Dædalus Astronautics @ Arizona State University

NASA University Student Launch Initiative
Post Launch Analysis Review

Angelo Colangelo and Matt Summers
Team Leads: USLI VCM Project. Arizona State University

James Villarreal and Jacob Dennis
Project Manager & Project Director, respectively. Arizona State University

and

Carlos Ballesteros, Christopher Gay, Felipe Hernandez,
Marjorie Rima, and **Thomas Villarreal**
USLI Project Members. Arizona State University

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I. “*Vertical Cruise Missile*” (VCM) Vehicle Summary

1. **Team Summary:** Daedalus Astronautics @ ASU

   Daedalus is a completely student run organization dedicated to the design, manufacture, and launching of sounding rockets. Daedalus members undertake self-driven advanced astronautical engineering projects to provide themselves the opportunity to enhance their educational experience and develop professional skills.

   Throughout the past six years Daedalus members have successfully designed, constructed, tested, and flown seven different large reusable sounding rocket designs. Each new rocket tests substantially improved technologies over the previous design with recent launch vehicles making use of advanced carbon fiber composites, real-time radio and GPS telemetry, and recently the addition of student designed and mixed experimental large solid rocket motors and hybrid rocket motors. Such design processes provide an extensive and unparalleled educational experience for Daedalus student members.

   These same students actively express their knowledge through University level rocket competitions, professional presentations, technical research writing, presentations at the American Institute of Aeronautics and Astronautics (AIAA) student conferences, detailed design methodologies for component systems, in-house seminars to underclassmen, leadership roles, effective participation in a cross-functional dynamic team environment, and creation of and participation in an extensive K-12 outreach program that has reached over 800 students over the past five years.

   Pertinent information:

   a. **School Name**: Arizona State University

   b. **Website**: http://www.daedalusastronautics.com

   c. **Location**: Tempe, Arizona

   d. **Mentors**: Dr. Marion Vance, Instructor; James Villarreal, PhD student.

2. **Launch Vehicle Summary:** *Vertical Cruise Missile* (VCM) is a high-powered sounding rocket designed to achieve an altitude of 5,280 feet AGL as required per USLI competition requirements. However, VCM includes a modular motor retention system that can accept up to 75mm motors such that it can achieve even higher altitudes in future launches. The structure of VCM is an all wet-cloth carbon fiber wrapped body, excluding the nosecone, and includes a dual-deployment parachute system. VCM, shown below in Fig. 1, has the following pertinent dimensions:

    a. **Rocket Height**: 100.5 inches

    b. **Rocket Diameter**: 4.25 inches

    c. **Rocket Dry Mass**: 16.42 lb (excluding payload)

    d. **Rocket Motor**: Loki K960 solid rocket motor.

Figure 1: *VCM rocket prior to launch at NASA USLI rocket competition.*

The design of VCM serves three purposes:

- Competition rocket for the NASA sponsored University Student Launch Initiative (USLI). The goal of this program is to deliver a payload to one mile altitude.

- Competition rocket for the 4th Intercollegiate Rocket Engineering Competition hosted by the Experimental Sounding Rocket Association. The goal of this program is to deliver a 10 pound payload to 10,000 feet. This launch date is set for June 26th. More information at: *http://soundingrocket.org/4thIREC.aspx* .

- Replacement second stage for a previous Daedalus rocket: Duck and Run to Safety (DARTS); see Fig. 2. The DARTS rocket had a successful first and second stage launch at the 2008 ESRA Intercollegiate rocket competition. However, the second stage electronics failed to ignite the ejection charges for the upper stage and the second stage rocket was destroyed. This is the primary reason for the forward placement of the fins on VCM (refer to Fig. 1). This allows adequate room for the friction fit between the VCM rocket and the interstage coupler.

Figure 2: *DARTS launch.*

3. **Payload Summary:** The payload for VCM was a student built flight computer, complete with three access accelerometers, pressure and temperature measurement devices, telemetry, and GPS. Most of the components were donated to Daedalus from Freescale Semiconductors. Our electrical engineers encountered far more difficulties than originally anticipated during the integration stages of our payload assembly. As a result we chose to launch the rocket without the complete flight computer assembly. Granted, the vast majority of the payload was in an operational state of completion, the safety risks were simply too great. Also, it was important for VCM to remain reusable since it is already planned to be launched again on May 23rd, 2009 for a test flight using our experimental solid motors, as well as another launch at the ESRA competition in June, 2009 as previously mentioned.

II. Data Analysis and Results of VCM Vehicle

1. Flight Profile

a. **Launch Pictures**:

Figure 3: *VCM rocket launch at the NASA USLI rocket competition.*

b. **Altitude, Velocity and Acceleration**:

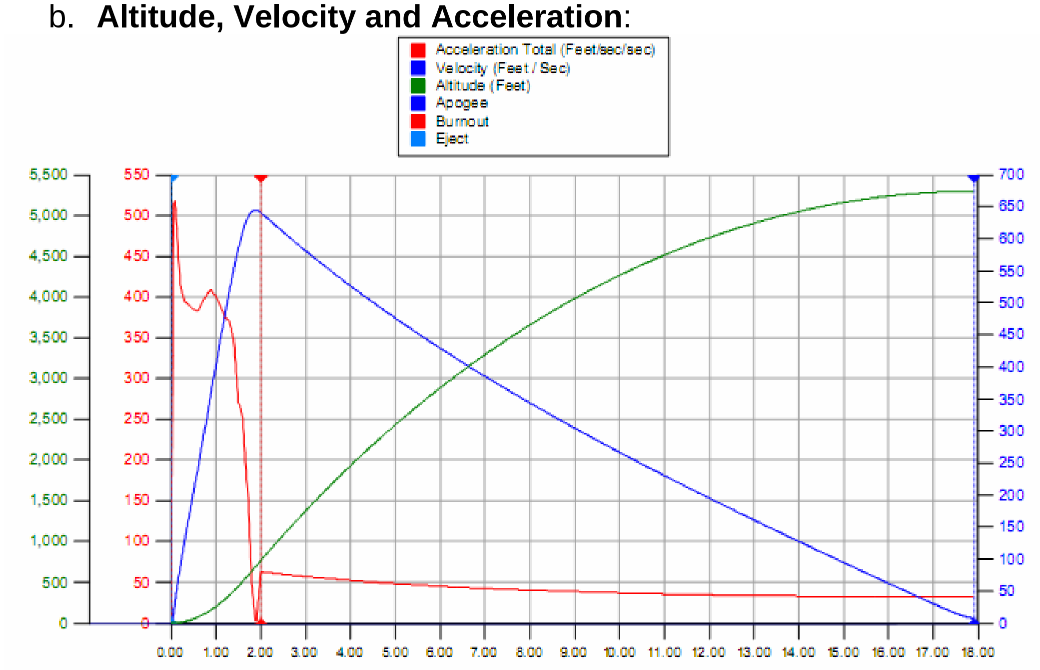

Figure 4: *VCM altitude, velocity and acceleration verses time.*

From Fig. 4, we were able to obtain the following maximum values.

Maximum Altitude: 5,293 feet
Maximum Velocity: 644.38 ft/sec
Maximum Acceleration: 517.98 ft/sec^2
Motor Burn Time: 2 sec
Time of Apogee: 17.92 sec

c. **Final Altitude:** The final altitude of the VCM rocket was **<u>5,293 feet</u>** as recorded by a PerfectFlite miniAlt/WD (MAWD) dual event logging altimeter. A secondary altitude logging device, a PerfectFlite Alt15k/WD (miniAlt), recorded a final altitude of 5,303 feet. However, the PerfectFlite MAWD was selected by the judges prior to the launch to be the primary recording altimeter.

Figure 5: *Recovering Final Altitude with Judges.*

The Arizona State University Daedalus Astronautics rocket team was closest to the one mile altitude goal amongst the other University-level competitors, off by a mere 13 feet. As such, **the team was awarded the "Closest to Altitude" award** at the ATK Sponsored USLI awards ceremony.

2. Visual Data

a. Some visual data gathered from the launch day is already provided by Section II 1.a. Apart from the images gathered before and after the launch, no other visual data was produced.

III. Payload Summary

1. Purpose of Payload

The ATLAS student built flight computer is designed to perform in-flight experiments in order to obtain a flight profile of the respective science experiment. The scientific experiments that ATLAS is capable of measuring are the determination of air density, maximum dynamic pressure, velocity, drag coefficient, maximum loads, the amount of off-axis thrust, motor burn time, and confirmation of the flight simulations of the vehicle.

2. Data Analysis and Results of Payload:

Although we were unable to have ATLAS fully-integrated for the launch, our commercial flight computers and altimeters provided us with a significant series of data sets. From this data we can perform much of the analysis desired. The commercial boards provided measurements for altitude, velocity, acceleration, and motor burn time. The plot, along with maximum values and periodic points of interest are given in Section II 1.b.

3. Scientific Value

Individually each of the recorded data sets serves a unique purpose as previously mentioned in past design reviews; however, the cumulative set of our flight profiles serves an even greater purpose. Together, these data sets are to be used as a basis for the research, design and development for future Daedalus rockets. This comparative analysis between our theoretical analysis and our numerical solution gathered during flight will provide a rough calibration from which we can extrapolate design parameters to meet certain mission requirements.

4. Future

For the upcoming ESRA competition we will be using ATLAS to perform the science during our flights, and to operate a secondary roll-control payload which members of our USLI team have designed and are preparing for preliminary testing later this month. Building our payload for all these different integrations eventually became our impeding difficulty in developing the payload by the launch date for the USLI competition. However, with the semester now coming to a close, Daedalus members can focus more of their efforts toward the completion of ATLAS and all of its integration features.

IV. Outreach Summary

1. Introduction to Rocket Design Outreach Program

Outreach is not a new concept to our student group. In fact Daedalus has been performing our highly successful ""Introduction to Rocket Design" outreach program" to K-12 students for over five years. All Daedalus members are required to participate in this community outreach program that promotes science, math, and engineering through interactive activities applying theoretical principles to innovative exercises and design competitions for K-12 students.

Daedalus participation in these programs helps reach a group particularly in need of such energy, excitement, and young role models. Through the very interactive and highly popular "Introduction to Rocket Design" outreach program, where students design, build, and launch their own small model rockets by applying basic Newtonian physics and simple aerodynamic principles, Daedalus members have individually reached well over 800 students from elementary, middle, and high school classrooms. The "Introduction to Rocket Design" format has been put into practice over the past five years. Throughout this time the program has evolved into a small series of rocket design lectures, building, and flight operations. The rocket outreach program has recently introduced model rocket competitions such as a rocket egg drop competition and flying small altimeters as payload to determine the final altitudes and match against the student's own calculations.

It is important to note that the outreach programs of Daedalus include those performed as part of our participation in the USLI competition, but are by no means limited to the competition. One of the USLI Team Leads, Matt Summers is currently working with the K-12 Outreach Coordinators of the ASU Fulton School of Engineering to setup four additional outreach events for the months of May-July, 2009. The rocketry events he is coordinating are the *YES! to Engineering Junior High Program*, *YES! to Engineering High School Program, Summer Transportation Institute Program*, and the *Success In Engineering Education (SEE) Summer Bridge Program*, all run by Arizona State University. Because of the large contributions and impacts Daedalus members have made with these programs in the past, we have been asked to return with more members, more events, and more rockets for future outreach events.

2. Navajo Elementary Outreach Program

One such outreach event was executed at Navajo Elementary School in January 2009. Daedalus members helped 79 5th graders from three classes over three days build and launch their own model rockets (59 total) on Navajo school grounds. The following are some model-approved pictures from the event:

Figure 6: *Collage of rocketry Outreach Event at Navajo Elementary.*

The Daedalus Project Manager, James Villarreal, is a NASA Space Grant Graduate Fellow for the 2009 Spring Semester. His informal outreach project includes an assessment of the Daedalus Introduction to Rocketry outreach program over the years. His work will conclude in the middle of May, 2009 with a “how-to” for the outreach program in the form of an information pamphlet.

For more information on our outreach programs, with a complete listing of schools including pictures and videos, please visit our website at:

http://www.daedalusastronautics.com/Outreach%20Events.htm

V. Lessons Learned

1. Summary of Overall Experience

From the onset, our participation in the NASA USLI competition is part of a larger "knowledge management" focus currently in progress at Daedalus. Our group works on a variety of projects throughout the year, but most of them are pretty complicated and do not always involve undergraduates. This includes projects on hybrid motors, aerospike nozzles, mixing and testing experimental solid rocket motors, ESRA competition in Utah, and very complicated rocket designs. In the past, our version of knowledge management has involved presenting at AIAA Regional student conferences, which we always perform very well in. However, the student conferences are only one small part of our big push towards more diverse forms of knowledge management. In that respect, this has been fantastic program for our group. USLI has been a great way to spread our knowledge around substantially and give our undergraduates experience in taking charge of a rocket design project.

Throughout the time spent designing, building, and preparing the rocket for the competition, group members who were new to Daedalus were involved in every step of the rocket. Integrating new members through all of the processes is the most efficient way to ensure adequate knowledge capture necessary to sustain our group in the long term.