

**NASA Student Launch Initiative 2006-2007**  
*Final Report*

**Post Rocket-Flight Expression of Stress  
Response Genes in Refrigerated  
Wild-Type *Arabidopsis thaliana*  
Compared to that of Agravitropic  
Mutants**

**NOTE: Because of the limited access to the necessary lab equipment and shortage of chemicals, the final step of the experiment analysis had to be postponed until mid-late September. The final report will be updated and posted as soon as the results are available.**

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## I) VEHICLE REPORT

### Construction

The body of the rocket is constructed mostly from fiberglass tubes. The nosecone is a pre-manufactured plastic nosecone, and the boat tail is cut from a pre-manufactured nosecone. The motor mount is constructed from phenolic tubes. The Payload Integration Modules (PIM) are constructed from phenolic tubes reinforced with an epoxy coating. The triangular fins are cut from sheets of G-10 Fiberglass, and are secured via through-the-wall (TTW) construction. The final rocket is approximately three inches in diameter and ten feet, eight inches in length, weighs approximately 13 pounds.

### Vehicle Drawings



Figure 1: Diagram showing the stability of the rocket. CG is located 68.75" from the nosetip and the CP is 85.61" from the nosetip. The rocket has 5.44 calibers of stability at the liftoff when J800T or J2135NP motor is used.



Figure 2: 3D Model. Color code: blue – structural elements, red – propulsion, cyan – cold temperature payload compartment, green – ambient temperature payload compartment, yellow – electronics bay. The drogue parachute is housed below the electronic bay, the main parachute is above the electronic bay.

### Parachute sizes

This rocket used a dual deployment recovery system. Both the drogue and main parachute were commercially available rip-stop nylon parachutes with nylon shroud-lines. To determine the proper parachute size for our vehicle, we used an online calculator. We wanted the drogue to return at 45-90 feet per second, and the main parachute to return at 15-20 feet per second. These goals yielded the following measurements:

	Parachute Diameter (in)	Vent Diameter (in)	Descent Rate (fps)	Ejection Charge (g)
Main	60	9.5	17.59	2.0
Drogue	24	0	43.37	1.8

The ejection charges for the final vehicle were calculated using the formula

$$E [g] = 0.002 \cdot F [lbs] \cdot L [in] + 1.0$$

## Electronics

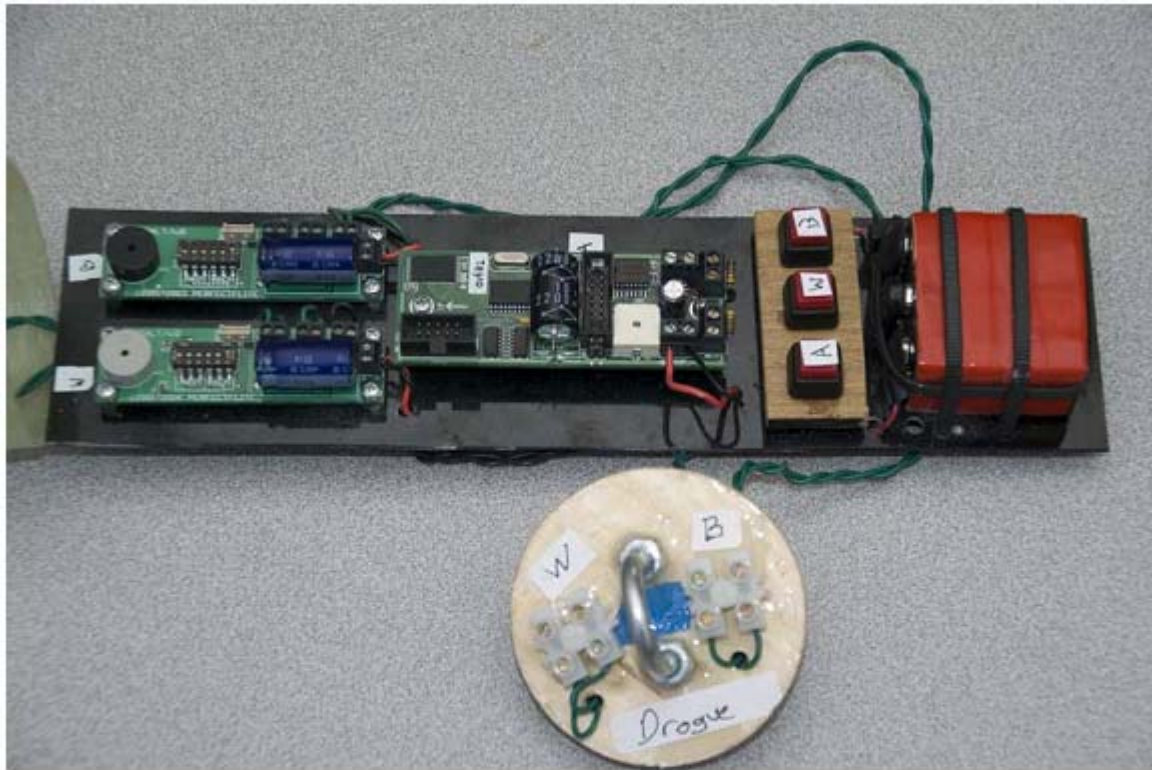


Figure 3: Electronics Board



Figures 4 and 5: E-bay and E-bay Cap

The electronics board holds two MAWD altimeters responsible for firing ejection charges, and one accelerometer for recording flight acceleration data. The two altimeters are programmed to fire the same charges (deployment redundancy). Each electronic device is powered by its own power source so a single power failure will not lead to a destruction of the whole rocket. Each device is actuated by its own push-on-push-off switch and the switches are mounted perpendicular to the g-force vector. The e-bay housing tube also couples the upper and lower airframes of the rocket. At the ends of the e-bay housing tube are plywood caps with terminal blocks for ease and secure attachment of ejection charges, and well secured U-bolts which serve as attachment points for the shock cords. The e-bay caps are secured with a steel tie rod and nuts.

### Attachment scheme

The Kevlar shock cords are attached using QuickLinks to the U-bolts in plywood bulkheads or electronics bay caps. The electronics bay caps are connected by a single 3/16" threaded metal rod. A standard dual deployment scheme with the drogue parachute under the electronics bay and the main parachute above the electronics bay is used. The electronics bay serves as a tube coupler between the booster and upper part of the rocket.



Figure 6: Shockcord, Nomex protector and quick-link

The shock cords for the parachutes are pre-folded and secured with a weak layer of masking tape to allow for ease of handling before flight. Upon parachute ejection during the course of the flight, the masking tape rips off and the shock cord unfolds itself. There are quick-links at both ends of the shock cords to fasten them securely to the rocket's attachment points. A fireproof Nomex cloth covers the part of the shock cord that is exposed to the blast of the ejection charge for protection. Nomex sheets are also used to protect both parachutes.



Figures 7 and 8: Shock Cord Attachment Points

The attachment points on bulkheads are steel U-bolts secured with nuts and epoxy. We also attached a steel eyebolt to the nosecone because the manufactured attachment points have proven faulty in the past.

## Final Flight Analysis

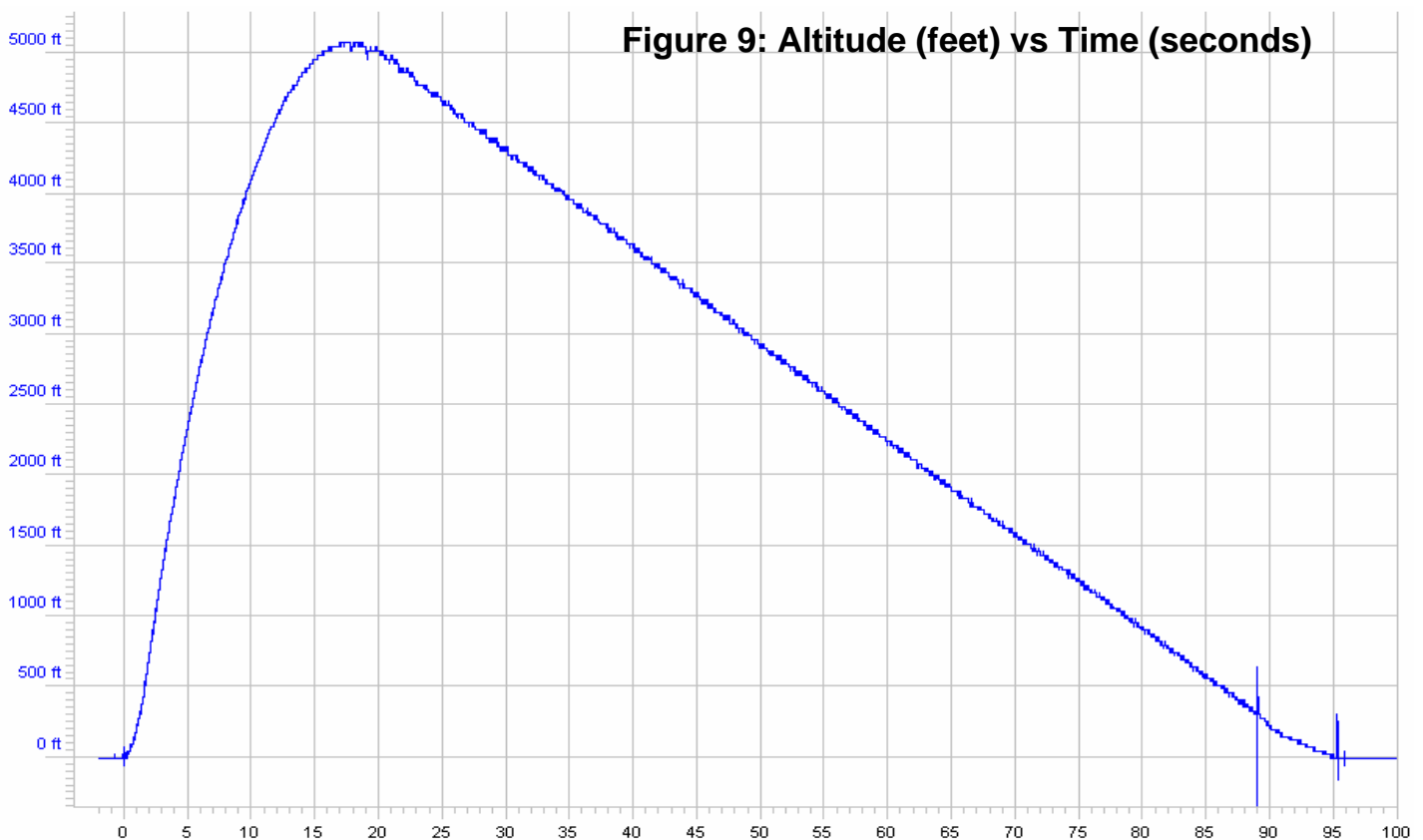
### Flight Observations

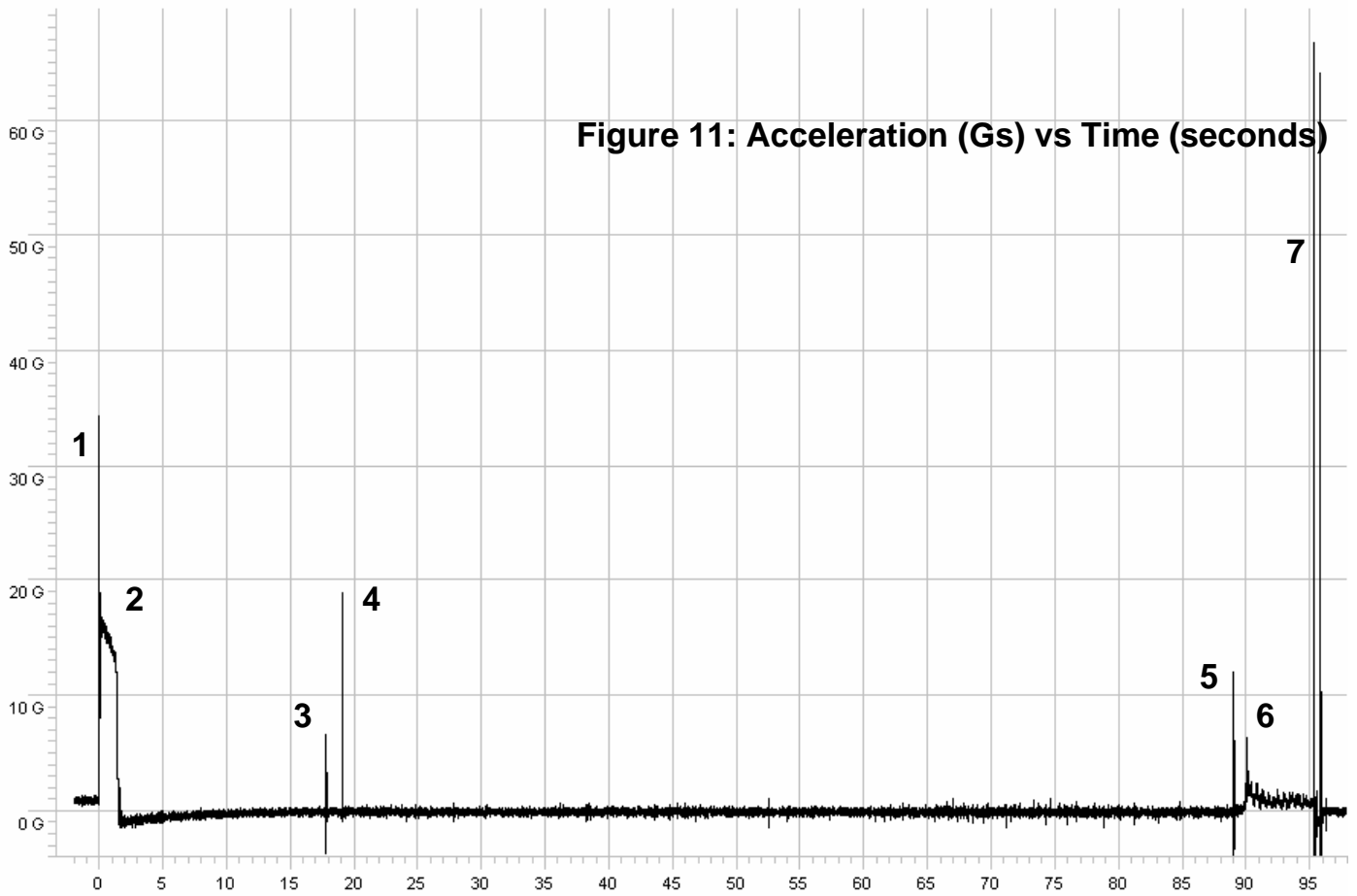
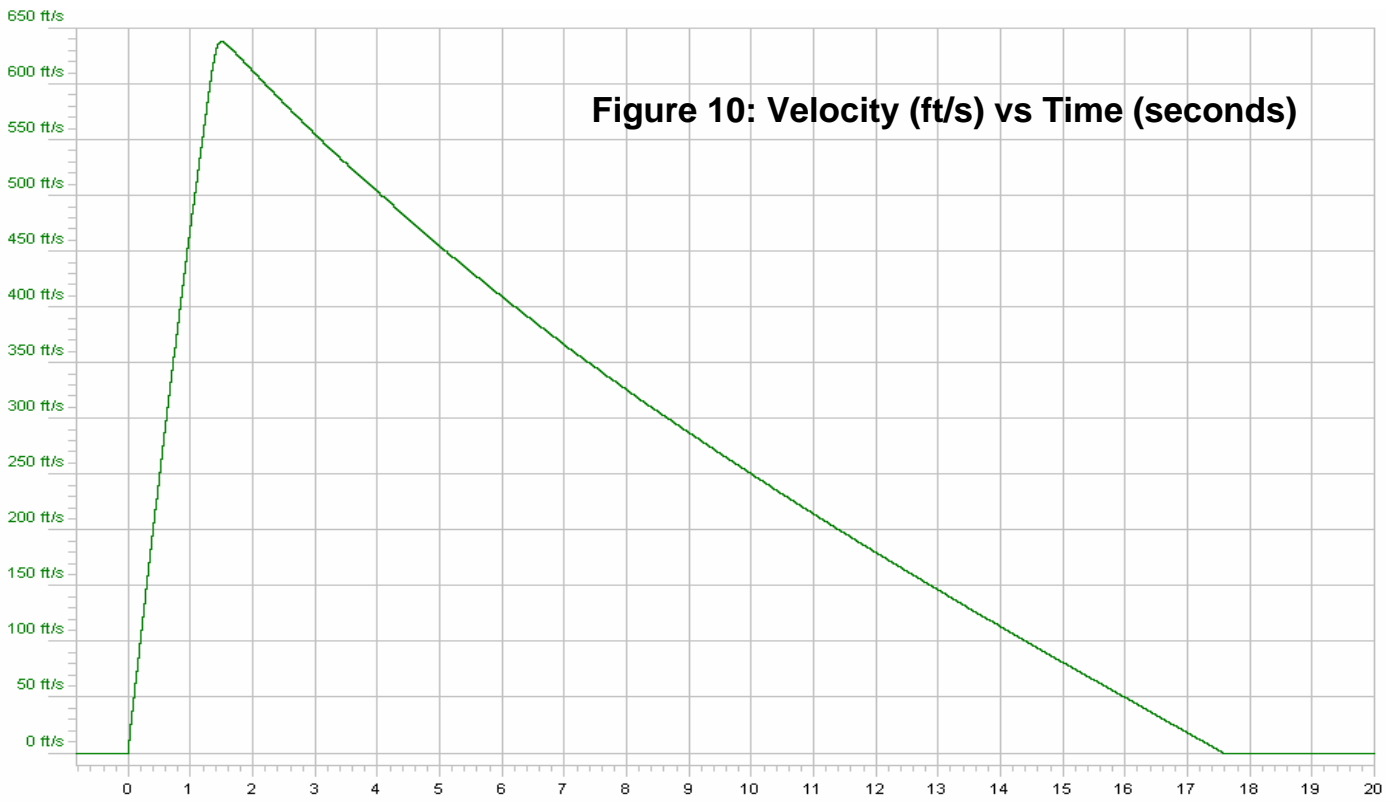
The rocket liftoff was flawless. Upon apogee, there was separation, but the drogue parachute was not visible. At approximately 300 ft, the main parachute ejected (as expected), but the rocket still descended unusually fast. Upon recovery, the electronics were shut off and the payload quickly extracted. It was later discovered that what was initially dubbed a “nearly perfect flight” was, in actuality, far from perfect.

### Post-Flight Rocket Observations

On recovery, we noticed that the main parachute had a snapped shroud line (which seemed to have been burned off by the ejection charge), and a large amount of dirt packed into the motor mount. The rest of the rocket seemed to be undamaged and, in the rush of the payload extraction, the rocket was placed aside. As we unpacked after our return from Alabama, we discovered the drogue parachute was neatly folded, covered in Nomex cloth, attached and inserted inside the rocket. Upon removal of the E-bay, we found the tie rod securing the two E-bay bulkheads (one of which is load bearing) bent significantly. In hindsight, although there was separation, a drogue parachute was not clearly visible during the rocket’s descent. We believe that the drogue parachute became entangled with the wires of the ejection charge, preventing it from ejecting and causing the tie rod to bend. However, we believe that the separation and the rocket’s tumbling descent simulated the drogue’s purpose of bringing the rocket slowly back to ground.

### RDAS Graph and Data





## **Altitude and Velocity Graphs Analysis**

The **Altitude vs. Time** and **Velocity vs. Time** graphs both have patterns typical of a high thrust motor (such as our J2135). The apogee recorded by the RDAS is 5068 ft, reached approximately 18 seconds from liftoff; the max velocity recorded by the RDAS is 639.6 ft/s, reached approximately 1.5 seconds from liftoff. The velocity graph only shows upward vertical velocity, and ends at apogee. It is interesting to note that although the drogue parachute failed to eject, the tumbling motion of the separated rocket slowed the descent.

## **Acceleration Graph Analysis**

The **Acceleration vs. Time** graph provides us with more insight as to what actually happened during the flight. We've broken down the acceleration profile into seven events corresponding with our flight.

**Event 1** is liftoff, reaching a maximum of 34.28 Gs at 0.020 seconds. **Event 2** is burnout and varies between 14 and 16 Gs. Burnout ends at 1.5 seconds from liftoff, which corresponds with the time at which the rocket reaches its peak velocity. **Event 3**, corresponding with apogee of the flight at 18 seconds, is the firing of the drogue parachute's ejection charge (peaking at approx. 7 Gs). **Event 4** would have been the ejection of the drogue parachute, had the parachute ejected. We believe the parachute stuck in the tube caused the intensity of acceleration (peaking at approx. 19 Gs). **Event 5** is the firing of the main parachute ejection charge (peaking at approx. 12 Gs) and **Event 6**, peaking at approx. 7 Gs, is the ejection of the main parachute. We believe that the snapping of a shroud line caused the "disturbance" recorded at this event. **Event 7**, the large spike at the end of the acceleration profile, corresponds with the rocket's landing. It is safe to say that the rocket had a very hard landing, explaining why dirt was packed into the motor mount upon recovery. The landing peaks at approx. 68 Gs, easily causing the most acceleration throughout the whole flight.

## **Conclusion**

Of all the events during the flight, the ones most significant to the experiment are **Events 2 and 7**. The purpose of the flight was to have the plants go through a large acceleration. **Event 2**, the burnout of the motor, is the most sustained acceleration throughout the flight, and perhaps elicits the most response from the plants. **Event 7**, although occurring for only an instant, easily provided the largest acceleration during the flight and, simply due to its sheer magnitude, might elicit a strong response in the plants. Although it was intended that the plants face this acceleration by means of a high thrust motor, the hard landing only helps us prove the flight's experimental success.

## ***II) Payload Report***

### **Experiment Synopsis**

On arrival in Alabama, it was our plan to subject two types of Arabidopsis plants (agravitropic and wild-type) under two temperature conditions (cold and ambient) to the stresses of rocket flight, and to analyze the effects of these treatments with RT-PCR on a molecular level and further growth observation on a holistic level. As will be explained, circumstances not in our favor have prevented us from completing all of our analyses.

### **Pre-Launch Status**

In the days immediately preceding launch, we noticed a remarkable amount of contamination on about half of our plates. While this development was by no means disastrous to the whole experiment, it required us to change our plans about how many and which plates to consign to each post-flight analysis. Contamination—either mold or bacteria—is detrimental to the growth of the plants sharing a plate with it. The plants growing on our contaminated plates were smaller and less healthy than we would have wished. Knowing that gene expression analysis requires a set amount of plant tissue to produce a measurable amount of RNA, we worried that our existing groups—plates for RT-PCR analysis and plates for further growth analysis—would not provide enough tissue for successful RT-PCR. Thus, we decided to put all of our existing plates to RT-PCR analysis, waiving our plans for observational analysis.

### **Launch and Post-Launch Treatment of the Payload**

As shown in the vehicle team's report, our flown plants were subjected to acute acceleratory forces—the most significant of which were events 2 and 7 (see Figure 11, vehicle section): event 2 for its duration, and 7 for its magnitude. While the flight provided satisfactory stimulus to our plants, nothing will enable us to distinguish which jolts of acceleration caused the effects we may see in our analysis of post-flight gene expression. Within five minutes of receiving the vehicle, we were able to quickly freeze all of our plants with liquid nitrogen and seal them in pre-labeled Eppendorf tubes. Afterward, plants were stored in a cooler with ice and returned safely to Wisconsin via ground transportation.

### **RNA Extraction**

After our return to Wisconsin, the payload team began to make arrangements with Professor Sara Patterson and her horticulture lab to extract RNA from our tissue samples and eventually to perform RT-PCR. On the 17<sup>th</sup> of June, after sufficient practice meetings, we accomplished the first task. Our RNA preps are safely stored in Professor Patterson's lab, and we can now plan for the final—RT-PCR analysis.

### **Plans for RT-PCR**

Due to the frequent absences and business of Professor Patterson, it has been impossible until recently to schedule a time to perform RT-PCR. We have ordered and received the primers specific to the sequences of RNA that interest us, and are therefore now ready to begin our analysis of gene expression. As ever, we will be analyzing four genes: ARG-1 and SGR-2, both upregulated in response to gravistimulation, TCH3, upregulated in response to touch, and RC13, upregulated in response to cold treatment. Until we have completed this process, we can make no conclusions on the successes or failures of our experiment; we intend to submit our data and a formal analysis of it as soon as possible.