Combining Undergraduate Student Curriculum, Research, and Outreach:

High-altitude Balloons and Rockets

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Background

Student research is known to be a high-impact learning to participating students. At Utah Valley University, we are introducing a student-driven research paradigm where the research is integrated with the undergraduate curriculum and students form their own scientific hypotheses and design experiments to address the science objectives.

To increase research opportunities, a high-altitude balloon program was recently established by the Utah Valley University (UVU) Society of Physic Students. The short-term objective of this project was to establish a platform for students to develop a variety of small scientific payloads to be flown in the Earth's near-space environment. This project has to date involved more than 50 students and has been included as part of the curriculum for both non-majors and majors.

Most recently, a group of UVU students received an institutional grant to implement small rockets capable of carrying payloads to this high-altitude program. Both balloon and rocket platforms are fundamental in-situ measuring techniques for numerous geoscience subjects, and are arguably best illustrated by the NASA balloon and sounding rocket programs.

OBJECTIVES

- Short-term: create a vibrant research program for students.
- Long-term: expand the program to compete for large-scale projects involving NASA balloon and sound rocket programs, and NSF cube-sat based science missions.

We present results from the short-term objective. Specifically, we report on the research opportunities, curriculum development, and outreach activities. **We will specifically focus on our most recent implementation of rocketry.**

Balloon Program

- Initiated in Fall 2013 and lead by the UVU Society of Physics Students.
- To-date five successful launches.
- Payloads build by systems flown include:
  - Transmitting telemetry system
  - Basic atmospheric sensors: pressure and temperature
  - Ozone sensor
  - Acceleration
  - Gimballl mounted GoPro camera system to photograph planets on the ecliptic plane.
  - Nadir mounted near-infrared camera.
  - Bio-aerosol collecting device
  - Solar Cell Performance
  - Cosmic ray detector

Preparing the balloon and payload for the maiden flight.

Rocket Program

The overarching objective of the rocket program is to explore the detailed physics behind sounding rockets (including their history) and expand the high-altitude research program to include sounding rockets to be flown with scientific payloads, all constructed by students. The specific objectives are:

OBJECTIVES

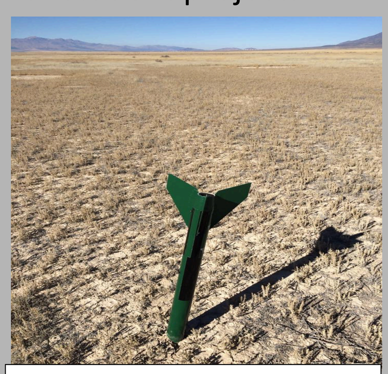
- Construct small payloads capable of high-stress environments, which are not encountered during balloon flights.
- Construct a variety of small rockets modeled after acclaimed rockets.
- Increase student knowledge of past rocket experiments and science behind rocket motion.

These objectives will greatly propel the UVU High Altitude Research Program to include rocketry, and significantly expand opportunities for student projects.

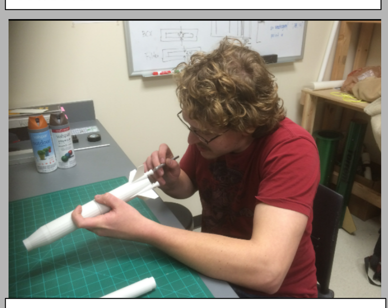
Approach

The research effort is directed by a group of students, who are currently involved with the high altitude research project.

- The Arduino family of micro controllers are utilized to gather scientific data during flights.
- The model rockets are purchased as kits to be assembled and tested prior to flight by our group of students. This provide the students with the experience to design and construct their own rockets.
- "Home brew" rockets will be designed and constructed as part of the projects.
- The group meets regularly to study the theory behind rocketry and history of rockets as a seminar-style of teaching. The seminar is available to anybody who is interested.



A model Black Brant II sounding rocket turned missile turned soil core collector.



Assembling a modular self-designed 3D printed Arianne I rocket.

Example Flights

We utilized a commercial rocket design software to make prediction regarding flight details. Figure 1 shows the rocket design incl. center of mass (blue) and pressure (red). Figure 2 shows the predicted flight information, including boost time (green), apogee (pink), and parachute deployment (blue).

Rocket Details
Length: 39.00" (99.06 cm)
Weight: 14.00 oz (396.89 g)
Diameter (Max): 2.60" (6.6 cm)
Fin Count: 3
Motor Size: 29mm
Recovery System: 22" Nylon Parachute

Motor Details
Delay: 10 sec
Burn Time: 1.4 sec
Total Impulse: 109.9 Newton-seconds
Total Mass: 125.0 g

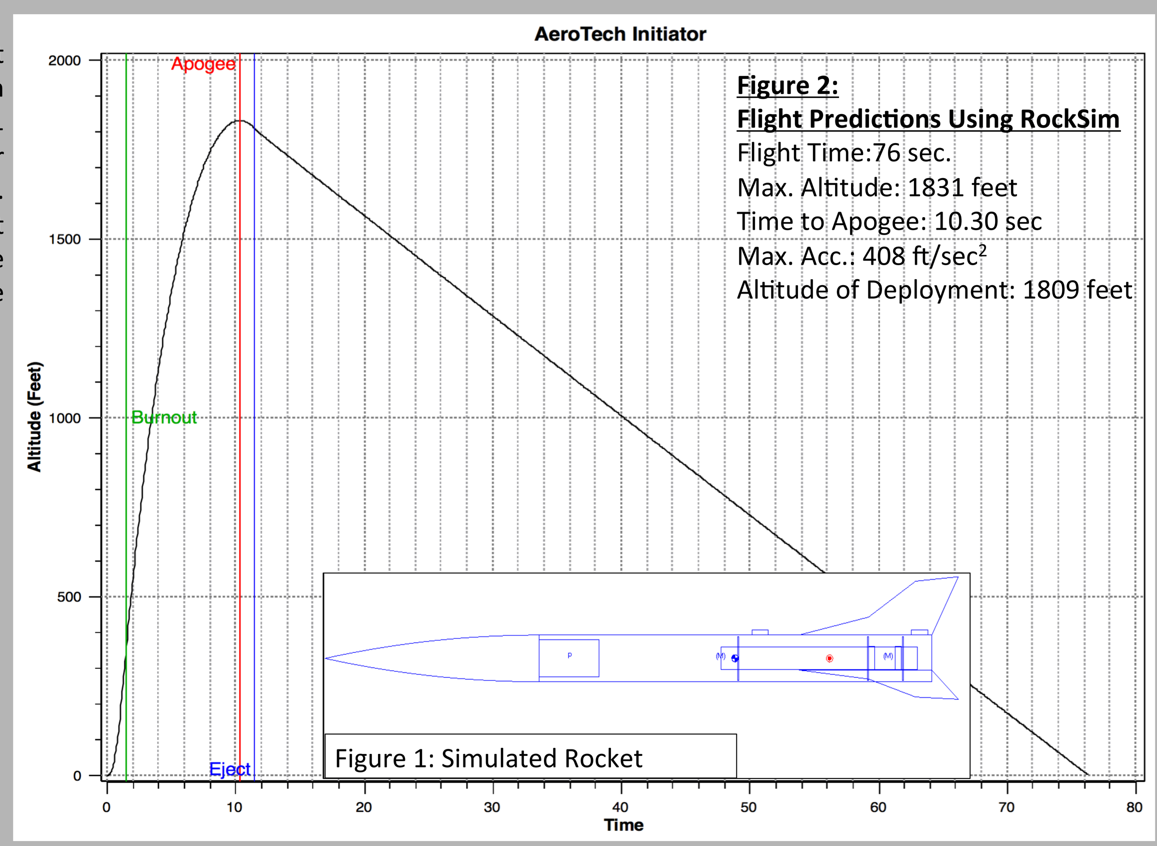
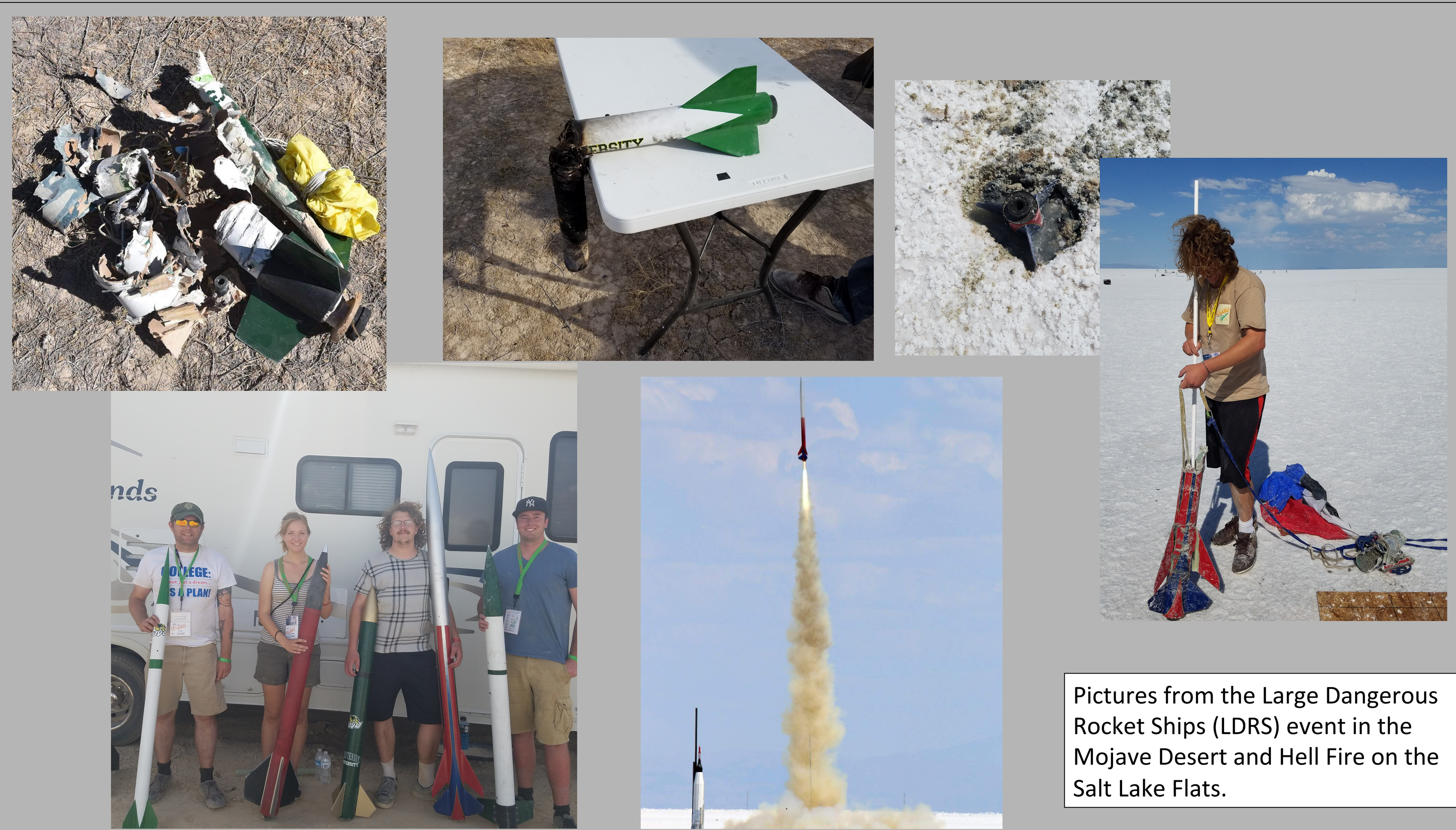


Figure 2:
Flight Predictions Using RockSim
Flight Time:76 sec.
Max. Altitude: 1831 feet
Time to Apogee: 10.30 sec
Max. Acc.: 408 ft/sec^2
Altitude of Deployment: 1809 feet

Figure 1: Simulated Rocket



Pictures from the Large Dangerous Rocket Ships (LDRS) event in the Mojave Desert and Hell Fire on the Salt Lake Flats.

With the gained experience, a large level 3 rocket was attempted. Designed from scratch, Eric Davis successfully flow a Tripoli L3 certification flight. Tripoli is the sanctioned organization for high-powered amateur rocketry and L3 is the highest level achievable. This particular rocket reached 8,000 ft.

Implementation into UVU's Curriculum

The high-altitude balloon and rocket program at UVU provides excellent opportunities for integration into the existing curriculum, but also for creating new courses. Examples of implementation include basic fluid dynamics and variable mass motion in introductory physics, realistic projectile motion solved numerically in computational physics, orbital and sub-orbital motion in advanced mechanics, and lastly, a newly developed course in rocket science where students learn more detail about rockets.

- History of Rockets
- Variable mass motion
- Gravity
- Orbital Dynamics
- Suborbital Rockets
- Rocket Design
- Electronics
- Assembly
- Flight

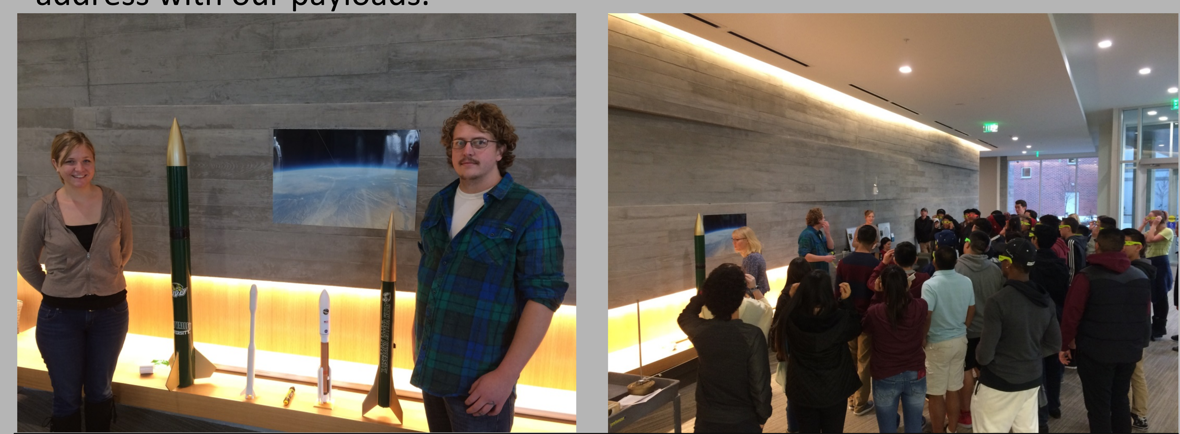
Topics covered in the anticipated Rocket Science Course.

Rocket Science Course

The course will be developed for students who have successfully passed introductory physics, and give them a rare opportunity to explore concepts in detail that are often omitted or lack detail from the introductory curriculum. These concepts include variable mass dynamics, orbital motion including transfer modes, more advanced fluid mechanics. The highlight of the course is the design, construction, and launch of a high-powered rocket (typically requires level 2 or 3 certification).

Outreach Activities

Both the balloon and rocket projects are excellent outreach events, which often draw a crowd. We invite students, families, and the larger community to actively participate in our launches. Specially the balloon launches are popular as everybody can help out with inflating and supporting the balloon during launch. The rocket launches are spectacular with their loud noises and billowing smoke, and it times, entertaining failures. During these events, we educate the participants of both flight and the science behind, and the scientific questions we are attempting to address with our payloads.



Pictures from our outreach event during Wolverine Weekend.

Space Port Cup 2017

The next step in our program is participation in the Space Port Cup in summer 2017. This event is an international collegiate engineering competition with focus on sounding rockets, and participation of more than 100 universities from all over the world. As part of this project, we are working with Maple Mountain High School to construct a eco sensor payload to be flown on the rocket.

Our rocket, Midoro-10,000, is designed to carry scientific payloads to 10,000 ft, but also designed with the future in mind. If the rocket survives its maiden flight during the competition, it can easily be expanded to a two-stage rocket capable of reaching 30,000 ft.

Acknowledgements

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