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NASA Undergraduate Student Instrument (USIP) Project--Lessons Learned

Dr. Joyce L. Winterton, Dave Pierce, Janet Letchworth, Brenda Dingwall
NASA Goddard Space Flight Centers Wallops Flight Facility
Telephone: 757-824-2685; Cell phone: 202-425-2591
E-mail: joyce.L.winterton@nasa.gov

ABSTRACT

NASA offers real-world experiences, with the goal of developing students' skills and capabilities in science, technology, engineering and math, skills critical to building a STEM-literate workforce and achieving the nation's exploration goals. In 2016, the NASA Science Mission Directorate (SMD) and the Office of Education National Space Grant Program (OE Space Grant) awarded $8 million through the Undergraduate Student Instrument Project (USIP) to 47 student teams to conduct hands-on research with 23 of the projects being CubeSat projects. The USIP student teams proposed science or technology experiments that are relevant to NASA missions, and the platform to fly their payload. The platforms include sounding rockets, scientific and hand-held balloons, aircraft, suborbital reusable and commercial launch vehicles, and CubeSats launched as a secondary payload on an orbital vehicle. The mission management for USIP was the responsibility of NASA Goddard Space Flight Centers Wallops Flight Facility (WFF) in Virginia. The university faculty supporting USIP attest to the benefits students are receiving in the hands-on aspects of the projects, as well as the real-world problem resolution. The USIP university teams are receiving an authentic NASA educational experience that will encourage the students to be part of NASA's or the Nations' future workforce and leaders.

INTRODUCTION

The National Aeronautics and Space Administration (NASA) continues to offer real-world experiences, with the goal of developing students' skills and capabilities in science, technology, engineering and math, skills critical to building a robust, STEM-literate workforce and achieving the nation's exploration goals through offering its unique research platforms for student flight research opportunities. NASA's Science Mission Directorate (SMD) in collaboration with the Office of Education National Space Grant and Fellowship Program (OE Space Grant) released a cooperative agreement notice for the Undergraduate Student Instrument Project (USIP) in 2016. The goals of USIP which is a Student Flight Research Opportunity (SFRO) are:

- To provide a hands-on flight project experience to enhance the science, technical, leadership and project skills for the selected undergraduate student teams.
- To fly a science and/or technology investigation relevant to NASA strategic goals and objectives on a suborbital-class platform.

NASA developed USIP in 2012 as part of a strategy to increase hands-on training opportunities for undergraduate students. There were 10 universities that received awards for this first USIP funded through SMD. These USIP teams used a mix of suborbital platforms to fly their instruments. WFF was involved in developing the initial concept, solicitation, and mission management for the first awards in 2012, and the current USIP university awardees. In 2016, the NASA's SMD and the OE Space Grant awarded more than $8 million through the Undergraduate Student Instrument Project (USIP) Cooperative Agreement Notice to 47 student teams to conduct hands-on research with 23 of the projects being CubeSat projects. As of June 2019, of the 47 projects, 20 projects

(43%) have flown and 18 are currently manifested for flights in 2019 or 2020. There are 9 projects that continue to work on their instruments, and thus will be manifested at a later date.

The USIP teams proposed the platform they wanted to fly their payload on including sounding rockets, scientific and hand-held balloons, aircraft, suborbital reusable launch vehicles, commercial suborbital vehicle, and CubeSats launched as a secondary payload on an orbital vehicle. The USIP teams flying a CubeSat were also required to submit a proposal and be selected by NASA CubeSat Launch Initiative (CSLI) to manifest their flight opportunity. Once manifested, the teams worked with the NASA CSLI team in addition to their project mission manager to work through challenges in testing and payload preparations.

The university USIP project teams are responsible for the formulation and implementation of the project. Teams were required to develop a project plan that was consistent with NASA project management principles as defined by NASA Procedural Requirement (NPR) 7120.8, NASA Research and Technology Program Management Requirements. In addition to this requirements, USIP required that the project team make-up be multidisciplinary (e.g. science, engineering, business, humanities). The USIP project team is responsible for submitting all documentation required for flight, delivery of the payload to the launch site, analysis of any mission data and for submittal of a final project report. The cross discipline student teams, with the support of their faculty, have 2 years plus a 1 year no cost extension to fly their payload. The mission management for USIP was the responsibility of NASA Goddard Space Flight Centers Wallops Flight Facility (WFF) in Virginia. The team of WFF mission managers with specific experience in these platforms have worked with the USIP student teams to plan and conduct the four required reviews during the project life cycle, including:

- Concept Review (CR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Mission Readiness Review (MRR)

Additionally, WFF mission manager worked to identify experts to support the USIP team reviews and provided feedback and constructive recommendations. The WFF USIP team worked directly with NASA Headquarters to address challenges, required funding and processes for reporting and no-cost extensions.

The university faculty supporting USIP attest to the benefits students are receiving in the hands-on aspects of the projects, the perspectives and technical information received from NASA experts and the real-world problem resolution and teamwork skills they gain throughout their participation in the USIP experience. The USIP university teams are receiving an authentic NASA educational experience that will encourage the students to be part of NASA's future workforce or part of the Nation's science, technology, engineering and mathematics workforce and leaders. Because the USIP projects are designed to lead students through the entire NASA project management cycle, students gain important experiences in project management, leadership, design, test, and integration in addition to deepening their technical skills in their area of study. USIP is one of the NASA Student Flight Research Opportunities that provide a continuum of experiences for undergraduate and graduate student teams. It has also been an opportunity for NASA to develop "lessons learned" including benefits and challenges.

Student and Faculty Experiences

The opportunity presented by USIP for the university teams to select the platform that they wanted to fly their science or technology experiment on created a diverse and interesting group of awardees. The 47 awards selected included 23 CubeSats, 5 sounding rockets, 5 scientific balloons, 7 hand-held balloons, 3 Zero-G flights, 2 unmanned aircraft systems (UAS), and 2 small Reusable Launch Vehicles (sRLV).

The USIP teams' experiments encompass a wide range of technologies and science. For example, the USIP team from the University of Southern Indiana developed the Undergraduate Nano Ionospheric Temperature Explorer (UNITE) CubeSat with the main goal of the mission to measure plasma in the lower ionosphere, a relatively unexplored region of space. The UNITE CubeSat which launched on December 5, 2018 on the Space-X 16 mission to the International Space Station (ISS) passed the 100th day of collecting data in May 2019. Montana State University develop RADSat-g a CubeSat that launched November 17, 2018 on the Antares resupply mission to the

ISS from WFF, and seeks to demonstrate a new radiation-tolerant computer system and radiation sensor in low Earth orbit. The Virginia CubeSat Constellation mission, a collaborative project of the Virginia Space Grant Consortium and four of its member universities: Old Dominion University, Virginia Tech, University of Virginia, and Hampton University built and launched three nano-satellites to obtain measurements of atmospheric properties and quantify atmospheric density with respect to orbital decay. The satellites were integrated into the NanoRacks CubeSat deployer and loaded into the Northrop Grumman Cygnus module which launched on the company's Antares rocket on April 17, 2019 as a resupply mission to the (ISS).

Students from the University of Central Florida in Orlando flew an experiment on a zero-gravity aircraft to investigate the behavior of granular matter, such as soil, in low-gravity environments to learn more about regolith formation on the surface of small solar system bodies such as asteroids, comets, and Mars' moon Phobos. The University of Idaho, Moscow team developed and tested two projects, a low-cost imaging payload and an experiment to understand the effects of a high-altitude environment on the growth rate of microbes. Both payloads launched on hand-held balloons. Four universities launched their USIP experiments on a 43-foot tall Terrier-Improved Malemute sounding rocket from WFF that flew to an altitude of approximately 100 miles. The Florida Institute of Technology tested a new wire insulation repair material in a microgravity, near vacuum environment. The test samples were subjected to a series of tests after retrieval to inspect the material and verify effectiveness in the space environment. The University of Kentucky, Lexington developed a spacecraft that deployed during flight to test and demonstrate a communications system, release mechanism and thermal protection system design for application in future research. Utah State University tested an arc-ignition, green propellant CubeSat thruster system. During the flight test, measurements were gathered in order to assess the potentially harmful effects of plume contamination on spacecraft optical sensors, external electronics and solar panels. University of Nebraska partnering with NASA's Langley Research Center in Hampton, Virginia, tested a deployable and retractable boom and solar blanket for space applications, including sounding rockets, CubeSats and small satellites. Following the flight, the experiments descended by parachute and landed in the Atlantic Ocean. The experiments were retrieved and returned to the students to analyze their data. A list of the 47 USIP teams and the title of their experiments is provided at the end of this paper in Table 1.

Benefits of USIP

Student Perspective

As part of the USIP mission management, WFF asked the students and faculty to provide feedback on their USIP experience. Several students commented that it was a "Life Changing" opportunity and that you do not have this type of experience in a classroom. The students indicated that they strongly agreed (4.62 on a 5 point Likert scale) that USIP was a positive experience and the USIP experience will help advance my career goals. The students also strongly agreed (average 4.55 on a 5 point scale) "My technical skills have improved as a result of participation in USIP." A frequent comment was the benefit of having undergraduate students lead the USIP project. For example a student reported, "It placed responsibility for all aspects of the project on the students. This made it a unique and invaluable opportunity to learn engineering project management skills and communications skills in addition to technical skills." The students appreciated that they were participating in meaningful and modern research. One student said it even allowed their university to grow and attract dozens of undergraduates to space science and engineering. Several students that were interviewed at the conclusion of the USIP project described their experience as "the most valuable experience of their undergraduate careers."

USIP did inspire many students to pursue majors and careers in the aerospace industry. The students said they learned how to work with NASA and also space-related industries. It was also helpful to hear that many students were able to obtain additional NASA and commercial industry internships and felt that being able to report their involvement in USIP had contributed to them receiving a job offer. A valuable lesson that students said they learned during the project was "learning how to work on a team with different backgrounds, and how to mediate and deal with conflicts." A positive but unexpected outcome was, "I think it's one way of creating innovative independent engineering minds rather than just job ready individuals; this program has built my confidence in engineering to start pursuing my own projects that I believe will yield some good benefits." The real-world aspect of USIP was mentioned by several students in their feedback including the statement, "Not many people can say as an undergraduate they worked on a project for NASA. This is an amazing opportunity and it is great knowing our project is doing something helpful and will actually be launched."

Faculty Perspective

The university faculty supporting USIP attest to the benefits students are receiving in the hands-on aspects of the projects, as well as the real-world problem resolution they are participating in throughout the USIP experience. An example of the positive comments was, "We are very grateful to have had the USIP opportunity. The students engaged experienced personal growth not possible in many other opportunities. The required rigor and accountability they were held to by NASA at WFF and the mentors gave them an appreciation of professional expectations, and built their confidence in their ability to understand and contribute meaningfully to a real world project." The feedback from the faculty indicated that they strongly agreed USIP was a positive experience for their team (4.63 on a 5 point Likert scale), and they would recommend the USIP opportunity to other universities and students (4.66 on a 5 point Likert scale). One of the faculty members stated, "This has been an excellent experience. It is extremely rare for undergraduate engineering students to gain experience beginning from conceptual design and proceed through testing and delivery. The universities had various previous experience with developing NASA payloads including CubeSats. For example one professor stated, "Our students and faculty primary goal for this project was to become familiar with the CubeSat world and what it takes to design, assemble, launch, and operate a CubeSat. We had no real-world experience prior to starting USIP. Toward this goal, the project has been a success and I feel the faculty and students will now have a significantly better understanding of such projects, as well as solid foundation for future projects."

The faculty were also asked, from their perspective, how the students benefitted from USIP. The following faculty quote is an example of the feedback, "Students who participated have a far greater knowledge and respect for the project management process, and how their individual performance impacts the team and the payload performance. They take these project management skills with them into their other coursework and careers, making them better contributors, learners, and mentors. Many of those who have graduated have pointed to their USIP experience as their most impactful and with regard to the skills they can bring to their employers beyond technical theory. They have a more encompassing understanding of project management teamwork, technical rigor, and professional communication."

In addition, the faculty share that students learned from the adversity of when things did not work as expected. Student leaders also gained valuable experience developing and presenting the monthly reports including reporting when things were not going well. Of course, in the real-world planning and implementation do not always go as planned thus, USIP reflected the practical world of NASA and the aerospace industry. The faculty also reported that, "The USIP project provided these students with many educational opportunities they would have never received through classes. First and foremost, they got hands-on experience, which is sorely lacking in our curriculum." Another comment was that, "There is little doubt all students involved in this project matured greatly from this opportunities—at least partly because the USIP was more ambitious, demanding and rigorous than a typical capstone project. Several of the graduates are now working in the aerospace industry." The USIP model requires a substantial involvement of the Principle Investigator (PI) and other faculty advisors.

Challenges from NASA and USIP Teams Perspectives

Even with the positive results and feedback from the students, faculty and NASA mission managers, there were lessons learned that could improve USIP. An effective approach for many teams was to have USIP as part of course with university credit or a capstone project, as was recommended by the USIP solicitation. It was more of a challenge if USIP was conducted as an extra experience, especially to keep a core group of students involved. The expected timeframe to design, build and launch a payload was challenging, especially for the teams that selected CubeSats, particularly since the teams were not ready to submit a CSLI application until they were well into the design process. Since manifest dates are generally at least a year from application, it was almost impossible to complete a CubeSat project within the intended timeframe. The USIP teams would have liked face to face or even more time with NASA experts, and travel that would allow them to meet other USIP teams. Although the NASA

USIP leaders understood the value of this request, the limitations with funding and personnel did not allow it to be part of the planning.

The growth of the USIP awards from 10 in the first solicitation to 47 awards in the second solicitation was a significant increase which made providing more individual team assistance a challenge. Further, NASA new mission duties required reassignment of mission managers for several projects. The timing of the academic school year, and members of the original USIP teams graduating also delayed some of the work and the responses to the WFF Mission Mangers, even though teams were required to submit a mentoring plan that detailed how student attrition would be accommodated by mentoring new students to take vacant positions. With a few teams, the lack of consistent faculty support needed was expressed as a frustration by the students. For the USIP teams that had less previous experience in engineering and flying payloads, additional guidance and templates from NASA to follow would have been beneficial. One suggestion from a student was, "encourage more communication and collaboration between school teams working on projects for the same platform. For example, have the suborbital rocket teams talk more to each other to learn how other teams are trouble shooting problems or learn from their previous experience." A faculty member offered that if the USIP teams had more interactions with other teams it would also help the students learn about other flight platforms.

Some of the USIP student teams learned the "real world" consequences that if your experiment payload is not delivered on time or ready for flight, the mission launches without you. Deadlines for delivery and platform launches are determined by many factors that often times cannot be changed. Another team, experience the challenges of a major storm that flooded their laboratory, thus creating a delay in the engineering of their experiment. An additional unexpected delay occurred for one team when during testing a part was broken on their experiment. As one student stated about USIP, "It felt real because it was real." That included the positive aspects and the challenges of science and space exploration. Even the most experience aerospace engineer or scientist deals with unexpected challenges and delays.

A Continuum of NASA Student Flight Opportunities

USIP is one of the NASA Student Flight Research Opportunities that provide a continuum of experiences for undergraduate and graduate student teams USIP has been a unique learning opportunity for the university teams because it offers not only an opportunity to build and develop flight hardware, it offers the opportunity to choose from a diversity of flight platforms In addition, the requirement to have a multidisciplinary team give students insight into other perspectives; engineers become aware of the impact of their decisions on the scientists ability to effectively conduct science and scientists become aware of the complexities engineers fact to enable science. Other, flight opportunities managed at WFF utilizing suborbital platforms include RockOn!, RockSatC, RockSatX, and HASP.

The RockOn! series of opportunities are a collaboration with the NASA Sounding Rocket Program Office based at WFF, and the Colorado Space Grant and Virginia Space Grant Consortiums. For 12 years university and community college students and faculty from across the country (nearly 200 each year) build and fly experiments on a NASA suborbital rocket. Participants in RockOn! receive instruction on the basics required to develop a scientific payload for flight on a suborbital rocket. After learning the basics in RockOn!, students may then participate in RockSat-C, where during the school year they design and build an experiment for rocket flight. The two-stage Terrier-Orion rocket launched from WFF is retrieved from the Atlantic Ocean, and the students then analyze their data from their payloads.

NASA's Balloon Program Office at WFF in partnership with the Louisiana Space Grant Consortium, conduct the High-Altitude Student Platform (HASP) which allows 12 student experiments built by college students from across the nation fly their experiments. The Scientific Balloon launched from Ft. Sumner, New Mexico flies to an altitude of 120,000 feet during a 10 to 20 hour mission. When the payloads are retrieved the students analyze their data. The HASP opportunity started in 2005.

NASA's CubeSat Launch Initiative (CSLI) provides opportunities for small satellite payloads built by universities, high schools and non-profit organizations to fly on upcoming launches. Through innovative technology partnerships NASA provides these CubeSat developers a low-cost pathway to conduct scientific investigations and technology demonstrations in space, thus enabling students, teachers and faculty to obtain hands-on flight hardware development experience. The USIP opportunity was supported by NASA CSLI to manifest the 23 USIP CubeSats and provided valuable assistance in preparing them for their launch.

NASA WFF also supports the planning and implementation of opportunities for younger students to experience the excitement of science research and space exploration. WFF along with the Colorado Space Grant Consortium and idoodledu, inc., offer a free STEAM education program for students ages 11-18. Cubes in Space™ lets students design and compete to launch an experiment into space. Selected student-designed payload cubes launched via a sounding rocket from WFF in June or from a high-altitude scientific balloon from NASA's Columbia Scientific Balloon Facility in New Mexico in late August. The Cubes in Space opportunity has been available to students for 5 years.

A key partner for WFF, Virginia Commercial Space Flight Authority with Twiggs Space Lab have partnered to create a program to advance STEM education and promote space science and engineering for students in grades 4 to 12. Student teams build a small ThinSat that launches on the Antares Cygnus rocket that launches from WFF to the International Space Station (ISS).

NASA provides paid internships each year at each of it Centers and Facilities. The NASA mentors determine the work that the high school and undergraduate will undertake during their internship. There are some that do prepare students for future student flight opportunities.

The Future of Student Flight Opportunities

Student flight opportunities including USIP utilize NASA's unique capabilities, facilities and experts. They also provide motivation for students to pursue STEM (science, technology, engineering and mathematics) majors and careers. In addition, these real-world student and faulty opportunities will contribute to the workforce and new expertise needed for NASA Mission—To the Moon, Mars and Beyond. The challenge continues to be consistent funding and support for student flight opportunities. The USIP students and faculty strongly recommended that "real world" undergraduate student flight research opportunities should continue to be offered by NASA.

Table 1: List of the 47 USIP Teams and Title of Their Experiments

Launch Platform	University	Title of Research
CubeSats		
	University of Missouri-Rolla	Multi-Mode Propulsion (M3)
	Michigan Tech	Cloud Structure and Winds (Stratus)
	University of Michigan	Langmuir Probe on Miniature Electrodynamics Tether (MTEE)
	Carthage College, Wisconsin	Canopy Near-IR Observing (CaNOP)
	SUNY-Buffalo	Broad-spectrum Radio Interference (LinkSat)
	University of Washington	Lunar Magnetic Field Mapper (Husky-sat)
	University of Massachusetts	Communication Engineering (Space-Hauc)
	University of South Alabama	Spatially Resolved Plasma Density (JagSat-1)
	Sonoma State	Monitor of Earth's Ecosystems (EdgeCube)
	Virginia Space Grant, Univ. of VA, VA Tech, Old Dominion Univ., Hampton University	Virginia CubeSat Constellation – atmospheric properties and density
	Northwestern University	Interface Convective Effects (SPACE ICE)
	University of Illinois Urbana-Champaign	(CAPSat)
	University of Illinois, UC	Aerothermal Spectrometer (SASSI^2)
	Arizona State University	Urban Heat Islands (Phoenix)

	Georgia Institute of Technology	LIDAR CubeSat
	University of Georgia	GA Water Resources
	University of Florida	Very Low Frequency Waves in Ionosphere (SwampSat)
	University of Minnesota	Cube Sat Ranging and Timing Experiments (SOCRATES)
	University of Alaska, Fairbanks	Space Systems Engineering Program
	Brigham Young University	Passive Inspection CubeSat
	NW Nazarene	Backscatter Radio Communications (RFTSat)
	University of South Indiana	Undergraduate Nano Ionospheric Temperature Explorer (UNITE)
	Montana State University	Radiation Tolerant Computer Technology (RadSat)
Sounding Rockets		
	Utah State University	Arc-Ignition Green Thruster
	University of Nebraska, Lincoln	Retractable Boom
	University of Kentucky, Lexington	Operational Rocket Experiment (KOROVET)
	Florida Institute of Technology	Polyimide Wire Repair
	Rochester Institute of Technology	Cryogenic Star Tracking Altitude Reg System
High Altitude Balloons		
	South Dakota School of Mines	Acoustic Temperature
	Montana State University	Light and Fast TGT Recorder (LAFTR)
	Gannon University	Cherenkov Radiator (CHERP)
	University of Alabama, Huntsville	Active Radiation Shielding (ALFRED)
	Harvard University	Measuring Stratospheric Hydrochloric Acid Levels (HUSCE)
Small Hand-Launched Balloons		
	University of Houston	Ultralight Balloon Multiple Launches
	Louisiana State University	COTEL
	University of Idaho, Moscow	Low-Cost Imaging Payload (TATERTOTS)
	University of Kentucky, Lexington	3D Printing
	University of Wyoming	Inexpensive Microgravity
	University of Connecticut, Hartford	High Altitude Robotic Puppet
	University of North Dakota	Digital Thermosonde
	South Dakota School of Mines	Multi-Spectral Imager (MOCHA)
ZeroG, sRLV		
	Ohio State University	Microgravity Sensing
	University of Kentucky, Lexington	3D Printing
	University of Central Florida	Simulating Low-Gravity Planetary Environments
	Gadsden State University	Veggie Watering System
Unmanned Aerial Systems (UAS)		
	University of Oklahoma	Airborne Radar Sensor
	University of California, San Diego	Solar Powered UAS