Wichita State Launch: Operation Sunflower

Team Members

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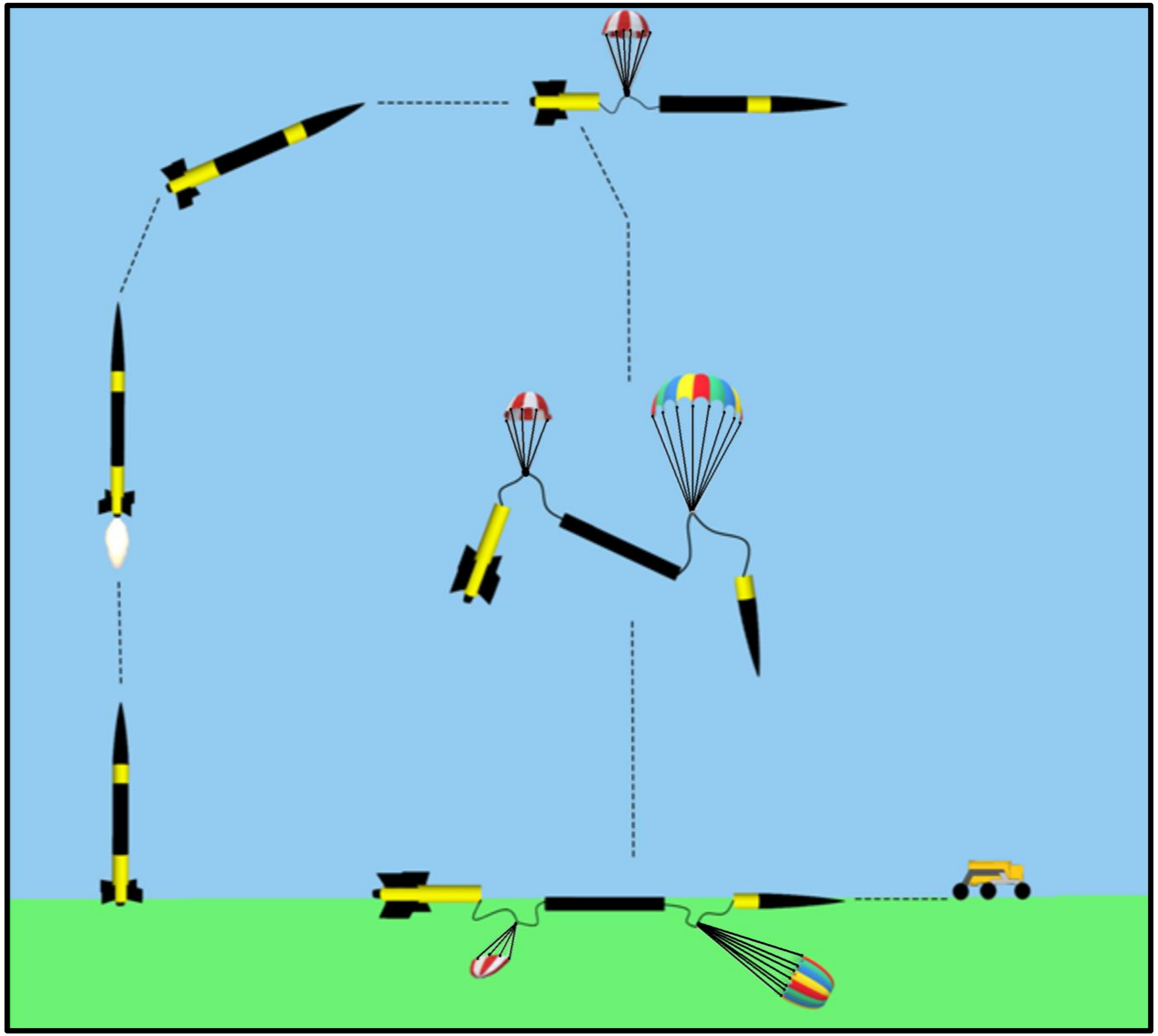
NASA Mission and Mission Sequence

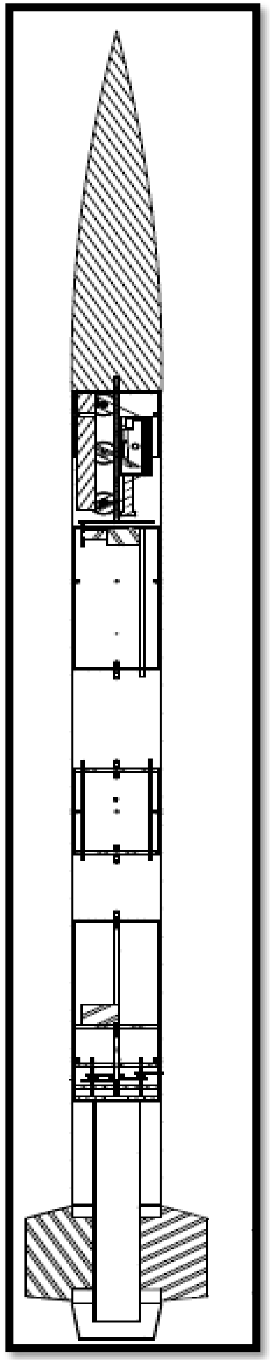


NASA University Student Launch Competition

- Design and build a high-powered rocket
- The rocket must hit a maximum altitude (apogee) between 3,500 ft and 5,500 ft
- The team will select a specific altitude to target, and will aim to launch to that apogee
- The rocket will carry a payload which will travel to a collection site
- The payload will collect and store 10 mL of "lunar ice" sample and transport the sample 10 feet.

MISSION SEQUENCE

1. Launch
2. Motor burnout
3. Drogue parachute deploys at apogee
4. Main parachute deploys at 700 ft altitude
5. Landing
6. Rover deployment



Vehicle Overview

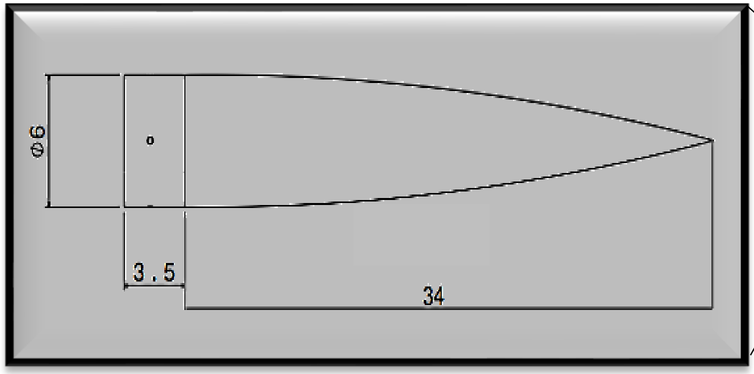
Parameter	Design
Nose Cone Geometry	5:1 LD-Haack Series
Fin	Cruciform-trapezoidal
Fin Attachment	Slotted with Epoxy
ADMS	4 Blade Rotary
Total Length	115 in
Body Diameter	6”
Dry Weight	34.83 lb.
Launch Weight	39.6 lb.
Payload Section Mass	9.76 lb.
Recovery Section Mass	10.80 lb.
Booster Section Mass	14.27 lb.
Motor	Cesaroni L1720-WT
T/W	10
Apogee (Target)	4,200
Apogee (Before ADMS)	4,665

Full-scale launch
March 1st, 2020
Argonia, KS

Photo By: Lance Licktieg

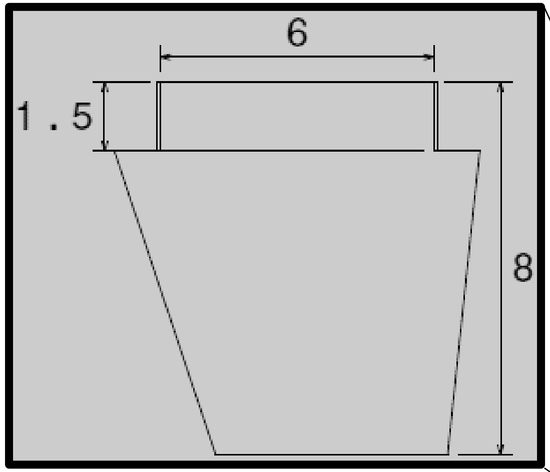
Nose Cone – 5:1 LD-Haack

- Fineness ratio chosen to allow reduction of form drag and market availability of choice was high.
- Fineness ratio compromised skin friction drag, but longer nose cone contributed to increased stability.



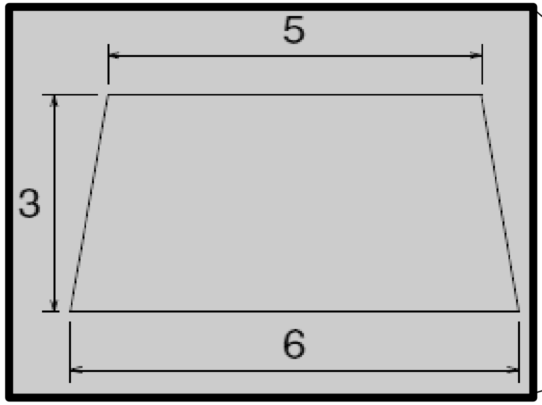
Fin – Trapezoidal Set

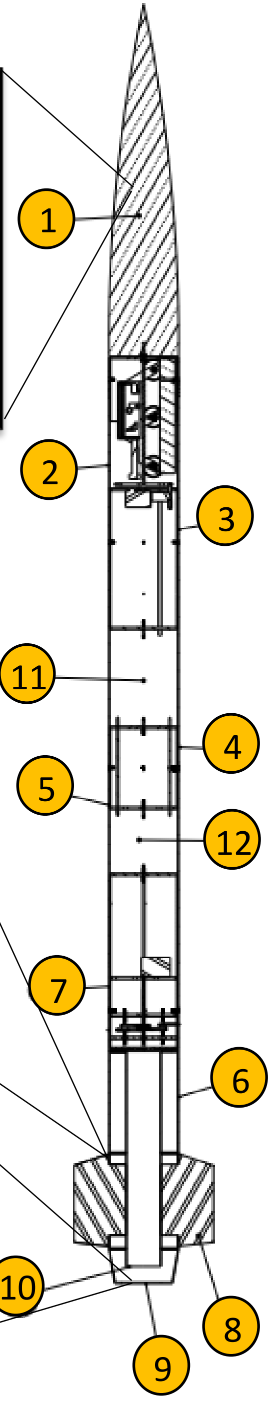
- Tapered to decrease induced drag
- 6” bottom tab for through-the-wall attachment to increase strength
- Relatively large planform for stability margin of 2.96
- Rounded edges for increased aerodynamics



Boat Tail

- Screws on for motor retention
- Tapered to decrease base drag, but still large enough to allow propellant flame to flow out freely





Vehicle Components

1. Nose Cone
2. Payload Bay
3. Payload Orientation/ Deployment (POD) Bay
4. Recovery Body Tube
5. Avionics Bay
6. Booster Body Tube
7. Active Drag Modulation System (ADMS)
8. Fins
9. Boat Tail
10. Motor
11. Main Parachute Bay
12. Drogue Parachute Bay

Motor Choice

Design T/W Range = 8 < T/W < 10

- Less susceptible to weather cocking (leaning into the wind)
- Less loss in stability
- Less drift

Cesaroni L1720

- Max T/W = 11*
- Avg T/W = 10*

*Original ratios were lower. Final weight of the rocket decreased from predictions, increasing the ratio

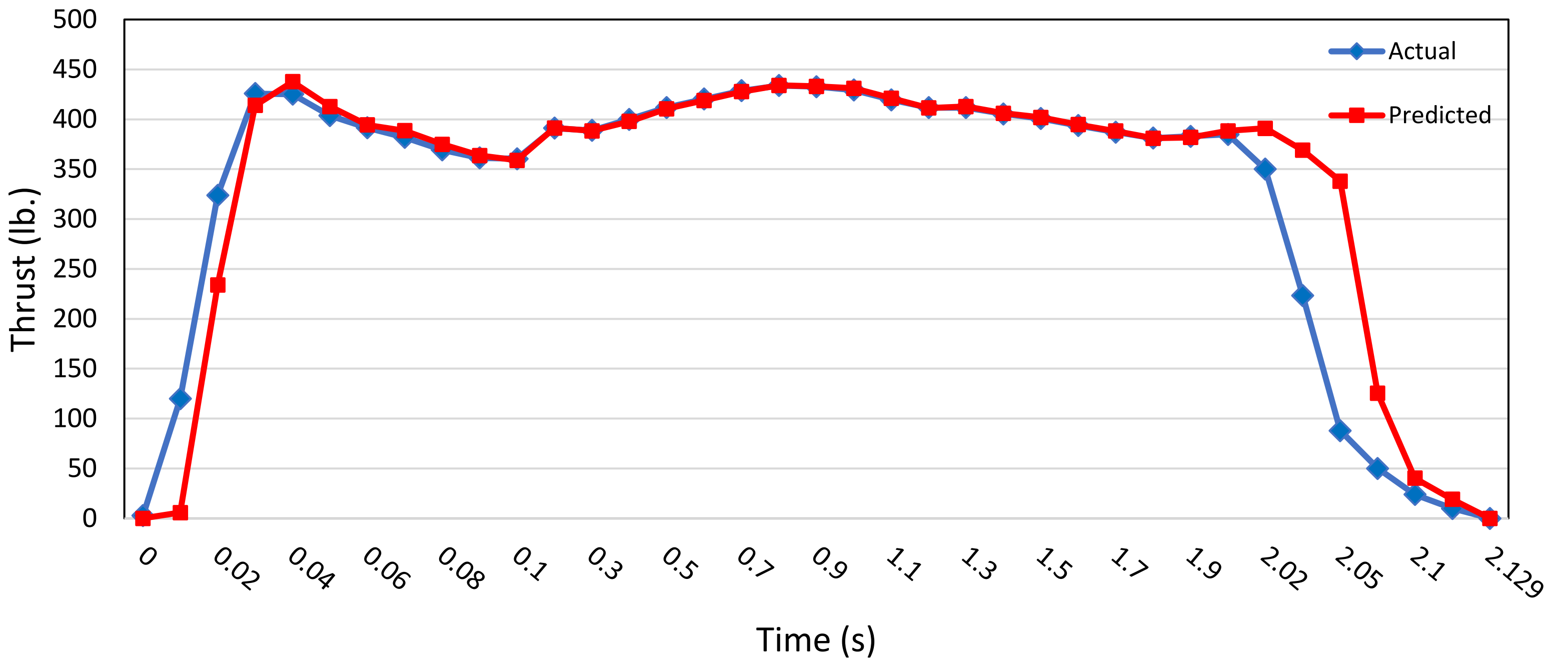
Motor Consistency

Motor performance was mostly consistent. The experimental thrust data closely matches thrust curve provided by manufacturer, with the exception of a quicker initial burn, and a quicker tapering of the thrust towards the end

Motor Specifications

Motor Specifications	
Motor Name	Cesaroni L1720-WT
Impulse	3,660 N*s (823 lb*s)
Average Thrust	1,771 N (398 lb.)
Maximum Thrust	1,946 N (437 lb.)
Burn Time	2 sec
Total Mass	3.341 Kg (7.4 lbm)
Propellant Mass	1.755 Kg (3.9 lbm)

Actual vs. Manufacturer Thrust Curve Comparison of Cesaroni 1720-WT Motor



Recovery

Main Parachute

- Descent velocity for weight of rocket and given ground hit kinetic energy constraint of 75 slug*ft^2/s^2, required ground hit velocity to be < 17 ft/s
- Increased Cd of main parachute to facilitate reduced ground hit velocity while avoiding volume and weight addition of a larger parachute for same effect

Annular Main Parachute	
Diameter	96”
Cd	2.2
Terminal Speed	16.4 ft/s

Drogue Parachute

- Needed to be small to decrease drift for most of descent and stay under 90 second descent time constraint
- Needed to be large enough to prevent high velocity opening forces for main parachute

Elliptical Drogue Parachute	
Diameter	24”
Cd	1.6
Terminal Speed	78.2 ft/s

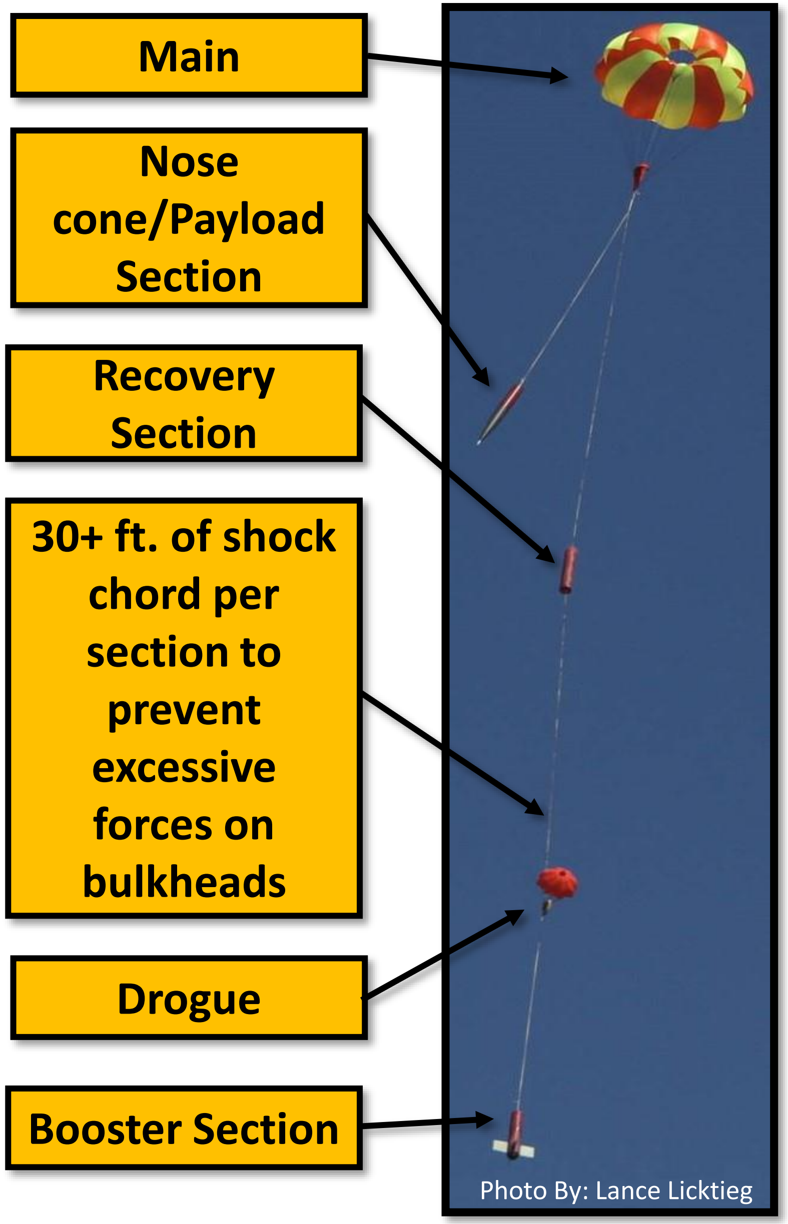


Photo By: Lance Licktieg

Active Drag Modulation System (ADMS)

Mission Requirements

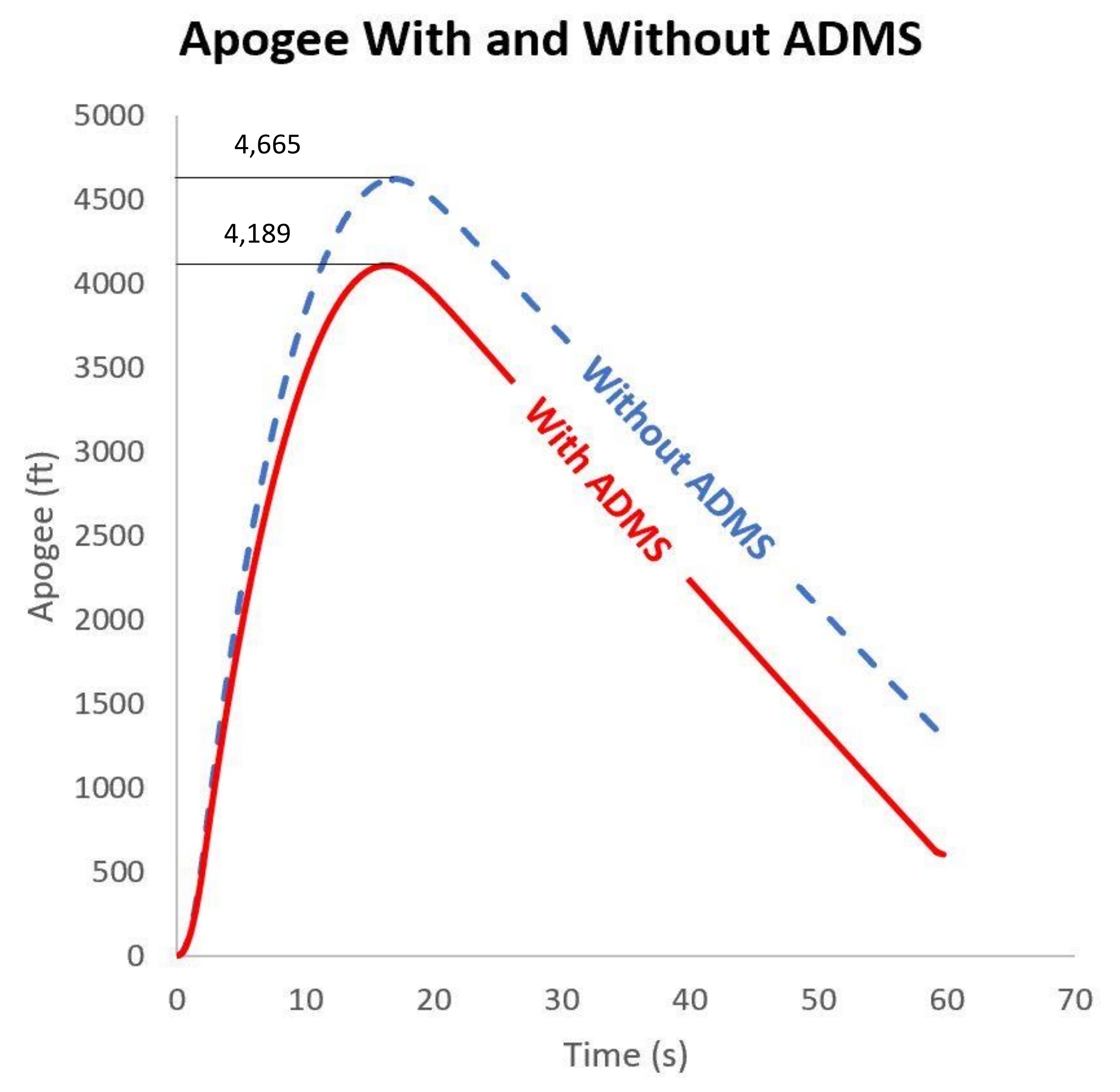
- The NASA Student Launch Competition includes the mission of taking your rocket to a targeted apogee
- The rocket must achieve an apogee between 3,500 and 5,500 feet to remain qualified
- Each team must select an apogee to target
    - A maximum apogee score is achieved by reaching an apogee within 100 feet of your target

Apogee Concerns

- A rocket's apogee depends on many factors including:
    - Weight of the rocket
    - Wind speed and direction
    - Launch pad angle
- These parameters are not always able to be controlled on launch day

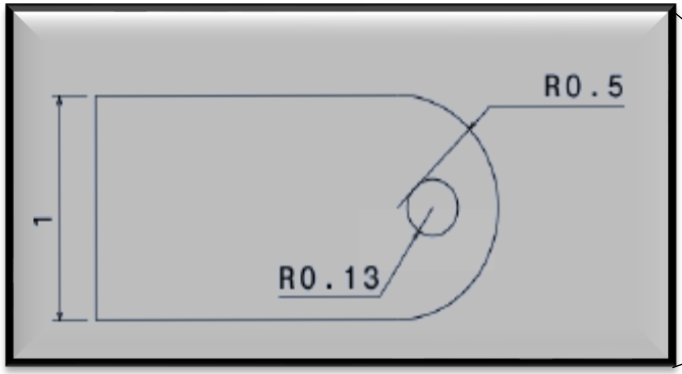
WSL's Strategy

- Select a motor that is strong enough to overshoot the apogee under multiple conditions
- Deploy an active drag, or airbrake, system to deploy blades perpendicular to the airflow
    - This creates controlled amounts of drag to reduce the apogee to our targeted value.



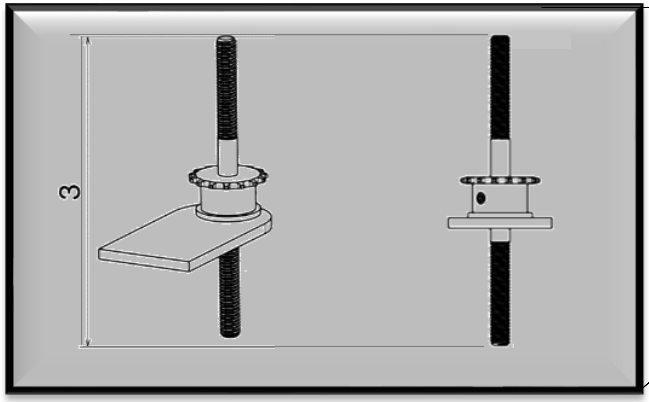
ADMS Blades

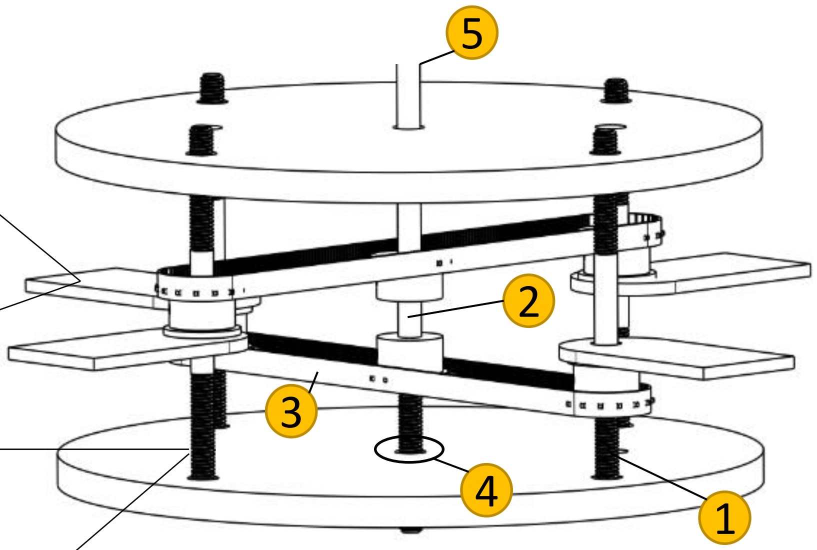
- ADMS Blades are cut out of a fiberglass sheet
- They rotate in and out of the rocket, driven by chains that rotate around a center post



Outer Posts

- Four posts hold the sprockets and the blades
- The sprocket sits in the middle, with the blade attached to the side opposite to its teeth.

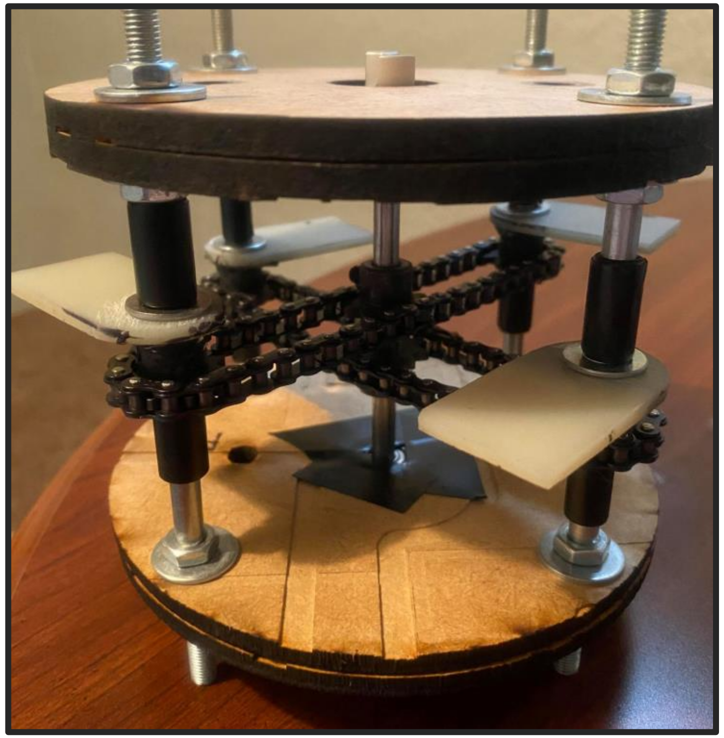




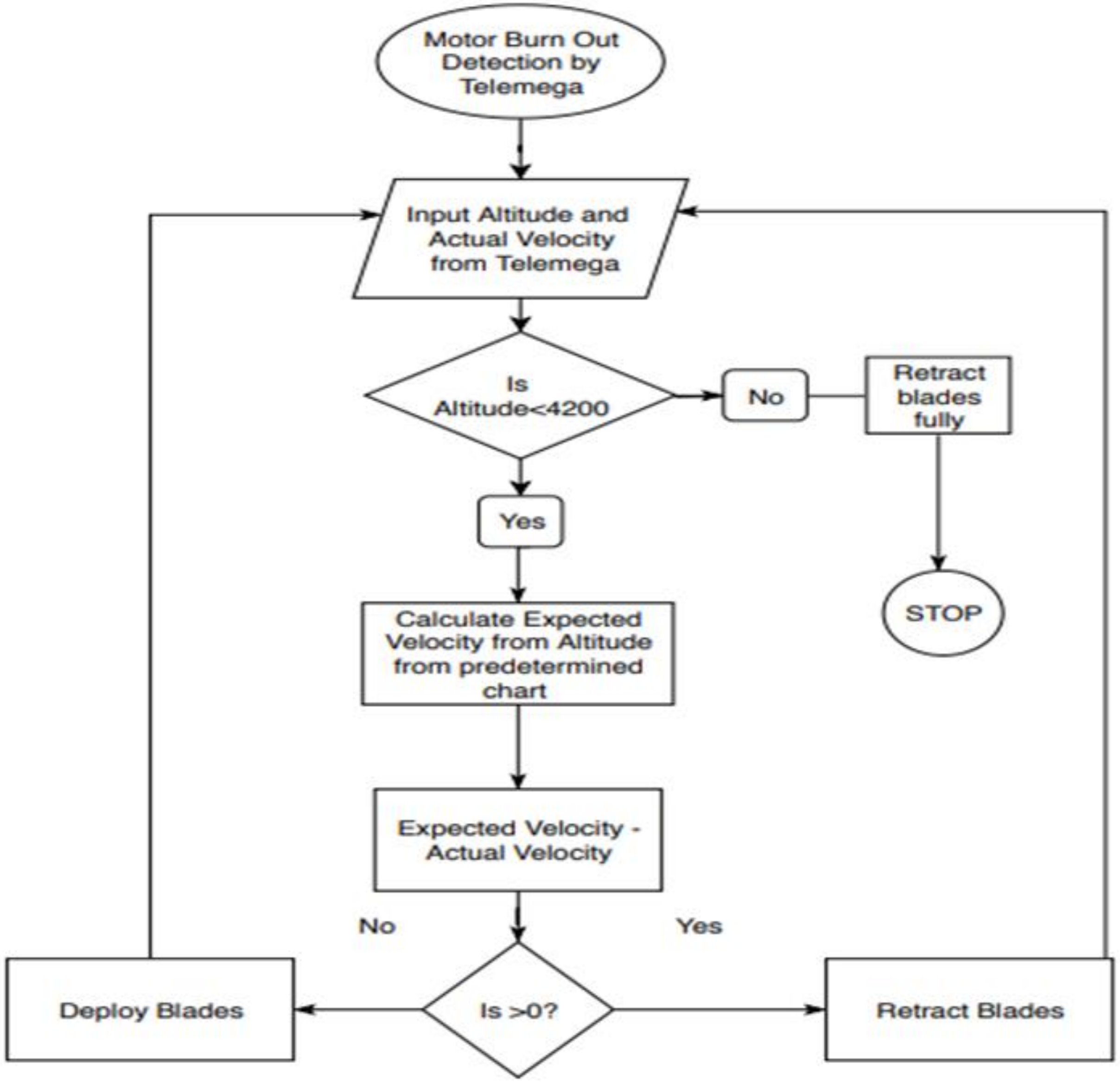
1. **Outer Posts (4)**
   - One sprocket and blade on each post
2. **Center Post (1)**
   - Two sprockets on this post
3. **Chain (2)**
   - Connects two outer posts to rotating center post
4. **Bearing**
   - Allows center post to rotate freely
5. **Connection to Servo**
   - Center post connected to servo via coupler

Constructed Model

- Blades cut out of fiberglass using hand saw
- Assembly held between laser-cut wooden plates
- Spent a lot of time properly tensioning chains



ADMS Controls System



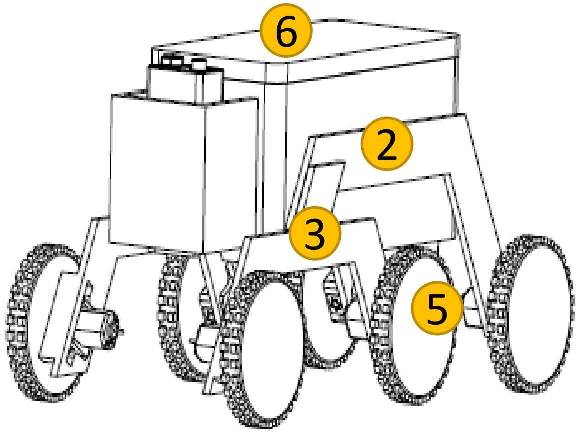
ADMS Logic

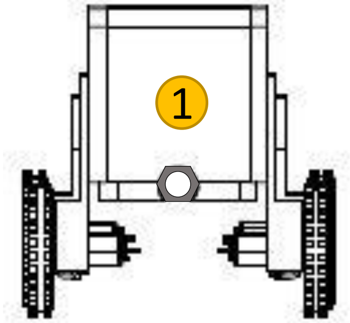
- After motor burn out has been detected by the altimeter, the barometric pressure, altitude, and velocity values for each time instant is sent to the processor.
- Using a predetermined chart the program finds the altitude the rocket theoretically should be at each velocity data point.
- The measured velocity is subtracted from the predetermined velocity.
- If this is positive then the program determines a percentage of blade area to deploy.
- If it is negative then the blades are retracted.
- The appropriate gain values were calculated for the controller to ensure that the program commands are mechanically reasonable.

Electronics Components

- Telemega/Altimeter
  - Measures pressure, velocity, and altitude
- Arduino Micro
- Large servo motor
  - Drives ADMS center post, which rotates blades out and in

Payload – Rocker Bogie System



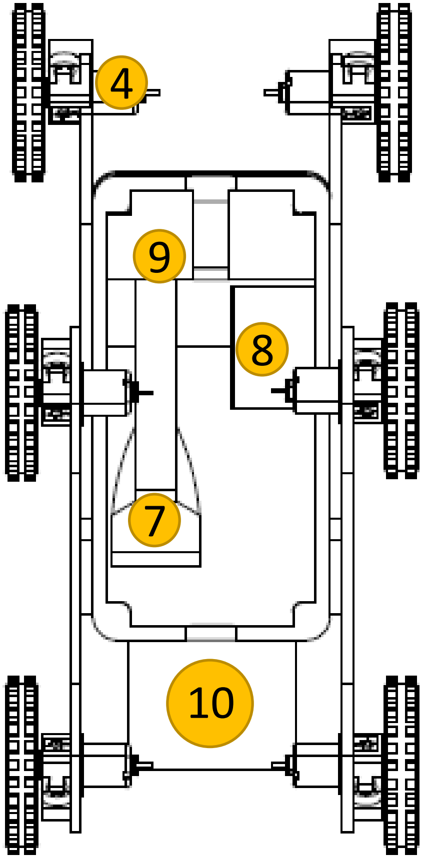


Payload

- Payload is based on the concept of NASA’s Martian rover.
- All six wheels remain in contact with ground on rough terrain.
- Collect “Lunar Ice” sample similar to small gravel.

Mission Requirements

- Upon landing, the payload will need to extract itself from rocket without human interaction.
- Travel to one of the five collection sites where “Lunar Ice” sample is located.
- Collect at least 10 mL of “Lunar Ice” from collection site and store it in payload.
- After collecting sample travel 10 ft without losing the sample.



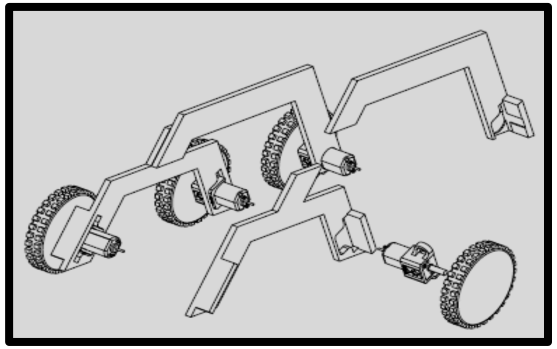
Components

1. Body
2. Rocker Frame
3. Bogie Frame
4. Motor
5. Wheel
6. Lid
7. Scoop
8. Scoop Motor
9. Lunar Ice Storage Bin
10. Battery Storage

Components & Electronics

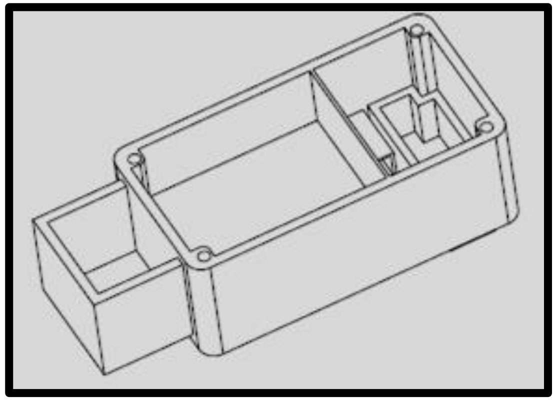
Rocker Bogie Frame

- Rocker frame and bogie frame are connected such that they are able to rotate freely, allowing all six wheels to stay on the ground.
- Each wheel has its own motor, so it’s independently driven, increasing maneuverability.



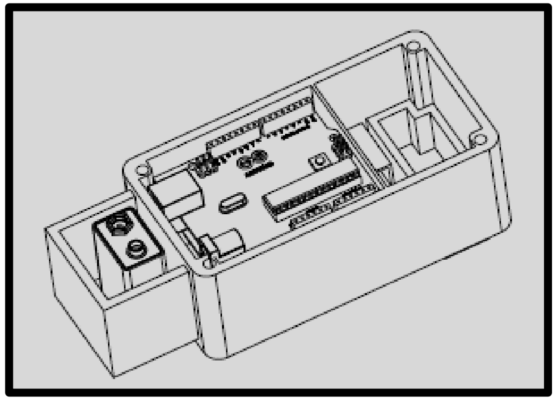
Body

- The body of the payload is designed to hold all electronics needed for driving the payload and collecting the sample.
- The body is closed with a lid on the top so all electronics are secured inside.
- The bottom of the payload is open to allow scoop movement.



Electronics

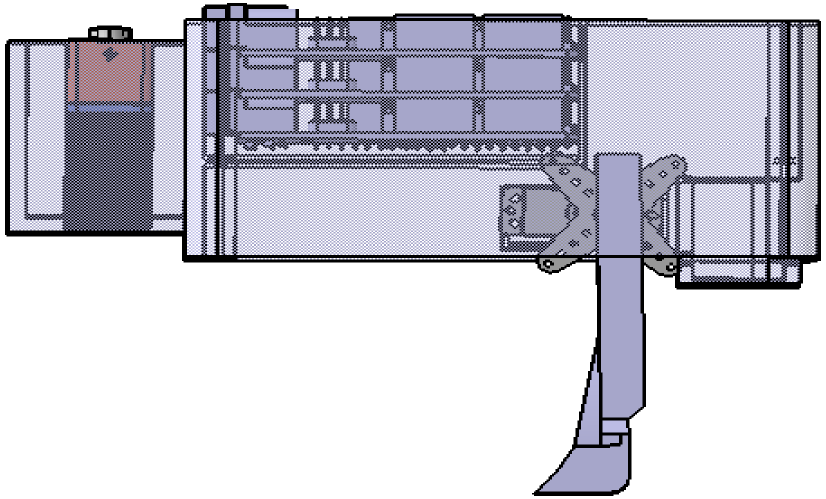
- Arduino UNO
- Motor Shields (2)
- Bluetooth Module
- Batteries
- Small servo for scoop
- DC motors for the wheels (6)



Collection & Storage

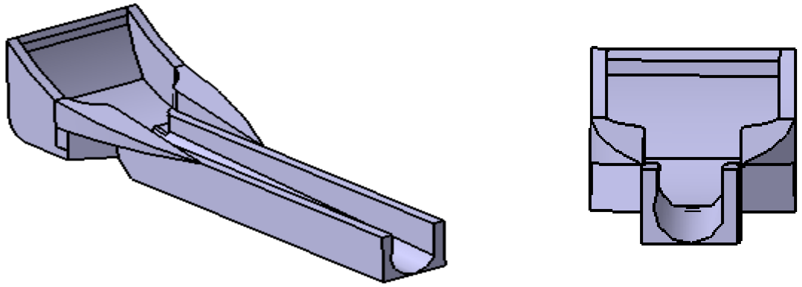
Collection System

- Collection system consists of scoop, motor needed to operate scoop, storage box and manual controller for operation.



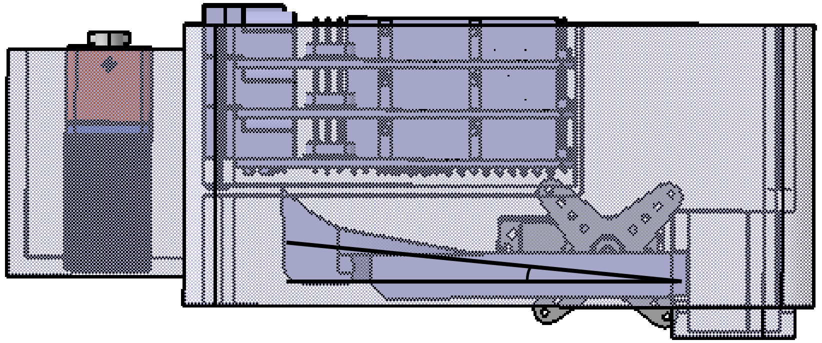
Scoop

- Scoop will be operated once the rover reaches the collection site.
- Scoop will perform sweep to collect sample and rotate back to its original position.
- Scoop arm is designed with a groove to allow the sample to slide down into collection area.



Storage

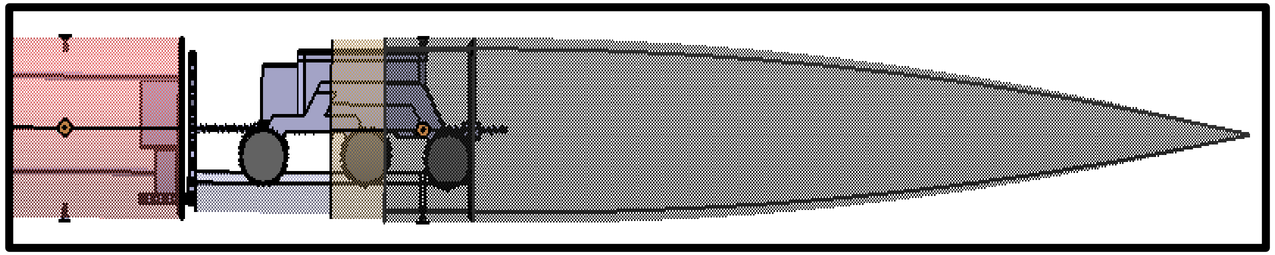
- In the stowed position the scoop will sit 10 degrees above horizontal so that collected sample travels to the storage area.
- Storage box is designed to store 20 mL of the sample.

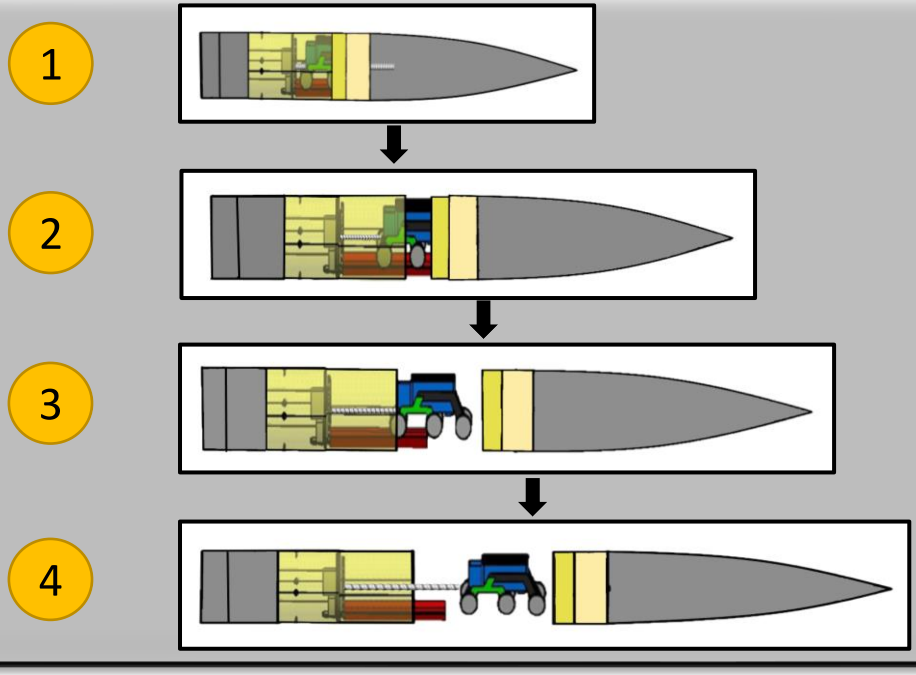


Payload Orientation & Deployment (POD)

POD

- ➢The POD assembly is designed to retain the payload during flight and facilitate payload deployment.
- ➢The payload is retained by a lead screw passing through two nuts on the bottom of the payload.
- ➢When the rocket lands the lead screw will turn, which translates the rover and the nosecone away from the rocket.





Components

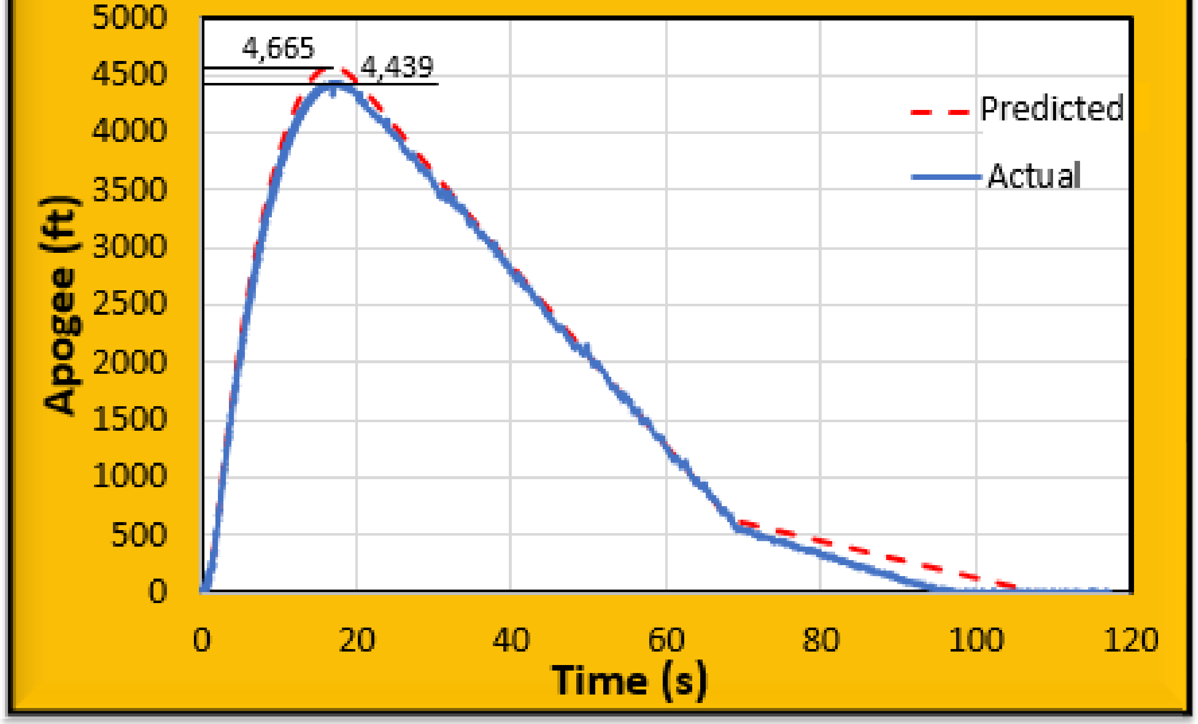
1. Lead Screw
   - ➢ Passes through payload and nosecone.
2. Sled
   - ➢ Payload sits on sled during flight. Sled is attached to large gear.
3. Gear System
   - ➢ Small gear rotates large gear with sled attached.
4. Servos
   - ➢ One rotates gear, one rotates lead screw.

Sequence

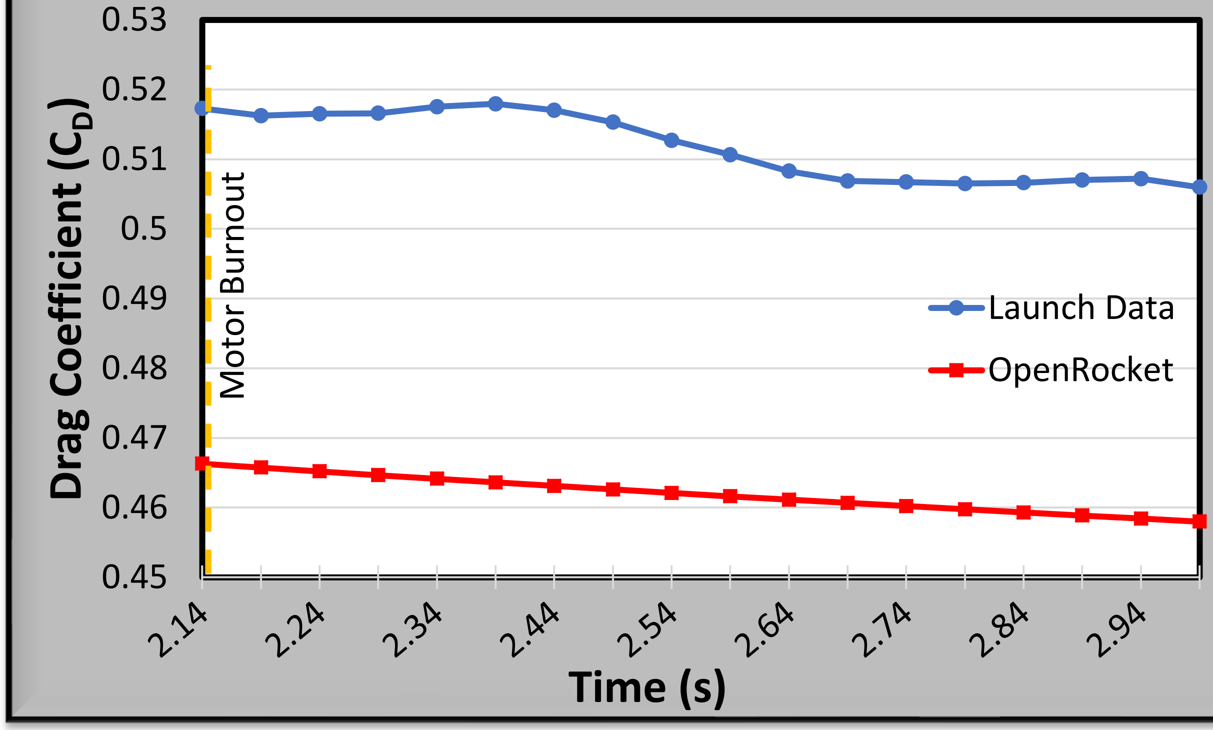
1. Rocket Landing.
2. The payload will orient upright if necessary, using a gear system driven by a small servo.
3. The lead screw will rotate, pushing the payload and nosecone forward.
4. Rover begins driving and completing the mission.

Mission Analysis

Comparison of Predicted and Actual Flight Profile of Full-Scale



Comparison of Launch Data and OpenRocket Drag Coefficient Values After Motor Burnout



Flight Summary

Data in the plot was taken from the TeleMega altimeter. The plot shows that the profile and apogee of the test launch compared to predictions were slightly lower. The apogee was short by 226 ft. This could be due to the motor burning out quicker than expected and a higher drag coefficient than expected. The data also shows that descent time is right at the 90 second constraint.

Drag Summary

Slight variation in the launch data is observed and can be attributed to the slight variation in dynamic stability and angle of attack from corrective forces. It additionally shows a C_D of ~0.05 higher than OpenRocket data. This contributes to the lower achieved apogee. The C_D was then changed to 0.51 in OpenRocket and the apogee dropped to 4,477 ft., significantly closer to actual apogee.

Mission Analysis

Design Parameter	Conceptual	Final
Apogee (w/o ADMS)	4,665 ft.	4,439 ft.
Launch Weight	40.2 lb.	39.6 lb.
Average T/W	9.9	10
Length	103”	115”
Nose Cone	5:1 Von Karman	5:1 Von Karman
Stability	2.96	2.84
Fin Design	4 fin through the wall, trapezoidal	4 fin through the wall, trapezoidal
ADMS Blades Shape	Pointed Petal	Rectangular
Main Parachute Size	72”	96”
Drogue Parachute Size	24”	24”
POD System	Spring Lock Mechanism	Lead Screw

This table shows a comparison of critical design features and how they have changed from preliminary conceptual design to the final built product.

Summary

- Many parameters remained consistent such as launch weight, T/W, Nose Cone, stability, fin design, and drogue parachute size.
- Apogee without ADMS was used because comparison between target apogee would require use of ADMS system, which was unable to be flown. However, this height with an active ADMS system would have been adequate to achieve the team’s target apogee goal.
- Overall length increased by a foot due to both change in POD system and coupler configuration to a more conventional approach. Weight added by extra length was offset by weight reduction in POD and Payload systems
- ADMS blade shape, and thus area, was changed due to a need for an increase in drag produced by the system
- Main parachute was increased in order to decrease ground hit velocity