

STUDENT INVOLVEMENT IN SPACE EXPLORATION: THE NEXT GENERATION. F. Bagenal and M. Horanyi, Laboratory for Atmospheric & Space Physics, University of Colorado, Boulder CO (bagenal@colorado.edu)

Involvement of students in space missions exposes students to the technical realities of space exploration – delivers deep learning experience and feeds the professional pipeline.

Student involvement at space missions: In the earlier days of space exploration student involvement in experimental work was limited to rocket and balloon payloads. LASP has a strong history of involving students in orbital missions and throughout all mission phases: design, build, test, operation, data analysis and science. Under the Directorship of Charles Barth, LASP built and operated two successful student-based missions in Earth orbit, SNOE and AIM which studied the Earth's upper atmosphere. This tradition has continued with student-based cubesats CSSWE (which measures energetic particles in the Earth's radiation belt) and MinXSS (which measures x-rays from the Sun). Students are also involved with single instruments on larger spacecraft, the most notable being the Student Dust Counter (PI M. Horanyi) on the New Horizons mission that flew past Pluto on 14 July 2015. In addition to specifically student-based missions and instruments, LASP involves students in many aspects of regular space missions, particularly operations and science.

Venetia Burney Student Dust Counter: SDC is part of the Education and Public Outreach (EPO) effort of the New Horizons mission and is the first science instrument on a planetary mission to be designed, built, tested and operated by students. The SDC project has an unusual history. A similar professional dust instrument was part of a competing proposal to New Horizons in a parallel Phase A study. After the selection of New Horizons, motivated by the potential scientific contribution of a dust instrument, the idea emerged to redirect some of the funds from traditional EPO activities so that a group of students could try their hands at building space hardware. The advanced state of the rest of the New Horizons payload and the risk of involving unexperienced students made this request difficult. With the strong support of the mission PI, the NASA EPO board agreed to try the "SDC experiment."

To minimize the risk SDC might pose to the mission, all quality assurance inspections and the final flight assembly was done by NASA-certified personnel, and student activities were supervised by professionals. However, the student team, consisting of up to 20 engineering and physics undergraduate and graduate students, was responsible for the work done in all phases of this project, including presentations at all NASA milestone reviews. SDC was built and tested to the same

NASA engineering standards as every other flight instrument. After launch of the New Horizons spacecraft on 19 January 2006, the SDC instrument was named after Venetia Burney, the young woman who named Pluto in 1930.

SDC provides the first set of dedicated dust measurements in the solar system beyond 18 AU, and will continue its observations while traversing into the Kuiper Belt (KB). Its data already provided unique and valuable science results, including an estimate of the total dust production rate in the KB. To date five publications on SDC data have been published in refereed scientific journals, and the results have been used in several other studies on the effects of dust influx to bodies in the outer solar system.

A total of 26 students have been involved in SDC with new students taking over responsibility for data processing and analysis through the extended mission. Due to the long duration of New Horizons, multiple generations of students continue to be involved, handing over their skills to the groups that follow. These SDC-trained students have moved on to a wide variety of professions. All undergraduates who applied to graduate school on graduation from CU were accepted to their first choice school (e.g., Stanford, New Hampshire). Several of them were hired at LASP as professional space scientists or engineers. Many continued in the space business at places such as NASA, SWRI, Orbital ATK, Ball, and Blue Canyon. All speak enthusiastically about their experience of being involved in SDC.

While NASA offered several opportunities since SDC to propose a student instrument for various missions, to date only the OSIRIS-Rex mission includes another student instrument.

REXIS on OSIRIS-REX: After a competitive selection process REXIS was selected as a Student Collaboration Experiment as part of OSIRIS-REx. The Regolith X-ray Imaging Spectrometer (REXIS) will provide an X-ray spectroscopy map of Bennu, complementing core OSIRIS-REx mission science. REXIS is a collaborative development by four groups within Massachusetts Institute of Technology (MIT) and Harvard University, with the potential to involve more than 100 students throughout the process. At MIT, faculty leadership is provided by Professor David Miller, Professor Richard Binzel, Professor Rebecca Masterson and Professor Sara Seager. At Harvard, faculty leadership is provided by Professor Josh Grindlay.

Students operate missions: The LASP Mission Operations & Data Systems (MO&DS) group staffs several

Mission Operations Centers and Science Operations Centers for the day-to-day operations of NASA spacecraft and instrument missions. LASP is one of very few university-based mission operations centers. One of the most exciting and unusual aspects of mission operations at LASP is the opportunity for CU undergraduate students to become certified mission operators. The student operators, who must pass a summer-long course held at LASP, work under the supervision of professional staff and perform mission operations for NASA satellites – from LASP-built student cubesat missions to national facilities such as Kepler. Each day, more than 100 gigabytes of data come through LASP servers to support ongoing space missions, as well as the scientific data that scientists from all over the world rely on.

There real-world experience in mission operations is a valuable balance to the academic training of their University coursework and these students are keenly recruited into a range of professions.

The workforce pipeline in planetary science: While we have mostly used examples at the University of Colorado's Laboratory for Atmospheric & Space Physics, there are similar examples at other universities across the US. But the reality is that the requirements associated with NASA missions of increasing technical sophistication, growing management, and escalating security mean that fewer universities are able to maintain student involvement in space missions. Yet the value – both educationally and creatively – of engaging young people in planetary exploration is glaringly obvious to anyone who witnessed the students presenting SDC to the New Horizons CDR panel or a student operator sitting down at the console for the next Kepler download.

The 2011 US Planetary Science Workforce Survey [1] estimates that there are about 1200 PhD planetary scientists working in the US. With many different types of university departments saying that they include planetary science it is hard to get an accurate number for the PhD production, but estimates are in the range of 75-100. About 90% come from just 10 universities. Experience suggests that only 20-30% continue as professional scientists. This indicates that planetary science is not over-producing PhDs – which is consistent with relatively small applicant pools for positions in planetary science and the relatively large number of non-US-born planetary scientists working in the US (including the two authors of this abstract). The number of planetary scientists graduating with experience in designing/building/testing/operating instruments is extremely small.

2050 vision for student involvement in planetary missions: To supply the creative workforce to implement NASA's Planetary Science Division's vision for solar system exploration in 2050 there needs to be a

healthy pipeline of experienced scientists and engineers. An effect way to maintain such a trained workforce is through direct university involvement in space missions. The best training for students comes from hands-on involvement throughout all phases of missions via student-based missions and/or instruments on planetary missions. What types of missions or instruments are we proposing be student-based? Students have demonstrated they can build a successful instrument that has made space measurements for 11 years and out to 33 AU. Students have built and operated a cubesat that has outlived its original design life by a factor of 5. *We see every reason to provide students the opportunity to explore every corner of the solar system.*



CU student Chelsey Bryant-Krug prepares for a calibration run of SDC in the dust accelerator in Heidelberg, Germany in 2004. She is now a LASP professional engineer..



The flight-qualified electronics box of SDC

[1]<http://lasp.colorado.edu/home/mop/resources/related-links/planetary-science-workforce-survey/>