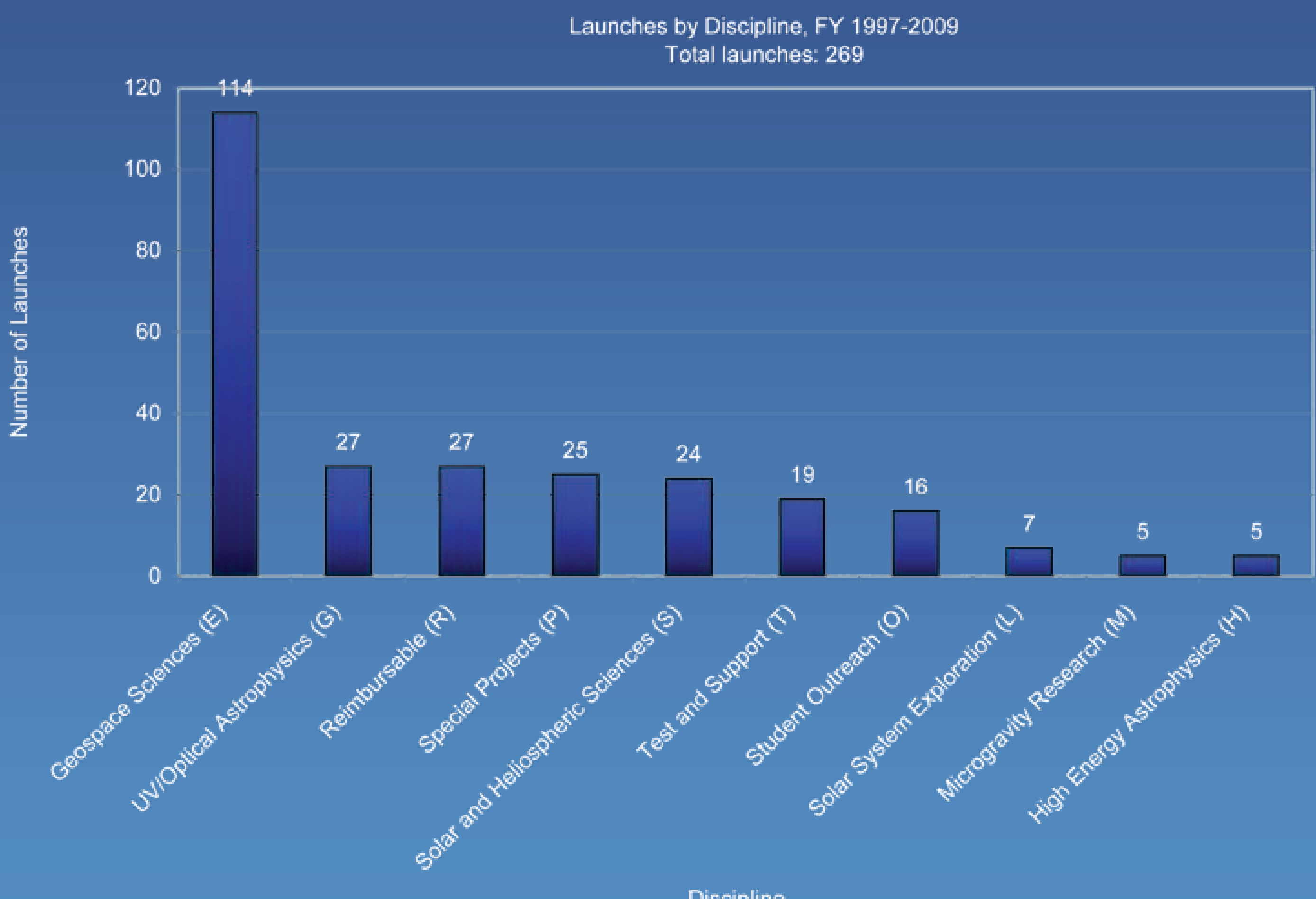

Launches by Discipline, FY 1997-2009
Total launches: 269
Number of Launches
Discipline
Geospace Sciences (E)
UV/Optical Astrophysics (G)
Reimbursable (R)
Special Projects (P)
Solar and Heliospheric Sciences (S)
Test and Support (T)
Student Outreach (O)
Solar System Exploration (L)
Microgravity Research (M)
High Energy Astrophysics (H)
114
27
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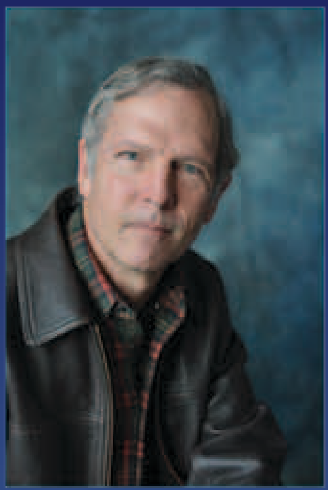

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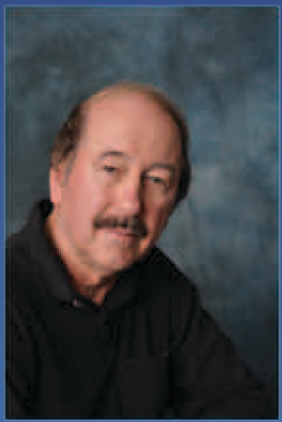
Assistant Chief



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36.226 UG Design Review Data Package, Dr. Jamie Bock/Caltech

40.023 UE Dartmouth College CASCADES website

41.083 NO Information provided by University of Colorado

41.075 NP Design Review Data Package

36.244 DR Design Review Data Package

36.221 DS Design Review Data Package

41.080 NR Information provided by Marc Murbach

36.254 NR Information provided by Dr. Neil Cheatwood

39.009 DR Information from NASA Wallops Flight Facility website

Intern information provided by Jan Jackson/NSROC

Flight Termination System information provided by Dave Burkhead/NSROC

X-band transmitter information provided by Steve Bundick/NASA

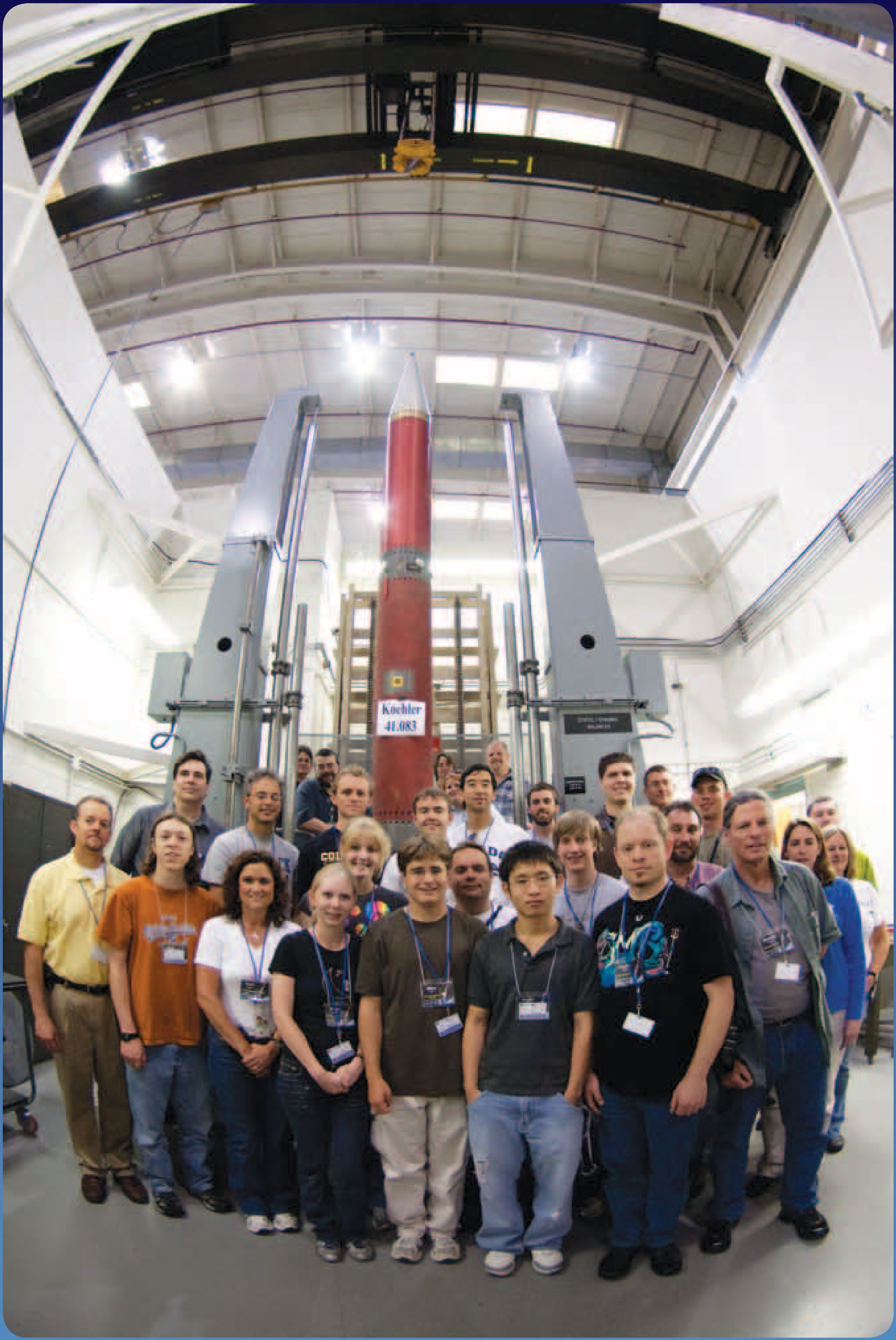
Credits

Cover launch photo and IRVE inflated photo (insert) by Sean Smith/NASA Langley Research Center

Photos by Berit Bland/BBCO except as noted.

Page 5 - IRVE launch photo by Sean Smith/NASA Langley Research Center
Page 7 - Aurora photo by Kohlbjorn Dahle/Andoya Rocket Range, Sun by SOHO, and astronmy image by Spitzer Space Telescope NASA/JPL-Caltech/Max-Planck Institute/P. Appleton (SSC/Caltech)
Page 10 - Photos by Visual Information Systems Branch/White Sands Missile Range
Page 11 - Launch photo by White Sands Missile Range (top) launch photo bottom Wallops Imaging Lab.
Page 12 - Photos by Visual Information Systems Branch/White Sands Missile Range
Page 13 - Launch photo by Wallops Imaging Lab
Page 14 - Payload photo with team members in Alaska by Scott Hesh/NSROC
Page 15 - Launch photo and TMA trail photo by Craig Heinselman
Page 21 - Photo of inflated IRVE by Sean Smith/NASA Langley
Page 22 - Photo by Visual Information Systems Branch/White Sands Missile Range
Page 23 - Launch photo by Wallops Imaging Lab
Page 25 - Launch photo by Wallops Imaging Lab
Page 26 - Ready for launch in Norway photo by Kohlbjorn Dahle
Page 29 - Photo by Visual Information Systems Branch/White Sands Missile Range
Page 37 - Launch photo by Wallops Imaging Lab
Page 44 & 47 - Rendering of SCRAMP provided by Marc Murbach
Page 49 & 50 - Rocket on the pad in Kwajalein by Bruce Scott/NSROC
Page 55 - Org chart photos taken by John Brinton/SRPO

Report Design by Berit Bland/BBCO
Editor Micaela Barnhill/CSC



RockOn! and RockSat participants with their payload on the balancing table.

NOTES

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