Project: ARP 142

2014-2015 NASA Student Launch Maxi MAV
Post-Launch Assessment Review

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Section 1 – Launch Vehicle

1.1 Launch Vehicle Summary

- Rail size: 10 ft 1515 aluminum extrusion
- Launch Vehicle Dimensions
    - Outer Diameter: 5.15 in
    - Total Length: 121.5 in
    - Three sections: Forward, Mid, and Aft Sections
- Motor: AeroTech K1050W
- Weight (before motor burn): 35.5 lb
- Altitude Reached: 2,568 ft
- Maximum Velocity: 373 ft/s
- Recovery System:
    - Two stage recovery: Drogue and Main phase
    - Drogue parachute slowed LV (Launch Vehicle) to 86.2 ft/s
    - Main parachute goal was to slow to 17 ft/s
    - Payload Parachutes goal was to slow Forward Section to 19 ft/s
    - Aft and Mid Section separate at Apogee to deploy drogue parachute
    - Mid and Forward Section separate at 1000 Feet to deploy main parachute

1.2 Flight Analysis

The general flight of the Launch Vehicle was stable as analyzed from the flight footage. From analyzing the flight footage, the Payload Bay did not come open on ascent. The Payload Bay did appeared to have come open during the impact with the ground upon retrieving the Forward Section. This was one anomaly that was not expected for the Huntsville flight. Another thing that was not expected during the Huntsville flight was reaching a much lower maximum altitude than was achieved. The Launch Vehicle has not changed shape. The coefficient of drag should not have changed between the full scale flight and the Huntsville flight. Using the g's from the accelerometer data, Clark Aerospace found the thrust curve of motor output. The thrust from Huntsville flight is graphed below against the expected thrust curve. The light blue line is the Huntsville flight thrust curve as found by Clark College Student Launch team.

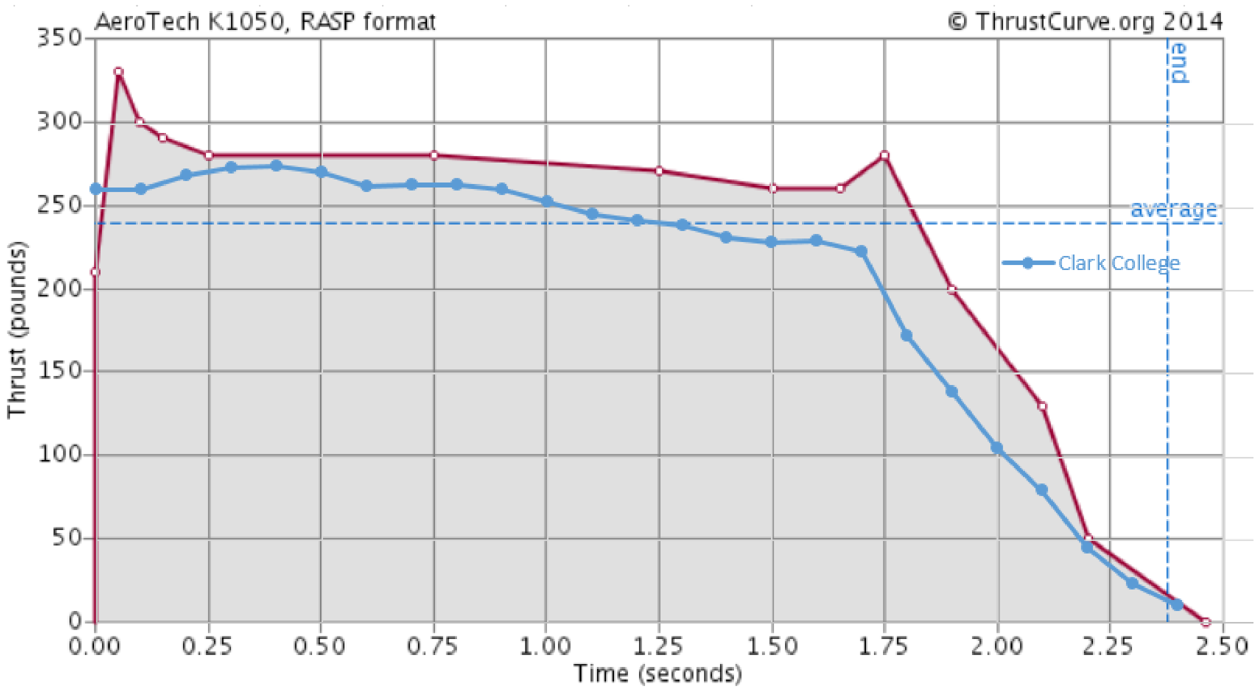

Figure 1: Thrust Curve Observed vs. Expected

The thrust of the motor is significantly less at every second of the burn. A reason the rocket did not perform as tested could be that the motor did not burn fully, this hypothesis was simulated. The motor data derived from the g's of the altimeter's accelerometer of the Huntsville launch was put into a simulated launch. The simulated apogee found using the derived motor data from the Huntsville flight was 2,542 feet. The altimeter measured the maximum altitude during the Huntsville flight to be 2,568 feet above ground level. Running the same simulation with the motor data taken from the official thrust curve the maximum altitude predicted is 2,976 feet. From this data, Clark Aerospace believes that the motor used, underburned during the flight and provide less thrust. This hypothesis was also supported by a comparison to the full scale flight test data. The full scale flight test showed that the maximum g's pulled by the Launch Vehicle was 12. During the flight in Huntsville, the maximum g's pulled by the Launch Vehicle was only 7 as measured by the accelerometer. This shows that the motor had a smaller burn during the flight at Huntsville. The data from the flight simulations are given below.

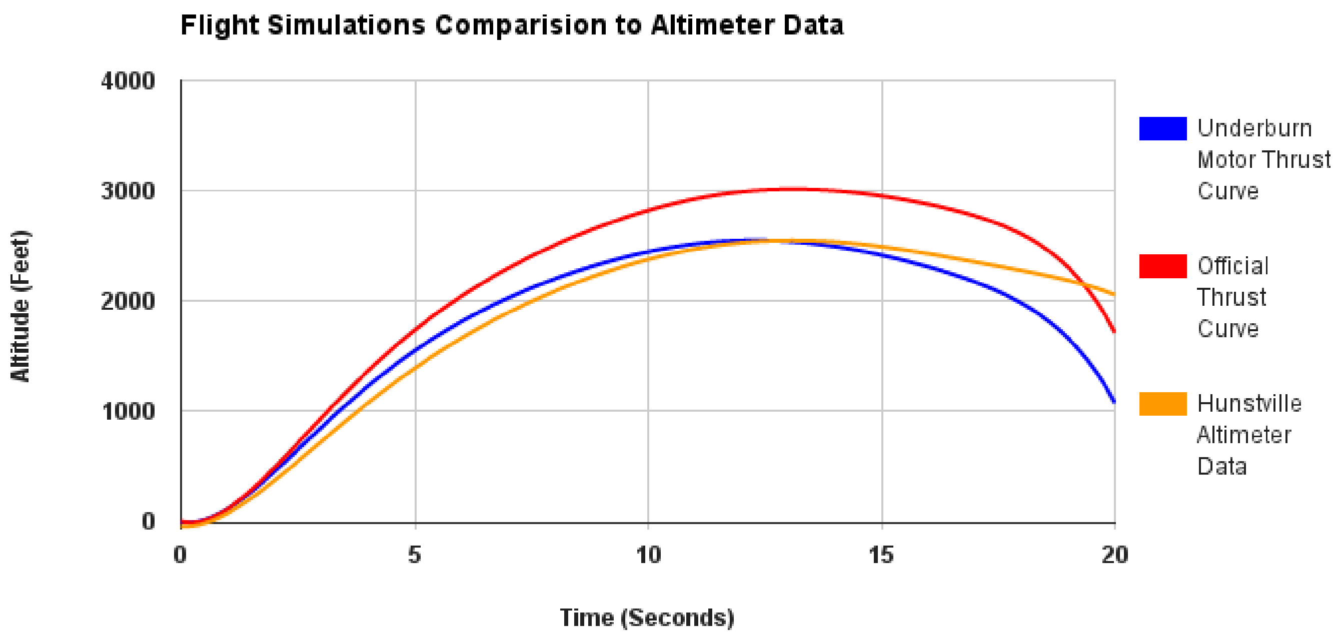

Figure 2: Motor Data Comparison

The underburned motor (blue line) derived from the accelerometer data of the Launch Vehicle flight in Alabama, closely relates to the altimeter altitude data (yellow line) taken from the launch. This shows how Launch Vehicle's performance matched the thrust of the under burnt (less than ideal thrust at each data point) motor without modeling parachute descent rates. This lack of full motor potential explains why Clark Aerospace's Launch Vehicle did hit an apogee closer to the target height.

The Launch Vehicle was observed to have a slight angle after the Launch Vehicle left the Launch Rail. Clark Aerospace believes this was caused by a deflection in the Launch Rail as the rocket passed up through the top of the rail. The Launch Rail was tied down from 7 feet up the rail. The Launch Rail was held up by linear actuator, with a 400 lb holding force, 1 foot up from the pivoting point. The ties at the top of the rail only held the rocket in one direction. Clark Aerospace was not able to setup the ties in a more helpful orientation since the fins would have hit the ties on liftoff. The Launch Vehicle was able to bend the Launch Rail as it pushed itself off the last couple of feet of the Launch Rail. This could be solved with a secondary pivoting rail that locks into place as the actuator lifts the rail. The rest of the flight worked smoothly, the Launch Vehicle straightened out its trajectory after a few feet off the Launch Rail; This was only a minor problem for the launch. The wind conditions were around seven miles per hour on launch. This lead to the Launch Vehicle remaining with property limits for the drift of the Launch Vehicle due to wind. Overall, the Launch Vehicle flew in straight path and descended to the ground with no problems. No damage was found on the Launch Vehicle after it was recovered. The system is fully recoverable and ready for another launch.

Figure 3: Huntsville Flight

This picture shows the Launch Vehicle right off of the Launchpad with a stable flight trajectory. The Recovery System worked perfectly. The drogue parachute slowed the descent rate down to 86 ft/s after apogee black powder charges were triggered. The main parachute and payload parachute both deployed at 1000 feet. The descent rates could not be found for this descent period, because the MARSA altimeters used stopped taking data at 32 seconds into the flight. Using the calculations in the FRR, Clark Aerospace believes the Launch Vehicle sections landed with less than 75 ft*lb of energy at impact with the ground.

Section 2 – AGSE

2.1 Payload Summary

The payload that was flown in the Launch Vehicle in the Huntsville flight was the Payload Containment System. The Payload Containment System was 3D printed plastic pieces assembled together and fit inside of the Launch Vehicle. The payload inside of the Payload Containment System was NASA's official payload; which simulated a PVC tube of a Martian soil sample. The 3D printed parts that were held in the Payload Bay were tested during the launch. The launch helped Clark Aerospace confirm if 3D printed plastics are a valid option for the inner workings of a high-powered rocket.

2.2 Scientific Value

The scientific value for Clark Aerospace's experiment was to confirm that 3D printed PLA plastic is a usable as a lightweight structure in a high acceleration environment. Clark Aerospace decided to design a 3D printed Payload Containment System for the Launch Vehicle to learn about how PLA plastic handles high acceleration. The Huntsville flight tested the Payload Containment System inside of the Launch Vehicle on launch day. The flight proved that the 3D printed material was able to handle up to 7 g's of acceleration. The Payload Containment System was retrieved still inside of the Launch Vehicle after impact. The Payload Containment System door was slightly ajar. This was not due to a lack of material strength, but rather the orientation of the door at impact. Since the door was held closed with a small 3D printed latch that was push aside during impact of the door directly onto the ground. From inspection of the Payload Containment System, no parts were broken. Only a small super glued plastic piece was ripped off during flight. The layers of the 3D print were perpendicular to the orientation of the Payload Containment System at flight. This gave a large amount of strength to the structure of the parts as they were compressed during launch. Instead of that accelerated weight force splitting layers apart if it were in parallel orientation. Clark Aerospace believes that this layering strategy in the creation of 3D printed parts that will help create stronger 3D printed parts.

2.3 Data and Analysis

One data point measured by Clark Aerospace was the time taken to lift the Launch Vehicle into the 85 degree launch position by a linear actuator. This was measured to be 37 seconds during the inspection of the AGSE. This is faster than the expected 48 seconds to lift the Launch Vehicle, predicted by the average speed under load given from the manufacturer. The calculation for the time needed to lift the Launch Vehicle was made using an overestimated of the weight of the Launch Vehicle. Rerunning the calculations for the Launch Rail lifting system with an accurate weight gives us 43 seconds for the estimated time needed to lift the Launch Vehicle. This gives Clark Aerospace a sixteen percent error in the estimation of the time taken to lift the Launch Vehicle. This inaccuracy of timing ability of lifting of the Launch Vehicle was the reason, the Launch Rail System was not run using a timer. To find the final angle of the Launch Rail for the final design. The final design of the Launch Rail System ended up using two limit switches as the primary stopping mechanism instead of a timer. This increased reliability in the lifting of the Launch Vehicle, because it did not rely on the state of the battery or the weight of the Launch Vehicle. If the battery was drained of energy, then the linear actuator would receive a smaller amount of amperage and lift more slowly, but would still lift the Launch Vehicle to the correct orientation.

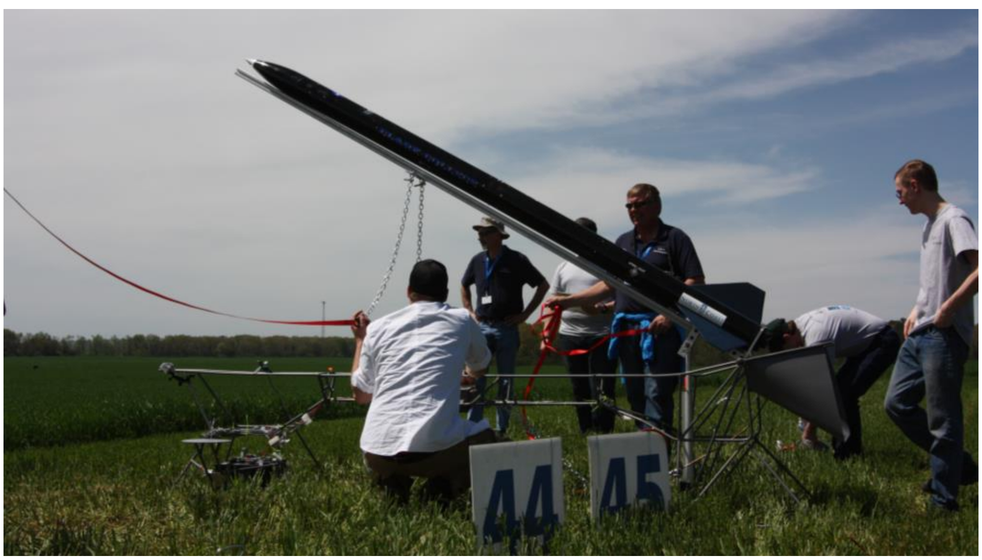

Figure 4: AGSE Lifting the Launch Vehicle

The Payload Containment System was initially having trouble opening the door to the Launch Vehicle. Clark Aerospace discovered the Payload Containment System was improperly measured and the top of the sliding rail was getting stuck on the airframe. This was fixed with simple sanding of the sliding rail in the Payload Containment System. Clark Aerospace believes the initial Payload Containment System calculations were correct. The 3D printed Payload Containment System was also checked for damage as part of the scientific payload; this showed that the 3D printed material was able to withstand the acceleration produced by the Launch Vehicle. Clark Aerospace's system shows that PLA parts that have been 3D printed may be suited to be used in rockets in the future as a lightweight product.

Section 3 – Project Experience

3.1 Summary of Experience

The NASA Student Launch competition was design intensive. Clark Aerospace is satisfied with the design of the Launch Vehicle and AGSE. More time would have been needed for full AGSE testing to ensure reliability. Since the robotic arms (Payload Retrieval System) first test was in the Huntsville during launch week. The Launch Vehicle performed very well, Clark Aerospace could not have predicted the unusual motor burn that occurred during the Huntsville launch. Clark Aerospace believes that this could not have been mitigated, since the motor was built and approved by the Clark Aerospace's mentor. The Recovery System parachutes deployed as accurately as possible. The altimeters functioned normally during the Huntsville flight. The black powder charges did not burn any holes in the parachute or shock cord. All AGSE subsystems besides the Payload Retrieval System functioned as expected. The Launch Vehicle was able to be lifted by the Launch Rail System. The igniter insertion was demonstrated with an inert motor. The Payload Containment System was able to open, close, and latch the airframe door closed in Huntsville. One major challenge faced during launch week was loss of electronics. Clark Aerospace had found four Arduino Nanos and six servos were fried during the travel to Huntsville. This forced the control system to be rewritten to run on 3 Arduino Nanos. The original Control System layout needed six Arduino Nanos to run the systems. This innovation in the code allowed for the AGSE to function during launch week inspections on a half as many Arduino Nanos. The major problem associated with the robotic arm used in the Payload Retrieval System was that a servo in the palm of the arm was burnt out that did not allow the robotic arm to grasp the payload. This lack of servo backups was the single problem holding back the Payload Retrieval System. Clark Aerospace still believes the design is viable, since robotic arms were used by other teams.

Clark Aerospace is a community college club with mostly second year students. Therefore, NASA Student Launch competition allowed for all students to gain a real world experience with a large scale project. The level of technical writing and editing required for this competition is not seen in college level classes. The writing and design provided a huge learning experience for Clark Aerospace members in project management and technical design. All of Clark Aerospace's members learned things outside of class experience to design systems for this competition. These are all skills that will be needed for real world research and development or project oriented jobs. All Clark Aerospace members feel more prepared for actual engineering jobs after having done the NASA Student Launch competition.

3.2 Budget Summary

A total of $ 4,979 (Goods & Services) was spent on the components used to build the AGSE and Launch Vehicle, not accounting for labor and shipping (is included in Other category). A breakdown of the total budget is given below. All items bought were given in the FRR; for a more detail budget see Clark Aerospace's FRR.

Item	Given	Spent
Goods & Services	$7,500.00	$4,978.66
Transportation	$7,500.00	$9,362.47
Meals	$4,200.00	$4,641.00
Lodging	$2,000.00	$3,180.00
Other	$3,760.00	$2,284.00
Group Contribution (Budgeted)	-$3,850.00	NA
Total	$21,110.00	$24,446.13
Contributions	$8,388.08	NA
Overall Total	$29,498.08	$24,446.13

Figure 5: Total Budget

3.3 Education Engagement Summary

Clark Aerospace reached 800 kids during an expo with the girl scouts. The lesson taught was on Newton's laws and how they relate to rocketry. The age range during this event was elementary school to high school.

Clark Aerospace also reached 20 kids during a small presentation of the NASA Student Launch Competition during a science in action event hosted by Clark College. Launch Vehicle and AGSE designs were explained to the children. The age range was middle school to high school.