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Given before the Subcommittee on Space and Aeronautics,
House of Representatives
Hearing on -
The Emerging Commercial Suborbital Reusable Launch Vehicle Market

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Mr. Chairman and Members of the Subcommittee, thank you for inviting me to address the following questions on suborbital research platforms. For the past 24 years I have conducted sounding rocket and laboratory experiments in astronomy using the launch services provided by the NASA Sounding Rocket Project Office. I have also Chaired and served on a number of NASA and NSF review panels for the purpose of ranking the scientific and technical merits of proposed research, including that conducted from suborbital platforms. In addition, I am a member of the NASA Astrophysics Sounding Rocket Assessment Team (ASRAT) charged with assessing how to reinvigorate the Astrophysics Sounding Rocket Program. The opinions expressed herein are my own and do not necessarily reflect the views of the Johns Hopkins University.

Questions from and answers for the committee:

1. What are the types of issues that need to be addressed when deciding on the merits of proposed research and the appropriate platform for that research (e.g. balloon, sounding rocket, ISS, commercial reusable launch vehicle)?

The NASA Science Mission Directorate provides guidance to each of its four Science Divisions in the form of its Strategic Plan. Each division then solicits proposals for basic research that will advance their own science and technical readiness in accordance with the Strategic Plan. These proposals then undergo peer review, where a panel of experts ranks them in order of intrinsic merit. In the case of suborbital research, panels are quite keen on proposals that seek to develop new science, as enabled by new technology, while training the next generation of space scientists. Each of these criteria, science, technology and training, are given roughly equal weight in determining the overall intrinsic merit of a proposal, depending somewhat on the instructions given by the Science Division to the panels.

The proposal solicitation often lists a number of suborbital launch services. For example the recent Astrophysics Research and Analysis Program (APRA) element of the NASA Research Announcement for Research Opportunities in Space and Earth Sciences

(ROSES) – 2012, offers opportunities to propose for science investigations to be carried out from sounding rockets - both expendable and reusable, balloons, CubeSats and ISS payloads. It is the charge of each review panel to decide how the proposed investigations, utilizing these various platforms, stack up against each other and whether they should be recommended for funding by NASA.

2. What particular capabilities and infrastructure (e.g. telemetry, guidance and navigation, payload processing, etc.) are needed to enable suborbital research, including your particular area of research?

For the past twenty-four years I have enjoyed the formidable support of the NASA Sounding Rocket Project Office (SRPO) for launching the fine-pointing experimental spectrographs that we build at Johns Hopkins University. (In fact, as we speak, my team is traveling from Baltimore to the NASA Wallops Island Flight Facility in Virginia to commence integration and testing of our latest experiment called FORTIS. Its goal is to explore the mysteries of escaping of ultraviolet radiation from the dusty confines of galaxies, using a new type of spectro/telescope that has more than six times the sensitivity of our previous experiments and can acquire spectra from forty-three individual targets simultaneously, within a region as large as the moon - 1/2 a degree = 1800 arcseconds. We expect to launch FORTIS this fall.)

The SRPO provides oversight to the operations of the NASA Sounding Rocket Operations Contract (NSROC), currently run by Orbital Sciences. This team supplies complete launch support for peer review selected experiments. They maintain a variety of mature standardized subsystems, including: a bevy of launch vehicle configurations, payload separation and de-spin modules, missile flight safety command destruct systems, recovery systems, shutter doors, payload skins, guidance and navigation modules of various precision, telemetry links at a variety of rates, and command uplink modules for specialized real-time payload interaction during flight – which includes the capability for steering the payload. NSROC also provides ground support in the form ground-station interface, environmental testing (shake, spin balance and moment-of-inertia measurement), and full experiment to subsystem integration services for the payload.

In addition to the launch infrastructure, the SRPO and NSROC will convene a series of project meetings, which include: a Mission Initiation Conference, a Requirements Definition Meeting, various Design Reviews, a Mission Readiness Review, and a Pre-Shoot Meeting. It is in these meetings that the experimenter outlines their mission goals and success criteria, chooses those systems that are necessary to meet their particular requirements, tracks the compatibility of the experiment with that of the subsystems, and establishes protocols to ensure the safety of all involved personnel.

For my own ultraviolet spectroscopic experiments, the vehicle of choice is a Black-Brant IX. It can throw 1000 lbs of payload to an apogee of approximately 300 kilometers. This vehicle provides approximately 400 seconds of time above 100 kilometers, which we require for unattenuated viewing of ultraviolet emissions from astronomical objects. We also require 3-axis (pitch, roll and yaw) fine-pointing acquisition and control system for tracking our targets with sub-arcsecond precision. A command uplink system is also used to make real-time fine pointing corrections. Students are usually chosen to “drive” the payload as they tend to have superior reaction time.

Recovery of the payload is also essential as it allows opportunity for reflight with improved technology and a means to learn from and correct mistakes. NASA expendable sounding rockets provide low cost, risk tolerant platforms from which experimenters can test technology to its limits. We seek to find “the edge of the envelope” without going over it. But failing that, as inevitably happens in experimental programs, we gain invaluable experience in learning how to recover once we do.

3. Please describe the end-to-end process in which students participate in suborbital research and the skills and benefits students acquire from that end-to-end approach.

Most suborbital research programs involve graduate and or undergraduate students in every aspect of an experiment. They learn to define science goals and measurement objectives and how they flow down into the instrument requirements that inform the systems engineering of the design, fabrication and testing phases of the experiment.

Students become an integral part of the science and technology they develop as they work in an apprentice-mentor relationship with a more senior researcher. Much of the knowhow is passed on in oral form, from one generation of experimenter to the next, much like a guild of old shipbuilders. In my own work, developing novel astronomy experiments in ultraviolet spectroscopy, we emphasize, in addition to the astrophysics, hands-on experience with optics, mechanics, electricity, magnetism, vacuum systems, computer programing, data acquisition, design, testing, calibration, integration, troubleshooting, mission planning, communication and publication of results. Within the short tenure of a graduate student, they become scientists with a fundamental regard for systems engineering and are highly prized by the aerospace community.

I have had the good fortune to work in productive collaborative relationships with nine graduate students in my past 24 years at Johns Hopkins and I can say without a doubt that I’ve learned as much from them as they have from me. Student participation in sounding rocket research is a longstanding hallmark of the program. Some would argue the most important product.

Many of the 40 Ph.D. students that have come out of Johns Hopkins University sounding rocket programs over the last 50+ years have gone on to fill key roles in the development of instrumentation for a host of NASA space mission, such as, the Advanced Camera for Surveys and the Cosmic Origins Spectrograph on Hubble, the James Webb Space Telescope, the Hopkins Ultraviolet Telescope, the Far-Ultraviolet Spectroscopic Explorer, the Galaxy Explorer, and the Mercury Messenger Mission to name a few. Some have even gone on to become Principal Investigators, leading exciting new science missions. Every academic, industrial and government research institution engaged in suborbital research has a similar story to tell. As of late the number of students receiving Ph.D.'s based on data from astrophysics experiments has fallen, as the attached Figure shows. It is symptomatic of a decrease in technically adept leadership.

4. What are the opportunities and challenges for suborbital research going forward?

There are many possible scientific research opportunities emerging for the commercial reusable suborbital sector. For example, in-situ research of upper atmospheric phenomena would be a logical fit for a vehicle with an apogee of 100 km. Understanding the effects of suborbital flight on normal human physiology would also appear to be a necessary prelude to the establishment of a routine commercial suborbital transportation capability.

I view the emerging stable of reusable suborbital vehicles with a mix of excitement and uncertainty. I am excited by the possibility of routine suborbital flight. I would love to fly across the Pacific Ocean in under an hour. However, I am uncertain as to whether the systems required to place a human-in-the-loop will lead to an increased experimental capability beyond that which we enjoy with the current stable of expendable NSROC vehicles. But then again, stories abound about how the student used the real-time command uplink system to save an expendable NASA sounding rocket mission from certain failure.

The challenge for developing reusable suborbital vehicles as meaningful research platforms will be to identify the appropriate niche markets, both commercial and scientific, where either human-in-the-loop or an in-situ access module provides some essential new scientific opportunity or technical capability that will pass the muster of Geospace, Heliophysics, Planetary and Astrophysics peer review panels.

It is important to note that most of the cost of carrying out a suborbital investigation goes well beyond the mere cost of the launch. The launch vehicle is the easy part. It will be necessary to develop a whole set of instrumentation infrastructures for collecting and recording data, along with integration and testing facilities. Moreover, review processes must be established to keep the launch providers and the experimenters on the same page and their workforce safe.

From my perspective as an astrophysics experimenter, the near term capabilities of reusable vehicles falls well short of the 300 km apogee we require to place our payloads above 100 km for approximately 400 seconds. In my view, generating new funding opportunities to advance the core capabilities of the expendable sounding rocket community are more likely to generate meaningful scientific, technical and programmatic impact for future national space based missions run by NASA, DOD and even private concerns.

For example, the recent Astro2010 decadal survey recommended expanded development of low cost missions operating in low earth orbit (LEO) and the upper atmosphere, as a means to rapidly respond to pressing scientific, technological, and workforce development needs. Currently, there exists a logarithmic gap in the funding profile between the approximately $2M to $4M that its costs to develop a sounding rocket mission and the approximately $200M plus cost of an Explorer mission; the lowest level of orbital flight opportunity offered by NASA.

The NASA Astrophysics Sounding Rocket Assessment Team (ASRAT - of which I am a member), convened by former Astrophysics Division Director Jon Morse during the tenure of then Science Mission Directorate Associate Administrator Alan Stern, outlined how a sounding rocket to orbit program could be implemented to fill this gap in the NASA launch portfolio. The purpose of this program would be to launch to LEO, for periods of up to a month, highly meritorious payloads that have been successfully flown as a sounding rocket.

Such a program would provide for the further maturation of sounding rocket initiated science and technology thrusts, but in an orbital environment more closely matched to the developmental needs of Explorer and Flagship missions. The ASRAT argued that establishing a sounding rocket to orbit line would ultimately reduce the costs for Explorers and Flagships because instrument development risk could be retired early. The ASRAT Astro2010 decadal survey White Papers that describe the core capability of the astrophysics sounding rocket program and benefits and envisioned methodology for establishing the sounding rocket to orbit program maybe downloaded from ASRAT Wiki page (http://www.galex.caltech.edu/ASRAT/).

The ASRAT identified two crucial components for enabling a sounding rocket to orbit program. One of those is the availability of low cost commercial launch systems capable of delivering payloads of modest mass to LEO, such as SpaceX's Falcon-1 or the recently announced Virgin Galactic Launcher-1. The other component is the development of standardized support subsystems for power, pointing, thermal control, and command and data handling, which are required to support these payloads in an orbital environment.

The SRPO, with its history of maintaining low costs through the use of standardized modular systems, in combination with the commercial interests of the NSROC, makes for an ideal partnership to migrate their formidable low cost and modular support system from the suborbital to the orbital regime. They would require only a modest amount of funding, not much more than the cost of a sounding rocket mission, to begin development of such systems. The expenditure would payback a hundred fold by increasing science return from the suborbitals and lowering development cost, and thereby risk, for instrumentation destined for Explorers and ultimately Flagships missions.

Research from suborbital platforms provides the nation with a vital base of core competency for advancing cutting edge science through the development of new technologies for future flagship missions while nurturing the next generation of technically adept leadership for the aerospace industry. I strongly recommend that the committee, on both sides of the aisle, become advocates for expansion of the workforce and capabilities of the NASA suborbital programs, and invite you to further investigate the benefits that establishing a sounding rocket to orbit line would have on reducing costs for future Explorer and Flagship missions. Expansion of these programs is a strategic investment towards accelerating the scientific and technical advancement required to maintain the future competitiveness of our aerospace sector. Now more than ever we need low cost access to space.

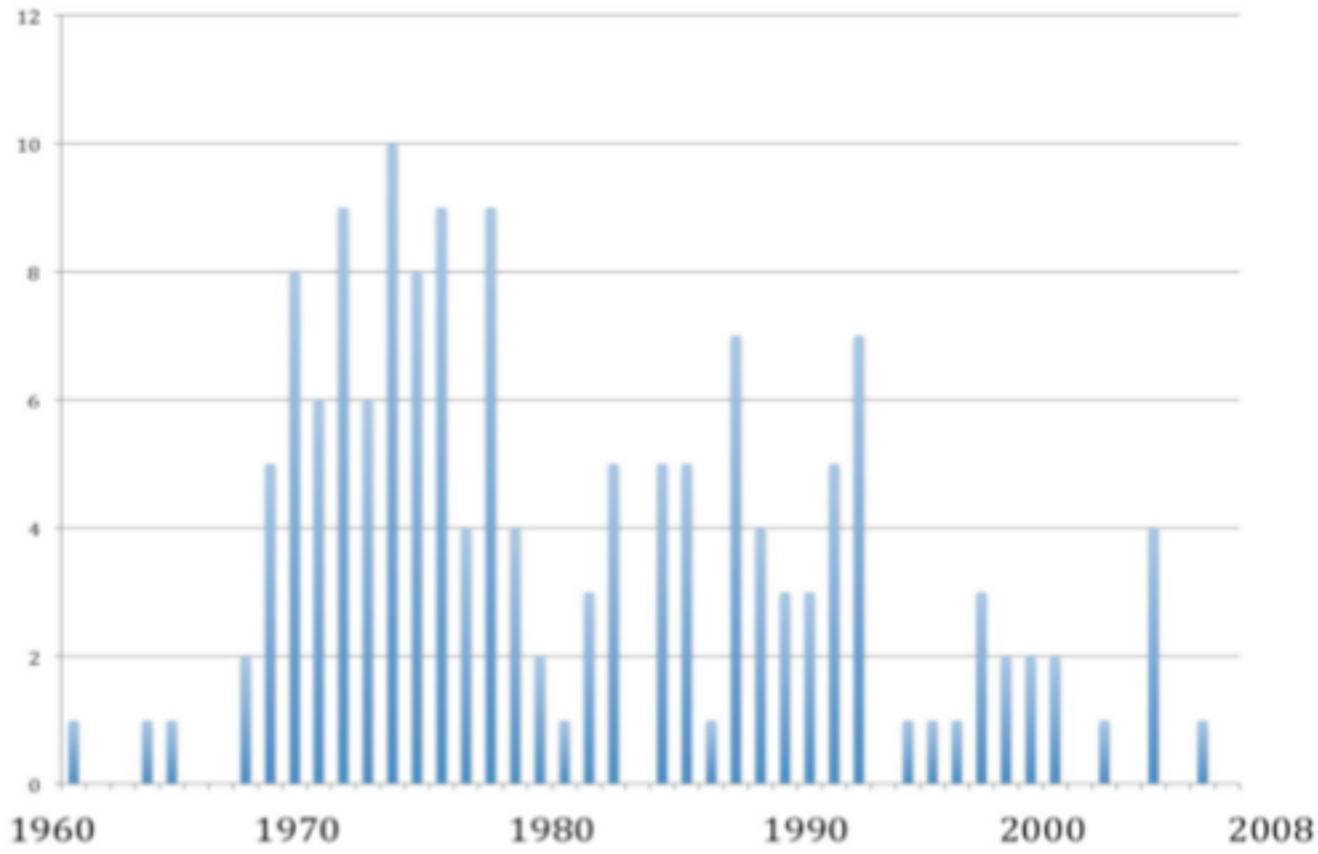
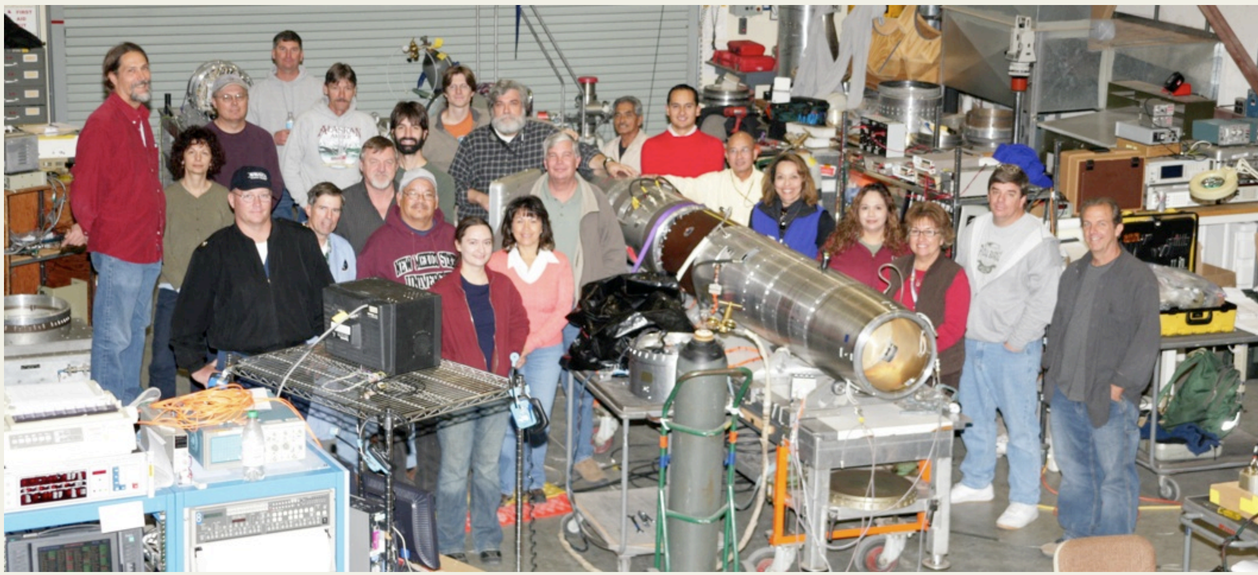


FIGURE 5-8 Number of PhDs per year resulting from sounding rocket programs between 1961 and 2008 (data compiled by the Astrophysics Sounding Rocket Assessment Team). Credit: NASA ASRAT.

Sounding Rocket Workforce Training:

From One Generation to the Next



Stephan R. McCandliss – Narrative Biography

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Stephan R. McCandliss is a Research Professor with the Johns Hopkins University (JHU) Department of Physics and Astronomy and is now Principal Investigator of a sounding rocket program. Born on 7 September 1955, in Salinas California, he received a B.S. in Physics and a B.S. in Astronomy from the University of Washington, Seattle in 1980, and received a Ph.D. in Astrophysics at the University of Colorado, Boulder in 1988. His primary professional interests are the ionization history of the universe, spectroscopy of extended objects, high efficiency spectroscopic design, and low cost access to space. Since coming to JHU in 1988, he has launched 15 sounding rocket borne far-UV spectroscopic instruments to observe various extended astronomical bodies, including comet Hale-Bopp, the Io torus, Jupiter, and an number of reflection and emission line nebulae. These investigations have provided observational insight into the process of molecular formation and destruction as mediated by interstellar dust and stellar radiation, and have served as the basis for the Ph.D. theses of 8 graduate students. The purpose of his current sounding rocket mission is to quantify how Lyman alpha radiation escapes star forming galaxies. Towards this end he has developed a new kind of optical system, a spectro/telescope called FORTIS, that can acquire both imagery and spectra of multiple objects within a field of view as large as the Moon. A GSFC developed microshutter array lies at the heart of this system, enabling the multiobject spectroscopic capability.

McCandliss has been PI and Co-I on several NASA grants to develop supporting technology for space missions as well as numerous *FUSE*, *HST* and *Spitzer* guest investigator programs. He served as a member of NASA's Sounding Rocket Working Group from 1999 – 2003 and on several NASA and NSF peer review panels. He is also a member of the Astrophysics Sounding Rocket Assessment Team advocating a reinvigoration of the sounding rocket program as a strategic investment in the future of space astronomy, and the creation of an low cost infrastructure for placing sounding rocket payloads in orbit for month long missions on a yearly basis.

SELECTED RECENT PUBLICATIONS

B. T. Fleming, S. R. McCandliss, M. E. Kaiser, J. Kruk, P. D. Feldman, A. S. Kutyrev, M. J. Li, D. A. Rapchun, E. Lyness, S. H. Moseley, O. Siegmund, J. Vallerga, and A. Martin 2011, Fabrication and calibration of FORTIS, SPIE 8145, 81450B-81450B-11

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Committee on Science, Space, and Technology

U.S. House of Representatives

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