Project Hermes

2023 NASA Student Launch Initiative
Post Launch Assessment Review

ResistoJets Rocketry 4-H Club of Morris County

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1. Competition Flight Results

1.1 Summary of flight:

Team name: ResistoJets Rocketry 4-H Club of Morris County
Vehicle dimensions: 4.01" diameter, 90.5” length
K1100T motor
Altitude reached: 3279'
Official altitude target: 3,800'
Total flight time: 78.8 seconds
Descent time: 65.9 seconds
Ground hit velocity: ~48 ft/s (nominally 20 ft/s)

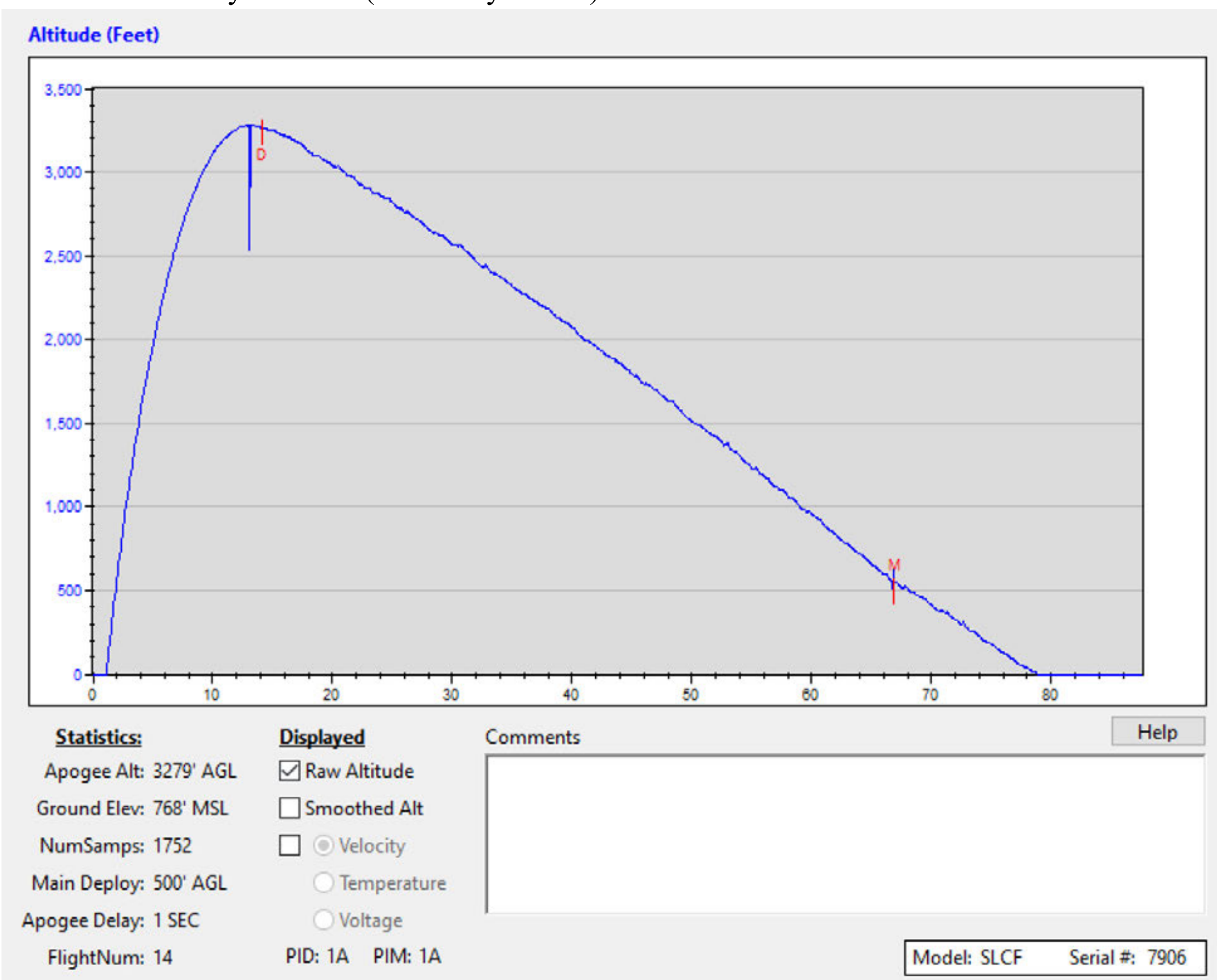

Figure 1. Official scoring altimeter flight data

The day prior to leaving for launch week, our payload software wasn’t finished, and we made the decision to not try finishing it during launch week for several reasons. Our payload hardware would fly, but in an inert state. During the flight, our vehicle had a clean ascent, and a nominal drogue parachute descent phase, however, the sustainer hit the main parachute as it deployed. The sustainer and main parachute were tangled and did not untangle before hitting the ground, at the drogue parachute descent rate. The payload hardware broke on landing, and part of a fin fillet fractured. The payload would not have been able to operate if it was active. The cause of parachute failure was a result of an earlier mitigation.

1.2 Vehicle Summary

1.2.1 Overview of Vehicle

Our vehicle is a 4” dual deploy fiberglass launch vehicle that flew on a 54mm Aerotech K1100T motor. The vehicle has 4 fiberglass fins bonded onto the vehicle with rocketpoxy and a through-the-wall fin design. An unusual feature of our vehicle is that it carries an externally payload for the SLI University challenge. It consists of a small robotic arm and camera which are closed up on the side of the vehicle and protected from the airflow by a 3D printed shroud, which helps with aerodynamics.

Our original expectation was that the vehicle would reach 3,800 ft (with margin to spare), however the vehicle came in heavier than anticipated after built, and only reached about 3,500 on a straight ascent. In our last two flights with the pads angled, we reached 2,900 ft and 3,200 ft. Another contribution to this was higher than expected drag from the payload shroud as a result of rough 3D printed surfaces.

Our recovery system faced early challenges with an undersized drogue parachute, failing our payload demonstration flight and requiring us to complete a VDF re-flight with an FRR Addendum which was successful. We replaced our drogue parachute with a larger one and moved the drogue parachute closer to the sustainer on its shock cord. While these fixes worked perfectly on our VDF re-flight, there was a problem during our launch week flight. Moving the drogue parachute's position closer to the sustainer than the upper airframe (where the parachute is deployed from) introduced a chance of the sustainer hitting the main parachute right after it's deployed; we were not aware of this. Reviewing the VDF re-flight, the sustainer came very close to hitting the main parachute. We would have been able to fix this and fly again if it happened during our reflight, resulting in a successful final flight at launch week.

1.2.2 Vehicle Final Flight

Our vehicle performed nearly as expected, with some difference in the apogee as a result of the pad angle. It was about 250 feet short of our expected apogee, of which was already 300 feet less than our official target. Our drogue parachute descent was nominal and on time. However, the sustainer hit the drogue parachute momentarily after deployment as a result of the sustainer being above the upper airframe (where the main parachute is deployed from) during drogue descent. Our vehicle landed a couple dozen feet from the launch pad, and was drifting towards the spectator area. The vehicle landed hard, 24 ft/s faster than nominal. The payload hardware was damaged and inoperable and a fillet on a fin broke. Additionally, there was damage to our avionics bay and nose cone electronics bay. There appeared to be soot/burn barks in our avionics bay, and some standoffs were broken. There wasn't an apparent cause for this, ejection charge gas may have entered from the ignitor lead holes, or the damage may have just been a result of the hard landing, despite having survived a hard landing in the past. The cause of nose cone avionics bay damage also isn't clear, as it had survived a hard landing in the past. The most likely cause of these damages was landing on hard ground, instead of the tall grass our other failed flight landed in.

Image 1. Launch of Vehicle

Image 2. Drogue Parachute Deployment

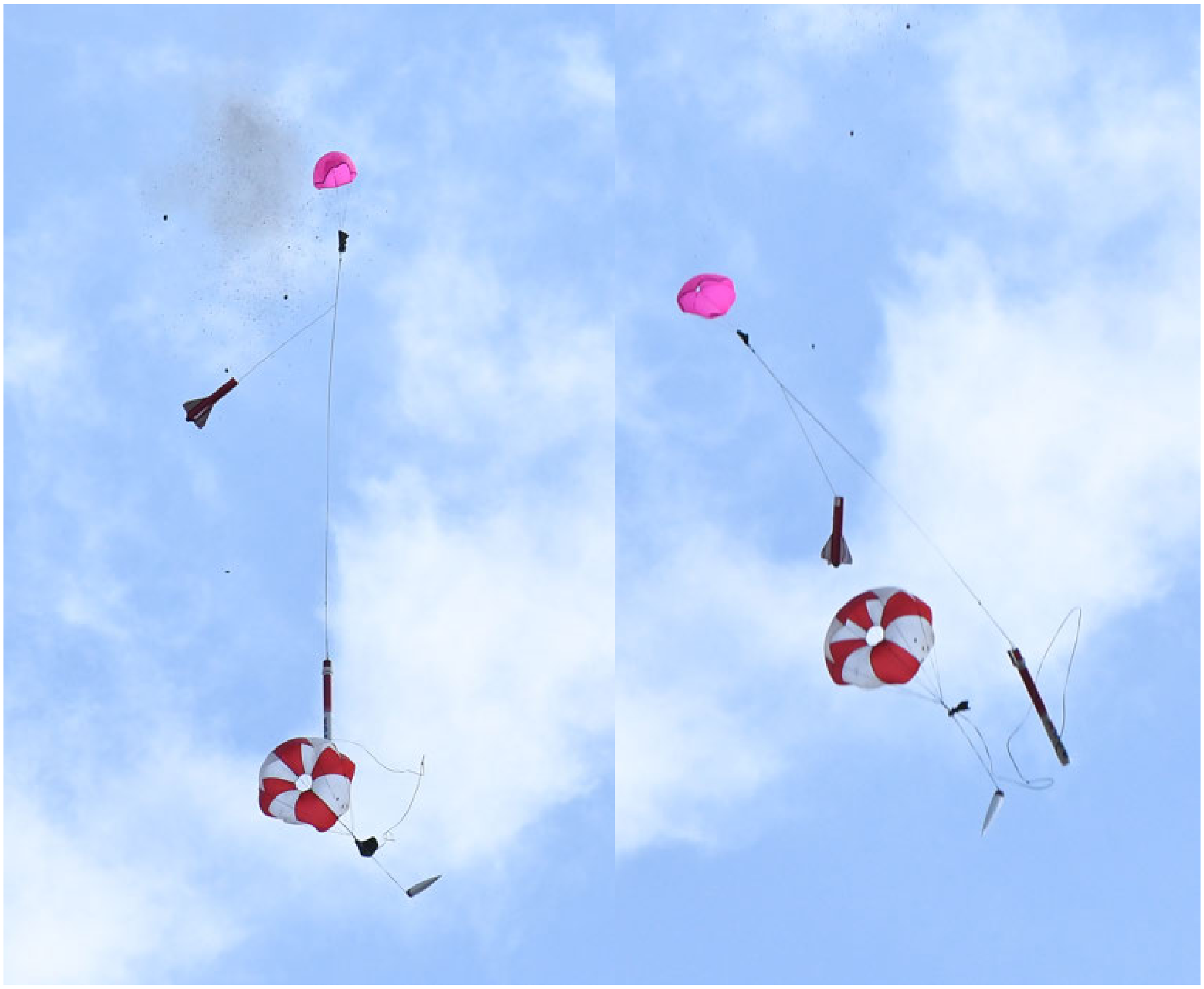

Image 3 & 4. Main parachute deployment

Image 5. Picture from onboard video of the sustainer making contact with the main parachute

Image 6. Picture from onboard video of the sustainer tangled, shortly before landing

Image 7. Sustainer hits Main Parachute

Image 8. Landing configuration of vehicle

Image 9. Vehicle on the ground

Image 10. Damaged payload

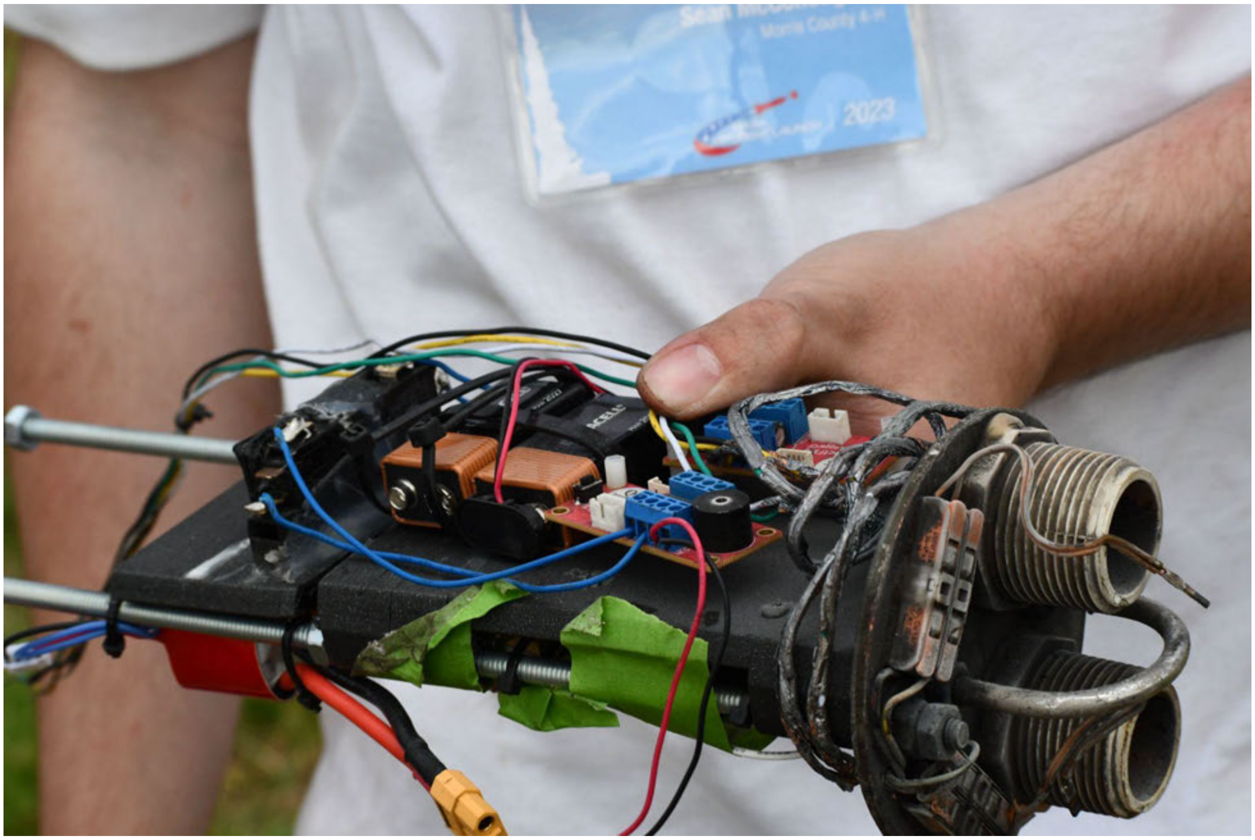

Image 11. Internal damage to the avionics bay (at altitude check)

Image 12. Soot inside of avionics bay coupler (at altitude check)

Video 1. Highlights of our launch week experience
https://youtu.be/s7uZ_-n5VfE

Video 2. Marshall Space Flight Center Livestream video of our launch
https://youtu.be/s7uZ_-n5VfE?t=965

Video 3. Video of launch with our members
https://youtu.be/s7uZ_-n5VfE?t=1000

Video 4. Onboard video from our vehicle
https://youtu.be/s7uZ_-n5VfE?t=1205

Video 5. Sustainer main parachute deployment failure:
https://youtu.be/MSNqEDZFe-Y

1.3 Payload Summary

1.3.1 Overview of Payload

Our team chose to undertake the USLI Payload challenge and committed to it in the PDR. We considered many different solutions to this challenge and decided on a camera arm that is mounted externally on the vehicle. This arm is contained within a shroud which is attached to a gear around the avionics bay and is in contact with the sustainer airframe.

1.3.2 Payload Final Flight

2. Payload Results

We have no results from our payload as a result of it not being finished and being destroyed during recovery.

3. Lessons Learned

3.1 General Lessons Learned

With this being our first year in the competition, everything was a lesson learned. Most of them aren't particularly notable, but just something we now know how to do properly in the future, or just a muscle memory moving forward. We detail several major lessons learned here, relating to the project plan or other parts of the program, some of which we are already working to address for next year.

- Inelasticity in project plan

In hindsight, there were several points in the project where we should have made changes but were either sunk into our current plan or reluctant to make major changes. While it was the case a few times that it would have been a significant stretch or difficulty to implement the change, we were nonetheless aware of a potential need for change and didn't implement it. We also failed to thoroughly assess most of these problem areas and decide on a clear path to implement them or mitigate risks. One of the reasons for this was overworking of the team members, resulting in simply not enough time to work through or think about these items properly. Some items we knew about and didn't change include:

- Switching away from the USLI Payload challenge during the PDR
- Replacing the drogue parachute with a larger parachute after the first failure, hoping smaller changes would fix it in order to avoid a more major change.

To address this, we want to frequently and broadly assess our whole project plan, and thoroughly look at problems as they come up, in order to implement changes early on to have the greatest odds of success.

- Lack of manpower/inefficient time management

One of our biggest and longest struggles in our team has been not having enough people and inefficient time management, the latter amplified by this being our first year. We didn't have enough people to complete all tasks comfortably, either without excessive crunch or to the degree of quality desired. We didn't have a feel for what was most important in our deliverables, causing more important areas to fall short. This extends to some engineering failures, as a result of not having enough time and effort available to fully study some aspects of our project, resulting in failures. The biggest example of this is our recovery system which had several different failures, all of which could have been avoided by taking a long look at the system and thinking through all of the possible failures in detail.

We want to grow our team significantly to be able to dedicate people to specific aspects of the program, to have leads of more areas, and to have backups to lead positions in case the current members in charge of their areas are no longer able to fulfill them fully.

- Crunch/not enough time to work on hardware

This year, we didn't have a good idea of when to start working on various deliverables, and started when they made the most sense or otherwise explicitly stated. The main problem was in our subscale vehicle, which we only started building after the PDR, and our full scale vehicle, which we only started working on after the CDR (which we believed we had to wait until after our CDR presentation in case we had to implement changes). As a result of this, our builds often involved a lot of crunch in order to meet goals or deadlines. A notable example of this was our first full scale flight, in which the vehicle wasn't fully finished, and as a result prevented us from fully realizing potential problems.

In the future, we'll begin deliverables sooner than this year in order to give us more time to make changes and to work on them more comfortably, even at the risk of needing to implement changes required by the SLI panel.

- Pay closer attention to our timeline and assess progress.

This year, both our payload and STEM Engagement program missed timeline goals, and started struggling as a result of that. Our payload was not at the point in development and testing, and that should have been a clear indicator that we were in trouble and should have made changes to our payload plan. Likewise, our STEM engagement program wasn't making much progress over most of the year, eventually we made changes to our team and plan and had a decent outcome, but it could have been better if we made those changes sooner.

- More detailed procedures

Our procedures were not as detailed as desired by the competition officials. While our procedures were operable with our team, if we had more members it would have been problematic. Some particular procedural items from the LRR include, what indicators we should see that the vehicle is healthy on the pad and what troubleshooting to do if it isn't, and to specify who safes the vehicle before the rest of the team approaches.

3.2 Vehicle Lessons Learned

Many of our vehicle lessons learned were related to project management and are explained in 3.1, however we have some specific items to talk about here.

- Use a larger fireproof nomex blanket for main parachutes.

We incorrectly thought that the nomex blankets were only supposed to separate the parachute from the direct blast of the ejection charges, however this was incorrect. In the future we now know that the fireproof nomex blankets need to fully wrap the parachutes, like a burrito.

- Practice folding parachutes

Understanding how to fold and untangle our main parachute was a recurring problem for us. The Fruitychutes parachute was new to us and we kept struggling to fold it properly, however this never resulted in an anomaly itself.

- Make better use of subscale vehicle

In the future, we should take the opportunity to make better use of the subscale vehicle. This year, we really only used it to demonstrate that our external payload would not be problematic. We didn't really get good information about how our full scale will perform or how much it'll weigh, etc. It isn't clear whether approaching our subscale differently would have prevented future problems. Many of the decisions to make our subscale dissimilar to the full scale wouldn't have been necessary if we began working on as early as possible.

- Have more generous mass margins for components

While we thought we had very generous mass margins, when both the weight of the vehicle and its drag were higher than we anticipated, we fell far short of our official vehicle target. This can also be mitigated by procuring and building hardware earlier, so if we find problems we can implement changes (like changing to a more powerful motor).

- Choose epoxy more carefully

In our flights, we had two instances where rocketpoxy shattered. While these weren't nominal situations, they probably should have been more survivable than they were. It may be the case that other epoxies were better suited for fiberglass vehicles, and we should have looked into that more carefully.

- Analyze flight results much more closely

We never analyzed our flights as closely as we should have. The main reason for this was most of our flights were completed shortly before a milestone due date, and we rushed to finish the documentation instead of fully analyzing flights. With closer analysis and assessments, we might have been able to prevent some future problems and implement better changes.

3.3 Payload Lessons Learned

Since we didn't finish our payload, we don't really have any lessons learned based on the payload results, but we definitely learned a lot about what resulted in our failure here.

- There need to be members dedicated solely to working on the payload.

This year, the payload was assigned as a side role, and didn't take priority over the rest of the competition. The payload, especially the USLI challenge, is an extremely complicated challenge that likely needs multiple people to work exclusively on it, starting as soon as the request for proposals is released.

- Make changes to the payload plan early on if needed

If we find that we may not be able to complete our payload project successfully, we are able to change it in the PDR.

4. Summary of overall experience

Image 13. Team picture after the opening ceremonies at launch week

Our primary goal this year was to complete the competition and learn as much as we could in doing so. We achieved that goal. As far as the vehicle and payload go, we missed many of our goals, including the altitude goal, reusability goal, and successfully completing the payload. However, we successfully built and operated a vehicle more advanced and powerful than any of us had before and gained a lot of experience in doing so. We also proposed, designed, and built a payload for the USLI payload challenge, and despite not finishing and operating it, we flew a unique payload solution, and worked through many hardware challenges with it and its integration with the vehicle. If we chose an easier payload that we came up with ourself, we wouldn't have faced a lot of the challenges and learning opportunities that we did. We believe we achieved our goal of learning as much as we can and successfully made it through the whole nine month competition, despite many struggles.

This year's competition challenged our team members in many ways and has taught us technical writing, technical presenting, project management, team/resource management, public relations, engineering skills/discipline, hardware integration skills, and more. These will undoubtedly be useful in our lives and hopefully will bring value to the aerospace industry in the future. We look forward to sharing what we've learned with new members, hopefully competing again next year, and establishing our team as a long term member of the Student Launch program.

5. Total Hours Spent on Project

80 - Proposal
115 - PDR Milestone
180 - CDR Milestone
380 - FRR Milestone
90 - FRR Addendum
840 - Launch Week
39 - PLAR Milestone

1,544 Reported man hours spent between our five teammates. This is slightly underreported.

6. STEM Engagement Summary

[Our final STEM engagement numbers have changed since our STEM Engagement report was submitted]
Our STEM engagement program consisted of three main parts. Our primary focus was creating and distributing rocketry-focused education packages which include model rocket kits, motors, and videos/articles for learning about rocketry and the current space industry. In total, we spent $2k on these packages, buying 360 kits and motors, which were sent to 20 schools and youth development groups. Through these kits and other STEM content, we expect to reach 972 people (estimates from schools/youth development groups registration for the program). We currently have 156 confirmed participants with this program. Our purpose for creating a program like this was to outsource the reach and logistics of organizing these events to schools and groups themselves. We found out early in our program that organizing these events to be ran by our own members would be extremely straining on our team, and very difficult to get the approval from these administrations to allow us to deliver our programming. We instead decided on an approach that would allow us to have the greatest reach we could with our five members. One downside of this approach is that we have no guarantee that the kit recipients would ever give us confirmation and pictures of their engagements, however we expected people would be in good faith and help us out in return. Our second part of the program mitigates this risk by having programs hosted by our team members when opportune.

Our second part includes hands-on demonstrations, public lessons, and straw rocket building and flying taught by our teams. At this time we've engaged 436 people through this.

Additionally, we've posted videos documenting our progress in the competition and highlights that have reached 956 people. We have also maintained a social media and news presence, but the reach of that is impossible to calculate accurately.

In summary, our STEM Engagement program has had this reach:

Educational Direct Engagement:
Confirmed: 592
Anticipated: 1408

Outreach Indirect Engagement:
956+ Engagements

7. Final Budget Summary

Item	Cost		Totals::
Fullscale:			
13" Nomex Blanket - 4" (98mm) Airframe × 2	$35.20		
Iris Ultra 48" Standard Parachute - 12.5lb @ 20fps	$162.01		
24" (15.28" Diameter) Hemispherical Spherachute - Heavy Duty	$32.25		
FCR4.0-2.1	$20.79		
G12-4.0 48" Body Tube	$92.47		
G12-4.0 32" Body Tube	$58.41		
4" 3/8" Tubular Kevlar Harness W/ 3 Sewn Loops 30 ft set	$75.05		
FNC4.0-4.5-1-VK-FW-MT Nose Cone	$68.31		
G12CT-4.0 x 12	$30.84		
av-bay lid 98mm x 3	$59.40		
G12-2.1 12" Coupler	$14.26		
54MM U-BOLT x 4	$15.20		
G10-1/8 12' x 12" Sheets for Fins	$89.10		
70cm 100mw GPS/APRS Transmitter	$285.00		$1,038.29
Fullscale Sustainer #2:			
G12-4.0 32" Body Tube	$58.41		
FCR4.0-2.1	$20.79		
G12-2.1 12" Coupler	$14.26		
1/4" EYE MALE	$6.00		
			$99.46
Consumables:			
Aerotech K1100T-14A Blue Thunder x 4	$503.96		
Aerotech G80-14A New Blue Thunder 29 mm - DMS x 3	$87.72		$591.68
Stem Program:			
30 Gnome Rocket Education Pack, 120 Estes 1/2A Motors	$2,400.00		
Subscale:			
IRIS 2.26″ - 29 mmt	$68.56		
BT-2.14 Electronics bay	$8.98		$77.54
Hardware:			

Spray Paint	$176		
Jig Supplies	$120		
3D Printed Plastic	$120		
Misc Hardware	$45		$461
Shipping Costs	$266.80		$266.80
Total:	$4,934.77		

Table 1. Line item expenses

Shipping costs:
$98.05
$4.12
$18.43
$103.86
$32.24
$10.10

Table 2. Shipping costs

We have $10k dedicated to reimbursing travel expenses. All five team members travel to Huntsville and as a result, $2k will be available to each member for reimbursement as we planned. At the moment this isn't fully settled, so we don't have a final funding status for our team, but we currently have remaining funding.

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