RockOn and RockSat: A NASA and COSGC Collaboration to Train Tomorrow's Engineers

Chris Koehler, Shawn Carroll, Emily Logan
Colorado Space Grant Consortium
University of Colorado at Boulder; 303-492-3141
koehler@colorado.edu

ABSTRACT

Colorado Space Grant Consortium's (COSGC) newest sounding rocket payload program, RocketSat, has been in development since 2005. By 2008, COSGC had developed a body of knowledge on building sounding rocket payloads that had reached a level it was ready to pass on to other students across the nation. Taking the lessons learned from three years of experience and three suborbital flights, COSGC faculty and students developed a standard payload to characterize the flight environment and measure radiation on the flight trajectory. The construction of this standard payload was turned into the RockOn workshop through a partnership with NASA's Wallops Flight Facility (WFF), NASA Education, the Colorado and Virginia Space Grant consortia. Over the course of the 6-day, hands-on RockOn workshop, university students and faculty build and test a fully functional sounding rocket payload and watch their payloads launch on a Terrier-Improved Orion to an altitude of approximately 70 miles. The payloads are then recovered, and participants analyze their flight data. The first RockOn launch was June 25, 2008, and since then two more workshop and launches have occurred in 2009 and 2010, with another scheduled in 2011. In an effort to continue this learning process, the canisters (RockSat Payload Canisters) used to streamline integration of the RockOn payloads are offered to universities at a fraction of the cost of the launch vehicle costs. This provides students across the United States with a standard interface and relatively inexpensive flight opportunity once a year to launch their payloads, building on the initial knowledge gained from the RockOn workshop. This student-managed national program organized at COSGC is known as RockSat and has flown 21 payloads from 11 universities on three sounding rocket flights in 2008, 2009, and 2010, with another 9 payloads scheduled to launch in 2011. The goal of RockSat is to foster the continued learning about the process of engineering and design after the RockOn Workshop with an original payload, as opposed to a predesigned payload. In 2010, WFF and COSGC began developing the RockSat-X program. Like RockSat, RockSat-X is a national, student-managed program. The biggest difference between RockSat and RockSat-X is that the latter provides full access to the space environment, power and telemetry, and the possibility to eject sub payloads. The first launch of RockSat-X is in July 2011. Students that partake in the RockOn Workshop and/or RockSat-C and X programs gain a level of hands-on learning unlike anything the classroom can provide. In addition to providing invaluable training with physical payloads, these programs have proven to be an excellent test bed for small satellite technology as student teams take off with original mission ideas. The next step is to further develop RockSat-C and RockSat-X payloads into small student satellites intended for orbit and create a program, through partnerships with WFF and others, to launch them on a consistent basis.

INTRODUCTION

The goals of RockOn and RockSat are similar and connected. Each program strives to provide college-level students with real-world, space flight opportunities that allow them to develop a space mission from initial idea to the launch concluding with data analysis. Through this experience, students gain a unique set of skills and tools that better prepare them for the needs of both the large and small satellite field, which make them better trained for the workforce needs of tomorrow.

It can be proven that students working on a hands-on project tied to an actual space flight opportunity are better prepared for the workforce. Student access to real space flight opportunities before graduation is minimal. While CubeSats are increasingly popular and even though there are more opportunities to get them into space, they are still cost prohibitive. RockOn and RockSat can be used as a stepping-stone between BalloonSats and CubeSats. In some cases, RockSats can exceed what CubeSats can do and accomplish. RockOn and RockSat could also be developed as an

entry point for some students that do not want to start with programs like BalloonSat.

RockOn is a six-day, hands-on workshop in which participants form teams of three that build a sounding rocket payload from a kit and launch it on a sounding rocket at the conclusion of the workshop. During the workshop, participants learn the skills required to develop their own unique sounding rocket payload at their home institutions. Participants can launch their payloads on their own sounding rocket or come back and participate in the RockSat program. The RockSat program is designed to provide college students and faculty the opportunity to fly their experiments on a sounding rocket for a relatively low cost and a schedule that is tied directly to the academic calendar.

A RockSat is a canister that is roughly 9.3 inches in diameter by 9.5 inches tall. The RockSat canister can hold roughly 12.5 pounds of payload. RockSats are launched each year on the same rocket flight that launches the RockOn payloads.

Both the RockOn and RockSat programs are currently implemented through a collaborative partnership with NASA's Wallops Flight Facility (WFF), NASA Education, and NASA's Colorado Space Grant Consortium (COSGC) and Virginia Space Grant Consortium (VASGC). All activities related to integration, test, launch and recovery take place at WFF.

BACKGROUND

In November 2000, COSGC started launching BalloonSats to 100,000 feet on high altitude balloons. The impetus for starting this program was tied to the fact that student access to space was so limited that students were becoming disenfranchised with certain aspects of space research and development. With no real improvements to this access to space problem on the horizon, COSGC looked at edge of space access via high altitude balloons as a suitable substitute. In 2002, a paper was presented at the Small Satellite Conference by the author on the success of the BalloonSat program and associated national hands-on workshops that had started that year. Since that presentation, 13 national hands-on workshops have been held, reaching over 500 students and faculty from 46 states. There are more than 100 active high-altitude ballooning programs around the country. While this can be viewed as a success and there are no plans to stop the ballooning programs currently impacting thousands of students each year, there are certain limitations of ballooning that warrant pursuing other ways to access space. For many, this next level step is CubeSats, but the step from BalloonSats and CubeSats is a big one. A step between was needed and was the motivation for COSGC's next development effort.

In 2005, COSGC began developing the next step to access space modeled after the same approach used for the ballooning programs and workshops. This next step was RocketSat. The concept was to develop a way to obtain higher altitudes while providing students with

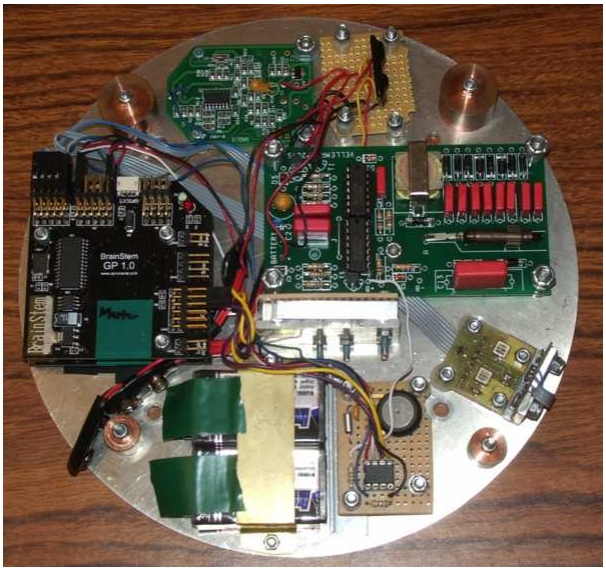

Figure 1: First RocketSat Payload Prototype 2005

increasingly more challenging engineering environments without having to purchase an entire sounding rocket. If a sounding rocket payload could be developed where, under small weight and volume constraints, numerous payloads could be flown on the same rocket, it would lower the overall costs associated with the rocket flight.

Initially, COSGC began working with Up Aerospace and Spaceport America in New Mexico. While this partnership seemed to be working well, a regular flight schedule could not be guaranteed. In late 2006, a chance meeting occurred with WFF at a National Space Grant meeting. The author presented his idea for the RockOn and RockSat concept and the idea was planted. With the help of the VASGC, a second meeting was held with WFF at WFF in July 2007. At the conclusion of that meeting, WFF had committed to an actual launch in June 2008 to see if RockOn could be done and if people would participate. RockOn 2008 was held and was very successful and WFF committed to another launch for 2009 and 2010, with a possible expansion in 2011.

Currently, RockOn and RockSat are active sounding rocket programs that are launching each June. These opportunities are available to any student or faculty

working students. More information on both of these programs is detailed sections below.

PROGRAM DESCRIPTION

RockOn was designed to be the entry point for students and faculty wanting to get involved with sounding rocket programs like RockSat. This section will describe both the RockOn and RockSat program flow. While the two programs are related, individuals can participate in each separately, since both provide valuable training in design, build, and testing of payloads.

The RockOn workshop is a six-day intensive hands-on workshop that culminates a sounding rocket launch at WFF each June. COSGC and VASGC conduct the actual workshop and WFF hosts the workshop on their facilities in Wallops, Virginia. RockOn participants pay a registration fee that provides most of the participants' meals, a handbook, the hardware used to build the payload, and the equipment used during the workshop. The RockOn registration process typically begins in early spring of the year the workshop will be held. Participants register on the RockOn website at spacegrant.colorado.edu/rockon. All interested participants must have experience with soldering and C programming prior to attending the workshop. Participants form teams of three and each team builds a single sounding rocket payload from a prepared kit. The single sounding rocket payload fits on a plate with a diameter of roughly 10 inches and weighs about 1.25 pounds.

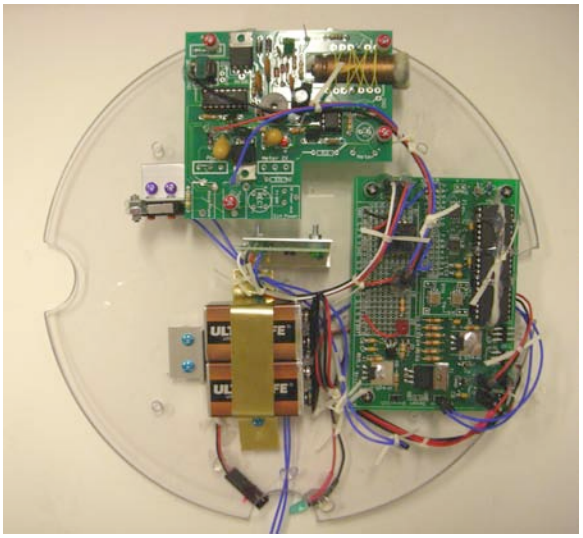

Figure 2: RockOn Payload Plate

The payload includes an AVR microcontroller board with six accelerometers, a pressure sensor, and temperature sensor.

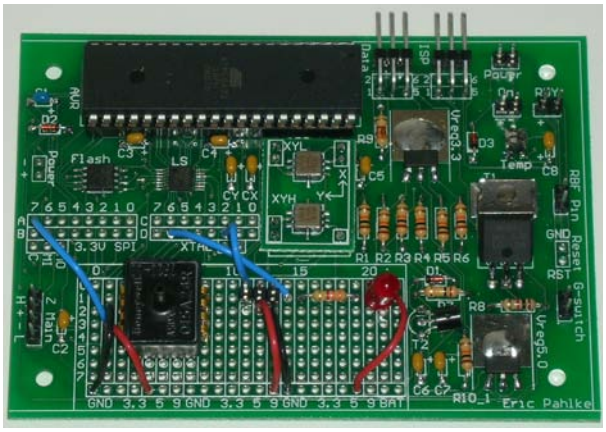

Figure 3: AVR Board

It also has 2 MB of flash memory and power regulation for 9.0 V, 5.0 V and 3.3 V. A former COSGC student, Eric Pahlke, who is now working at First RF, designed the AVR board. With the pre-designed board, each team populates the board during the workshop with resistors, capacitors, IC chips, regulators, transistors, and sensors. After participants complete the build the AVR board, they spend roughly 7 hours programing it for the flight. Participants also build a Geiger counter board designed by former COSGC student David Ferguson, who is now working at SpaceX. The Geiger counter serves as the science mission for each payload.

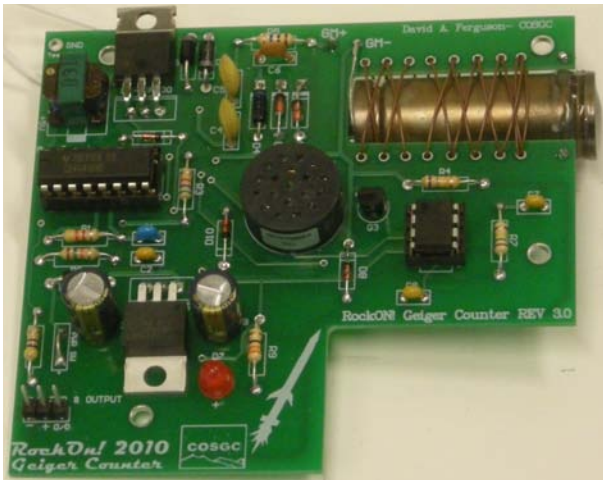

Figure 4: Geiger Counter Board

Upon completion of all the electrical components, each team conducts a full systems test. Following the testing, teams mechanically integrate their components to their Makrolon plate. Once each team has completed mechanical integration and performed their final mission simulation test, five RockOn plates are

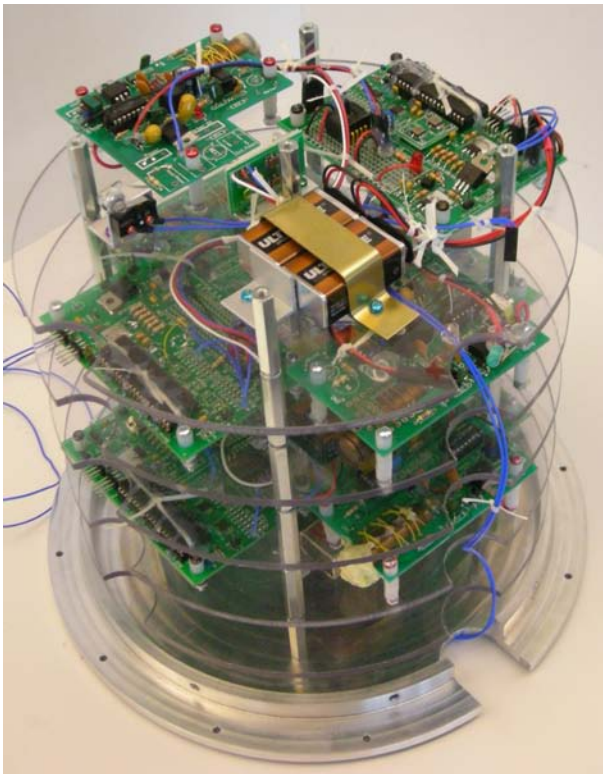

Figure 5: RockOn Payload Plates - Stacked

assembled into a stack and then placed in the RockSat canister. The major advantage of this experience is that participants walk away with a useable payload and enough training to redesign it into an original experiment.

The RockSat canister is a 9.3-inch diameter by 9.5-inch tall aluminum cylinder that provides both the mechanical interface to the sounding rocket structure and the containment of the payload equipment. While this concept is not new to WFF, it has been refined for the RockOn and RockSat programs.

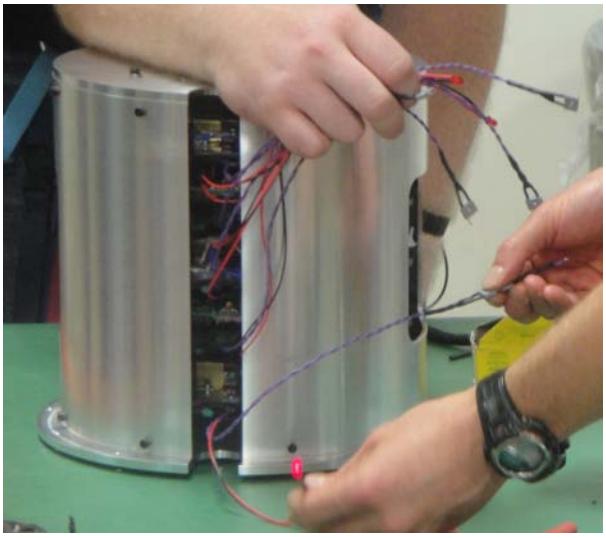

Figure 6: RockSat Canister with 5 integrated RockOn Payload Plates (wire way visible)

The RockSat canister interfaces directly with internal structure of sounding rocket, which consists of four longerons, shelf brackets, and 12-inch diameter rings. There are 12 bolts that attach each RockSat canister directly to these rings. Each canister has a wire-way running along one edge of the canister and this wire continues through the ring of the internal structure,

Figure 7: RockSat Canister being integrated with rings and longerons

allowing for easy electrical harnessing on the rocket. This relatively simple mechanical and electrical interface allows the integration of the RockSat canisters to be integrated in minutes, not hours. A typical RockOn/RockSat launch consists of nine RockSat canisters in two experiment sections. In previous years, these sections have been fully integrated within a matter of hours.

The RockSat program was designed to be the next step after RockOn. Those participating in the RockSat program are not required to participate in RockOn, but it is preferred. COSGC manages the RockSat program from the campus of the University of Colorado at Boulder. The RockSat program utilizes the same RockSat canister although RockSat payloads weigh 20 pounds (including the canister) while RockSat canister holding RockOn payloads only weighs 13 pounds. Experimenters with the RockSat program also have access to the space environment through static and dynamic pressure ports. They also have access to optical ports for imaging and antenna ports for other types of detectors. Those interested in flying a RockSat are expected to meet all the requirements of the RockSat Users Guide, which is freely available on the RockSat website. RockSat payloads do not receive power or data storage from the rocket but the rocket is recovered after the flight.

The first step in the RockSat program is to state one's intent to fly. There is an Intent to Fly Form (IFF) that users complete, indicating their intended mission and what types of ports their mission would need. Contact information is also provided on the IFF form. The IFFs are reviewed by COSGC and a preliminary manifest is created. Users are notified by COSGC to proceed or reapply next year. Users will then begin the RockSat design review process that meets all the requirements and specifications of the RockSat Users Guide, which includes Conceptual (CoDR), Preliminary (PDR) and Critical Design Reviews (CDR). At the conclusion of the CDR, COSGC will finalize the flight manifest with WFF and notify users of their selection status. Once selected, users are required to submit one-half of their flight fees to COSGC. Users complete additional reviews and documentation for COSGC and WFF, similar, but accelerated, process seen in industry design. The users are guided through three design reviews and several interim-testing reviews leading up the final Mission Readiness Review one to two weeks before launch. One week before launch, users travel to WFF to conduct mechanical and electrical interface checkouts along with pre-flight environmental tests. Users have two days to correct any issues before final integration begins. Once all the canisters are integrated to the rocket, the entire rocket assembly is spin balanced and pressurized for flight. The assembled rocket is moved to the launch rail and the final preparations are made for the launch the following day. The day before launch, RockSat users present their missions to that year's RockOn participants. This helps motivate and illustrate to the RockOn participants to become users of the upcoming year's RockSat program.

Launch of the Terrier Improved Orion occurs early in the morning to increase the chances of favorable weather conditions. The first stage Terrier motor burns for ~5 seconds. There is ~7 second delay before the second stage Improved Orion motor ignites for a burn of ~25 seconds. Both motors separate during the flight and the payload experiment sections continue for ~171 seconds before reaching an apogee of ~73 miles. The parachute deploys at 412 seconds and followed by splashdown at 929 seconds at ~40 miles downrange from the launch site. The payload section is recovered

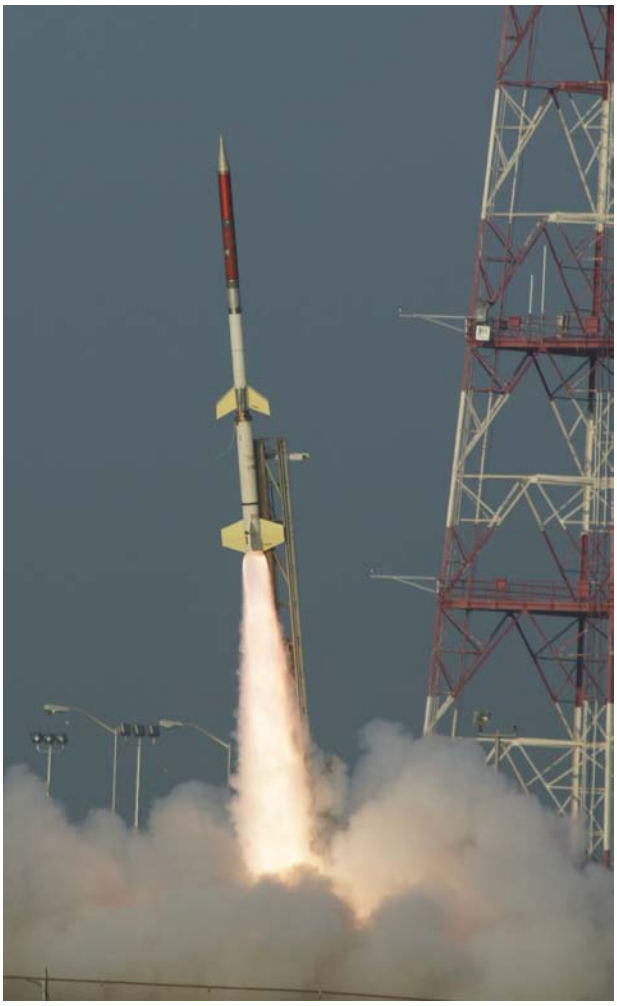

Figure 8: Terrier Improved Orion 2010 Launch

in the water and returned to WFF on the same day as launch, where users and workshop participants work side by side with WFF technicians to de-integrate their payloads. Users that participate in the RockSat program are expected to complete a final report two months after launch, which is then posted to the RockSat website.

The registration fee for RockOn is roughly $1,500 per person but each person brings a portion of the flight hardware home. The flight fee for RockSat varies depending on the portion of the RockSat canister used. Users can use the whole can for $12,000 or a half can for $7,000. In some situations, canisters can be subdivided into quarters with each quarter selling for $5,000. COSGC uses the funds generated to cover the expenses to administer and manage the RockOn and RockSat program with any extra funds reinvested into the next year's program. This is a relatively inexpensive price for universities to provide students with valuable industry-like experiences with engineering design and testing.

OUTCOMES

Since the first RockOn workshop in 2008, a total of four workshops have been held. 150 people have participated from 32 states. 50 payloads have been built and 41 payloads have successfully worked on flight (nine are still awaiting launch at the time of writing this paper). There have been 23 RockSat payloads launched since the first one launched in 2008, with another 9 scheduled for launch in June 2011. 17 universities now have active sounding rocket programs, many of which have started as result of participating in the RockOn workshop.

Types of experiments that have been flown include:

The 2011 Drexel RockSat team designed a payload with a goal to experimentally determine the feasibility of a de-spun platform under high acceleration and turbulence, driven by a low power system. This payload was designed to provide a stable platform with respect to the exterior environment to accommodate any future experiments that require a constant frame of reference in an ascending rocket.

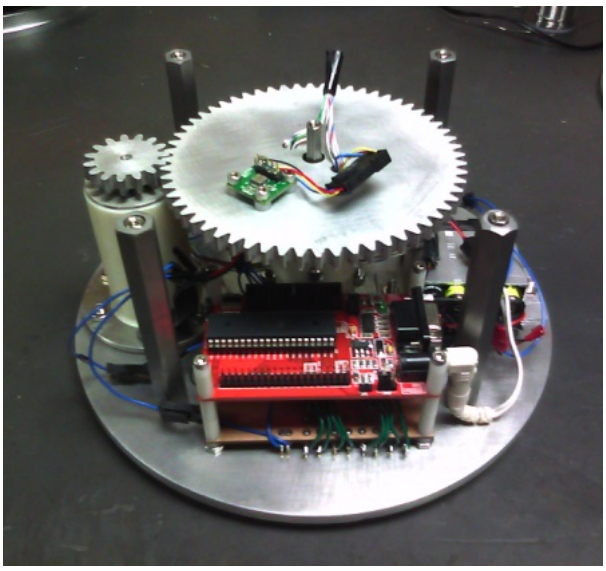

Figure 9: Drexel University RockSat 2011 Payload

The University of Puerto Rico flew a RockSat payload to conduct experiments related to the identification of gases during the flight using a semiconductor gas sensor. It also collected aerosols using a polymer nano-scale filter (25 to1000 nm), contained a bio-sample culture collection and survey, and performed element characterization using laser spectroscopy analysis. This team has had a payload on every RockSat flight since their original participation in the RockOn workshop in 2008.

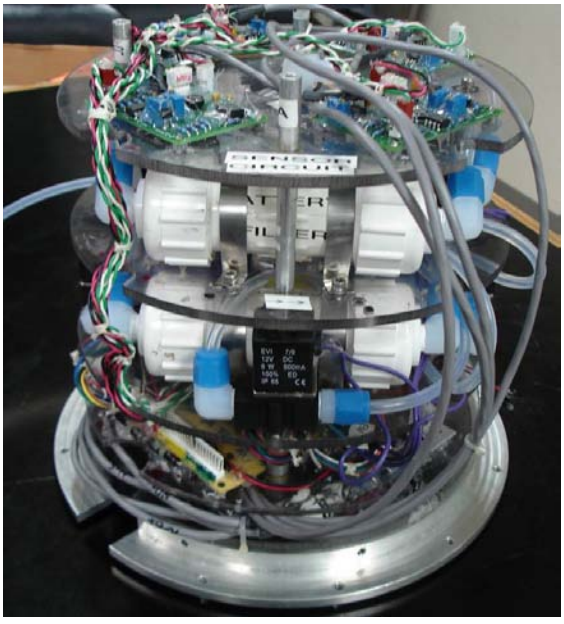

Figure 10: University of Puerto Rico RockSat 2010 Payload

The University of North Dakota flew on the RockSat 2009 flight. Their mission was to measure concentrations of H_2, CH_4, CO (reducing), O_3, O_2, N_2O (oxidizing), in the mesosphere in nearly real-time using nano-crystalline oxide semiconductor sensors arrays, to measure the number of particulates in the air, using a particle counter, and to obtain information on the magnetic field strength.

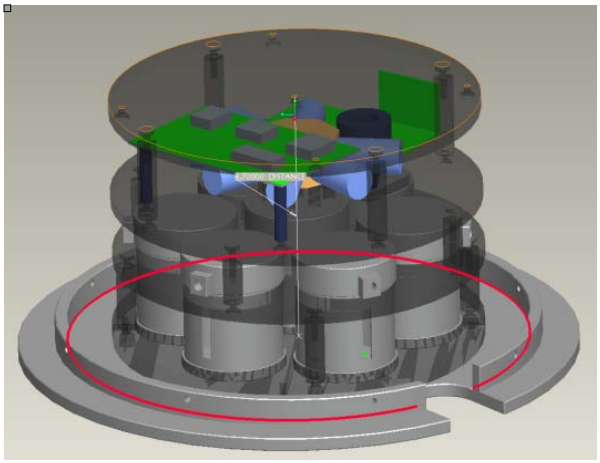

Figure 11: University of North Dakota RockSat 2009 Payload

The University of Wyoming experiment in 2010 was to characterize the flight and measure the generation of power by tapping the rotational energy of the rocket. The team also tested a wireless data recovery system that was used after the rocket landed in the ocean.

The RocketSat team from the Colorado Space Grant has had a payload on every flight since the program began in 2008. The objective of RocketSat IV and V was a collaborative effort with the National Oceanic and Atmospheric Administration (NOAA) to fly an Aircore payload on a rocket flight. Aircores are typically flown on aircraft, and the challenge for the CU team was to integrate the Aircore coils into the standardized payload canister.

Figure 12: University of Colorado at Boulder RocketSat VI Payload 2010

It is hard to determine exactly how many students the RockOn workshop and the RockSat program have directly impacted but it has been estimated to be over 1,500 students. Of this group of students, many have moved on to more advanced projects and/or advanced degrees while many others have moved on to successful careers in the small and large satellite programs in industry. There are many of examples of anecdotal evidence directly from students detailing that their experience with RockOn and RockSat programs have directly affected their career path and subsequent opportunities.

FUTURE

For the last four years, the RockOn and RockSat programs have been successful in training students through the real-world space experiments that are tied directly to actual space launches. Each year, steps are taken to incorporate lessons learned from the previous year to make the programs better the following year. WFF has been very supportive of these programs and has worked side by side with COSGC to institute refinements to the programs each year as they grow. WFF is also supportive and enthusiastic in looking for ways to expand the RockOn and RockSat programs. In fall of 2009, WFF and COSGC started discussions on the next step of the RockSat program. This step was called RockSat-X. With the RockSat-X program, all users have full access to the space environment, as the skin of the rocket will be ejected during the flight. Users will also receive telemetry and power from the rocket. After landing in the water, the RockSat-X payloads will be recovered. The first launch of the RockSat-X program is scheduled for July 2011 with

four experiments from four schools that all got their start in RockOn and then continued their experience with the original RockSat program. The RockSat-X program will follow the same design model as the original RockSat program and User's Guide is available on the RockSat-X website, which can be found at spacegrant.colorado.edu/rockon. The cost for 30 pounds of payload on the RockSat-X flight is ~$24,000. The intention of WFF and COSGC is to continue offer all three programs each year as long as student interest in the programs continues. WFF is also interested in supporting multiple RockSat launches each year if interest levels increase to such a level as to warrant additional launches. WFF is also willing to consider different launch locations depending the science and engineering requirements of the mission as the RockSat program users develop. Eventually, like the BalloonSat programs, students will start to look beyond sub-orbital rockets. COSGC has discussed, at a very top level, their idea of the next step beyond RockSat in which students' payloads would reach orbital altitudes on a regular and consistent basis with WFF. This program too would be modeled around the same philosophy of both the BalloonSat and RockSat workshops and programs. COSGC began preliminary work on this next step in 2010 and hopes to have the groundwork completed for a first workshop as well as flight in 2014.

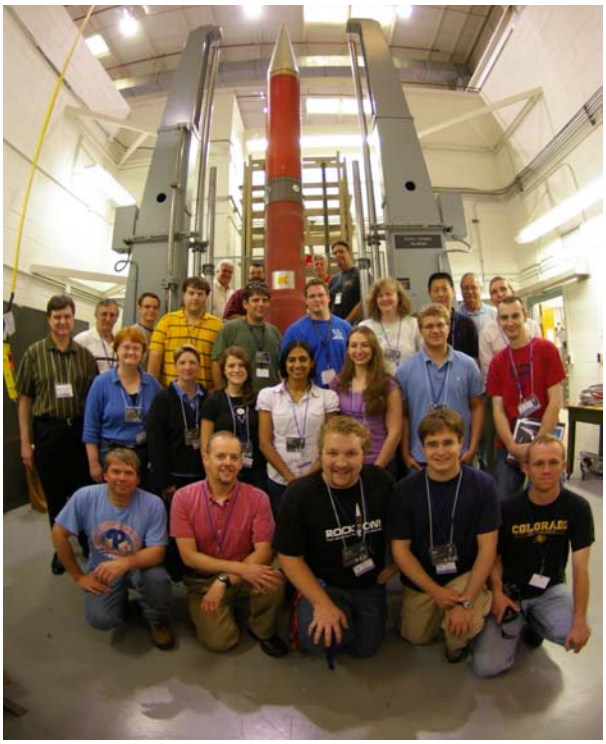

Figure 13: 2010 RockSat Participants

CONCLUSION

The RockOn and RockSat programs are enabling students to gain valuable experience with real-world space missions that are tied to actual launch opportunities. These programs provide regular and consistent access to space for students and the faculty and companies that they are partnering with. Both RockOn and RockSat, and soon RockSat-X, have demonstrated a successful model for students develop their missions with NASA's Wallops Flight Facility, who is know for their regular and reliable sounding rocket program. This direct connection with NASA is attractive to many of the students involved with the RockOn and RockSat programs and motivates them to pursue further space related opportunities. The RockOn and RockSat programs will be active for the next several years, allowing any student interested in gaining the experiences and skills needed for the workforce of tomorrow to obtain it in a valuable and meaningful way.