River City Rocketry

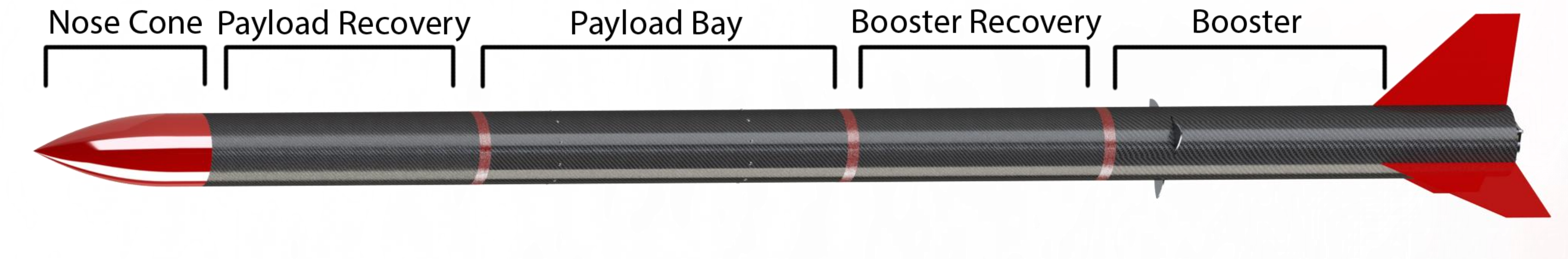
CRITICAL DESIGN REVIEW (CDR) PRESENTATION

CDR Presentation Agenda

- Launch Vehicle
- Variable Drag System
- Recovery
- Subscale Vehicle
- Safety
- Payload
- Educational Outreach
- Budget

Launch Vehicle Overview

- 6.25 in. Diameter
- 4 Independent Sections
- Custom Carbon Fiber Airframe
- Custom 12in. Parabolic Nose Cone
- 3 Carbon Fiber Fins
- Variable Drag System
- Removable Fin System
- Aerotech L2200-G Motor



Vehicle Sections, Dimensions, and Mass

- 4 independent sections
- Dimensions dictated by payload, motor, and recovery hardware size
- Recovery bays shortened since PDR
- Nose Cone shortened since PDR

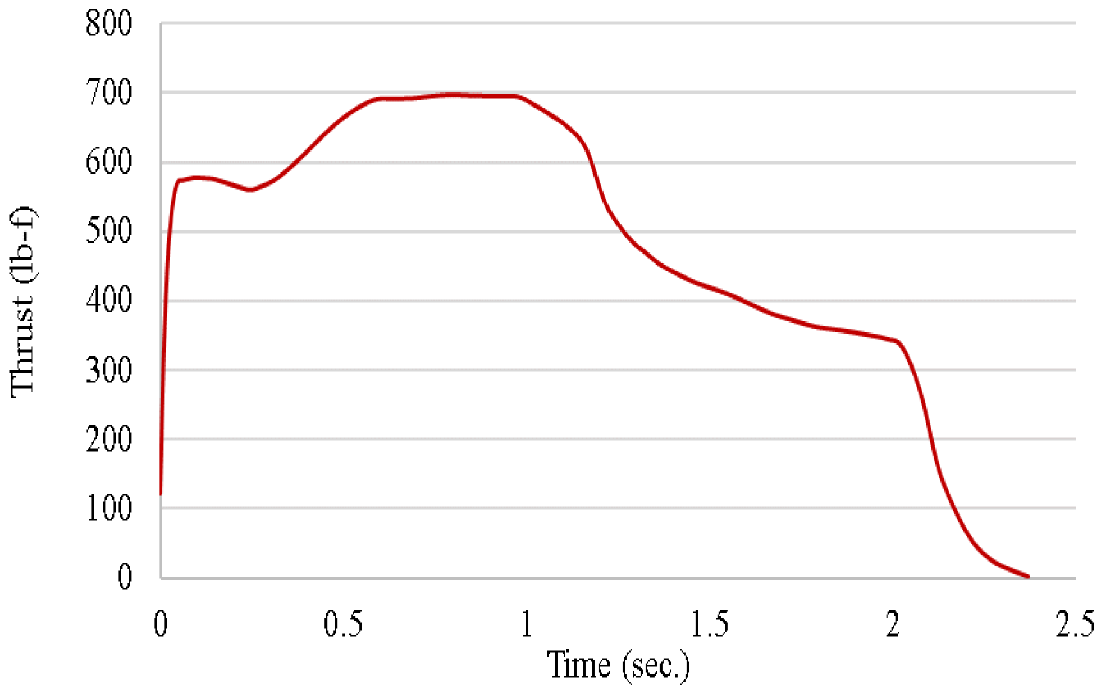
- **Mass Margin**
  - Max weight to achieve 5,300ft apogee: 49lbs
  - Min weight to stay under 5,600ft: 45lbs

<table>
<tr><th>Section</th><th>Length (in.)</th><th>Wet Mass (lbs.)</th></tr>
<tr><td>Booster</td><td>37</td><td rowspan="2">25.149</td></tr>
<tr><td>Booster Recovery Bay</td><td>23</td></tr>
<tr><td>Coupler</td><td>-</td><td>1.791</td></tr>
<tr><td>Payload Bay</td><td>33</td><td rowspan="2">16.818</td></tr>
<tr><td>Payload Recovery Bay</td><td>25</td></tr>
<tr><td>Nose Cone</td><td>15</td><td>3.465</td></tr>
<tr><td>Total</td><td>133</td><td>47.223</td></tr>
</table>

Final Motor Selection

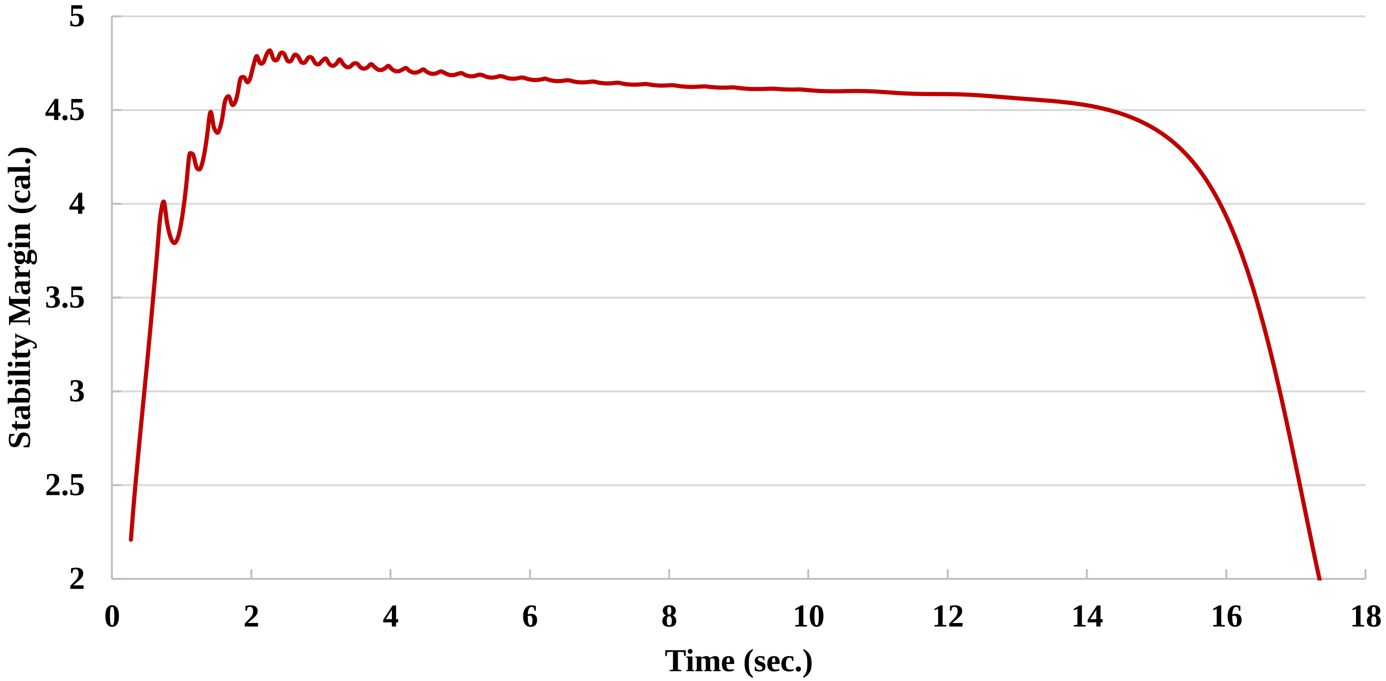
- Motor selection dictated by the estimated mass of vehicle components
- Aerotech L2200-G

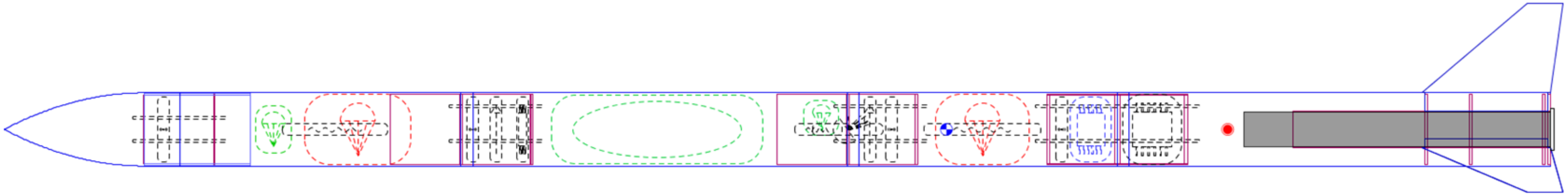
Diameter	75 mm / 2.95 in.
Length	68.1 cm / 26.81 in.
Total Weight	4,783 g / 10.54 lbs.
Propellant Weight	2,518 g / 5.55 lbs.
Average Thrust	2,200 N / 495 lbs.
Maximum Thrust	3,104 N / 698 lbs.
Total Impulse	5,104 Ns / 1147 lb. sec
Burn Time	2.3 sec



Stability Margin

- Diameter: 6.25 in.
- CP location at rail exit: 92.26 in.
- CG location at rail exit: 78.46 in.
- Stability margin at rail exit: 2.21



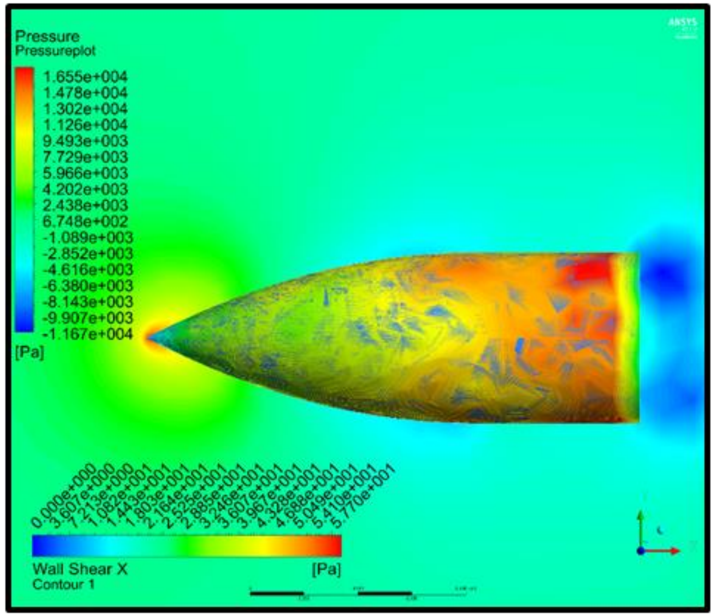


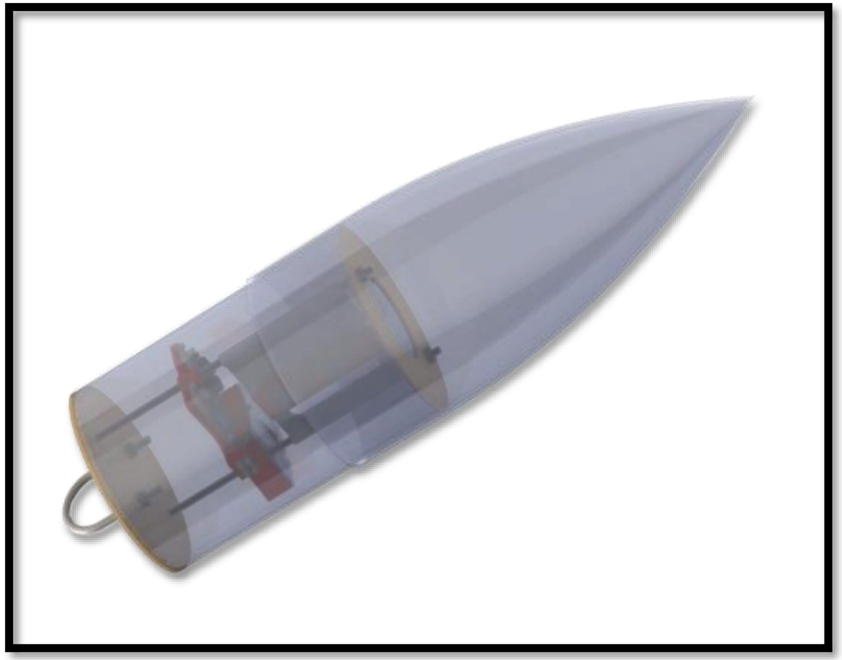
Flight Characteristics

Maximum Acceleration (ft./s^2)	456
Maximum Velocity (ft./s)	702
Thrust to Weight Ratio	14.44
Predicted apogee in 10mph wind (ft.)	5,435
Time to Apogee (sec.)	17.8
Exit Rail Velocity from a 141-inch rail (ft./s)	94.5
Center of Pressure Location at Rail Exit (in. from nose cone tip)	92.26
Center of Gravity Location at Rail Exit (in. from nose cone tip)	78.46
Stability Margin at Rail Exit (cal.)	2.21

Nose Cone Design

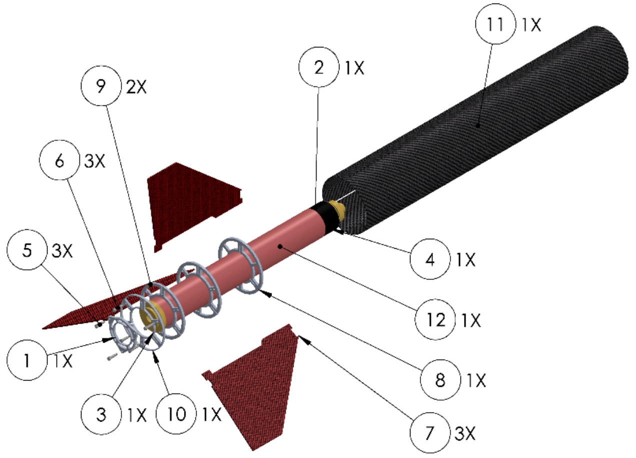
- 12in. Parabolic Nose Cone with a 3 in. transition section (reduced from PDR)
- Additively manufactured from Nylon 12
- Will store altimeter and AIM XTRA GPS tracker in coupler during flight



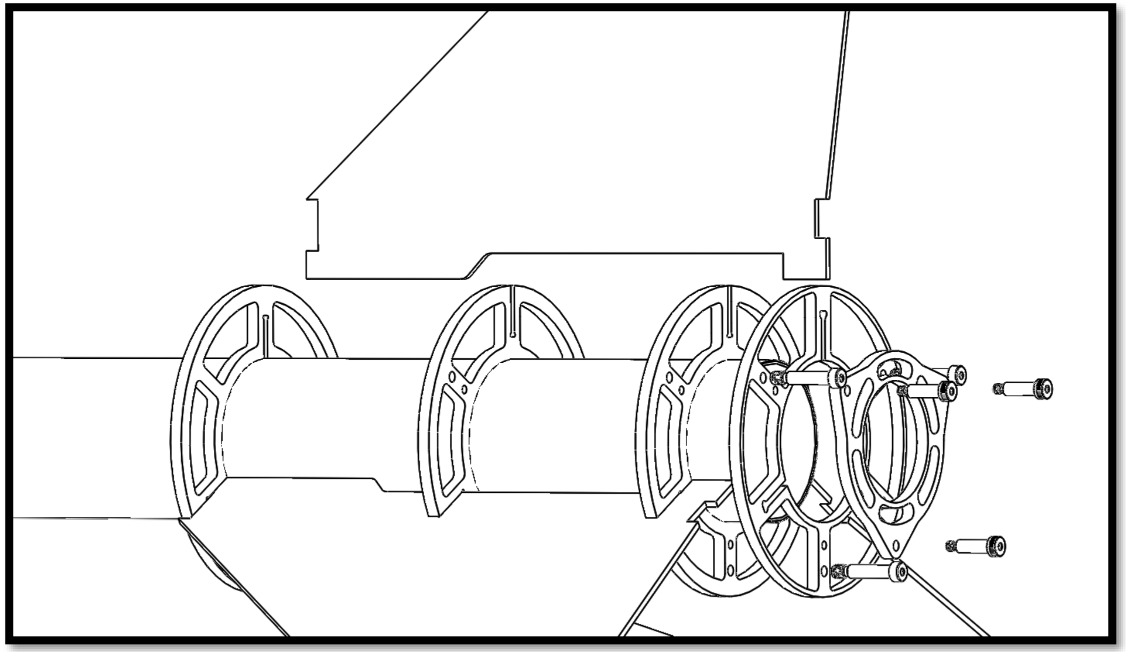


Removeable Fin System

- Quick and easy installation/removal of fins
- Adjustable fin dimensions
- Easy transportation
- Can replace a damaged fin

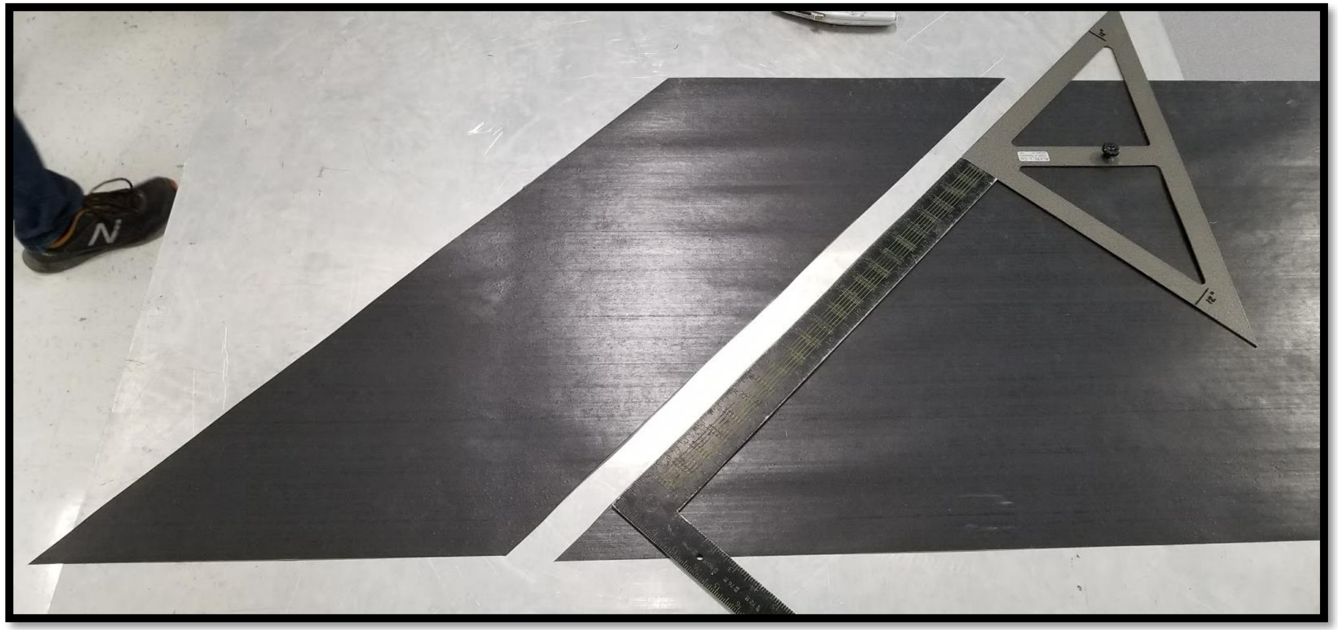


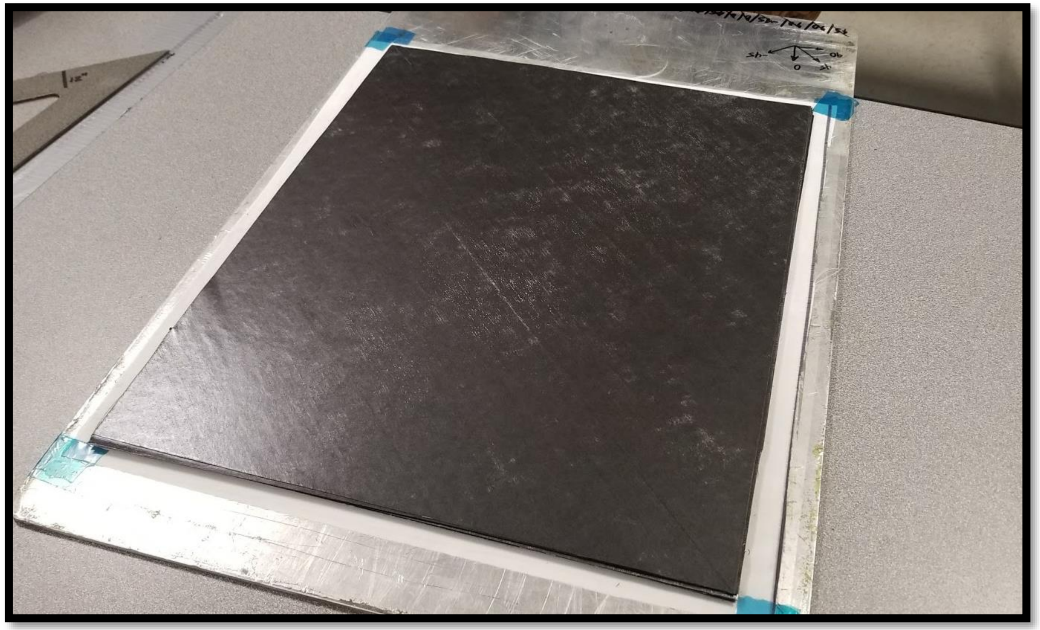
ITEM NO.	PART NUMBER	QTY.
1	Motor Retainer	1
2	Motor Casing	1
3	Aft Closure	1
4	Forward Closure	1
5	#10-32 Shoulder Bolt	3
6	1/4" - 20 Shoulder Bolt	3
7	Swept Cropped Delta Fin	3
8	Fore Centering Ring	1
9	Mid Centering Ring	2
10	Fin Retainer	1
11	Booster Tube	1
12	Motor Mount Tube	1



Fin Material

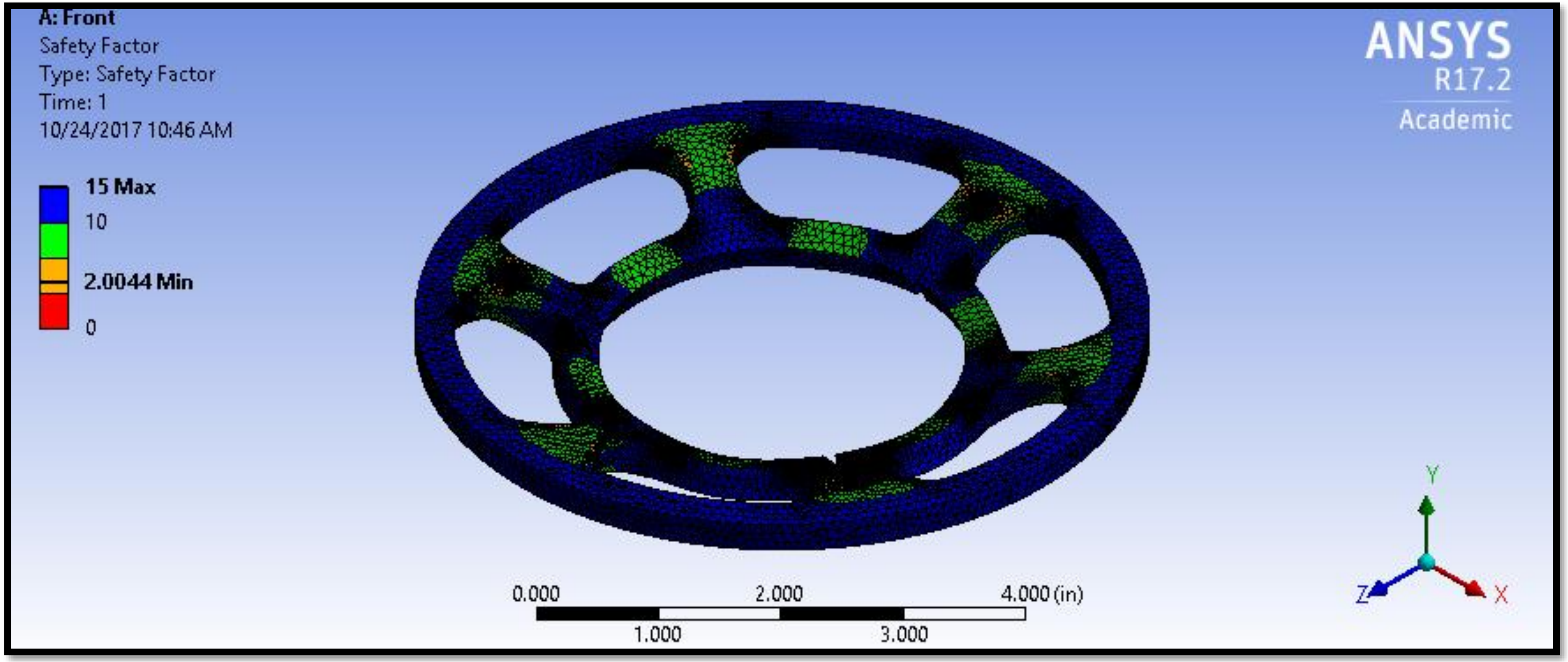
- Custom quasi-isotropic 20 layer lay up: $[45/90_2/-45/90/-45/0_2]_S$
- Toray prepreg unidirectional fiber used on Boeing 777, 787
- Pressed into 12in. X 15in. sheets, will be cut with a water jet to fin design





Centering Ring Design

- 0.25 in. thick 6061-T6 aluminum
- Mass reduction slots
- High factor of safety
- Epoxied to motor mount tube and booster airframe with Glenmarc G5000 epoxy



GPS Tracking

- **Booster**: SkyTraq (902-928 MHz)

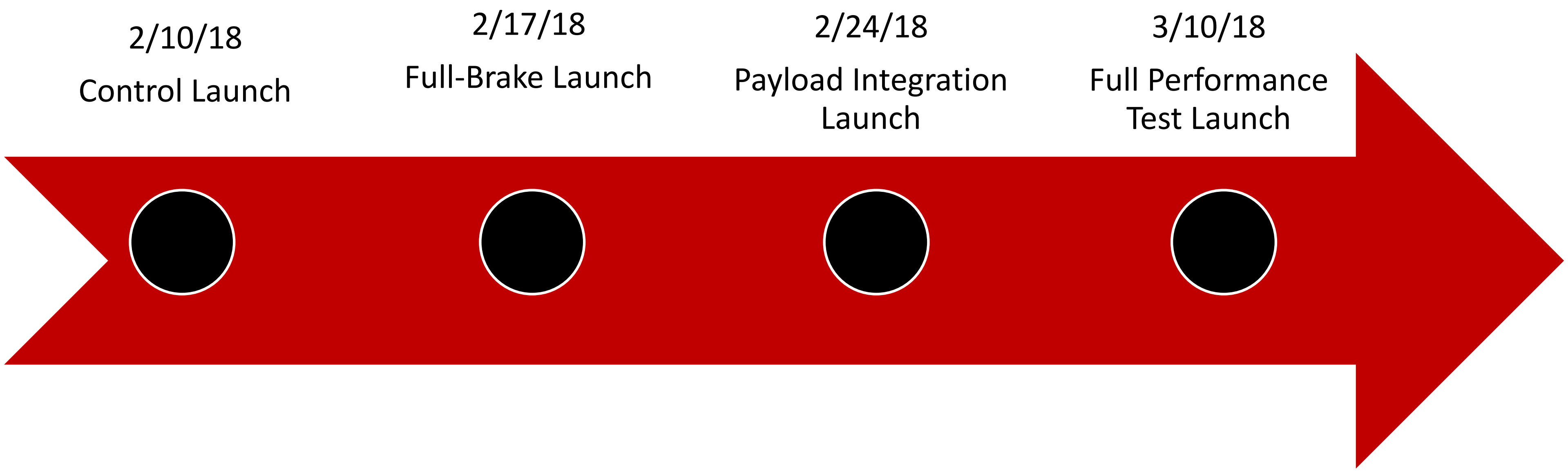
- **Payload Bay**: Eggfinder (900 MHz)

- **Coupler**: Trackimo (850, 900, 1800, and 1900 MHz)

- **Nose Cone**: AIM XTRA (473 MHz)

Vehicle Verification Progress

- 25/46 Requirements verified
- Remaining requirements scheduled to be verified in February
- All requirements will be verified by FRR

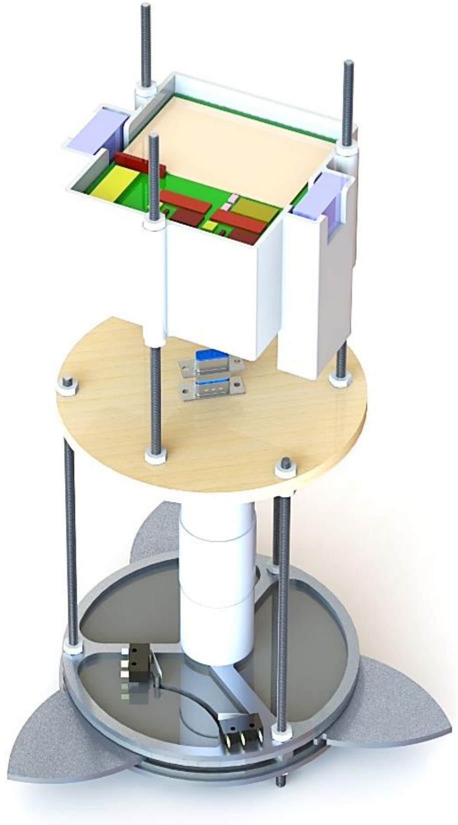


CDR Presentation Agenda

- Launch Vehicle
- Variable Drag System
- Recovery
- Subscale Vehicle
- Safety
- Payload
- Educational Outreach
- Budget

Variable Drag System

The Variable Drag System (VDS) is designed to alter the drag force on the rocket, to safely and repeatedly deliver the vehicle to 1 mile AGL +/- 23 ft.



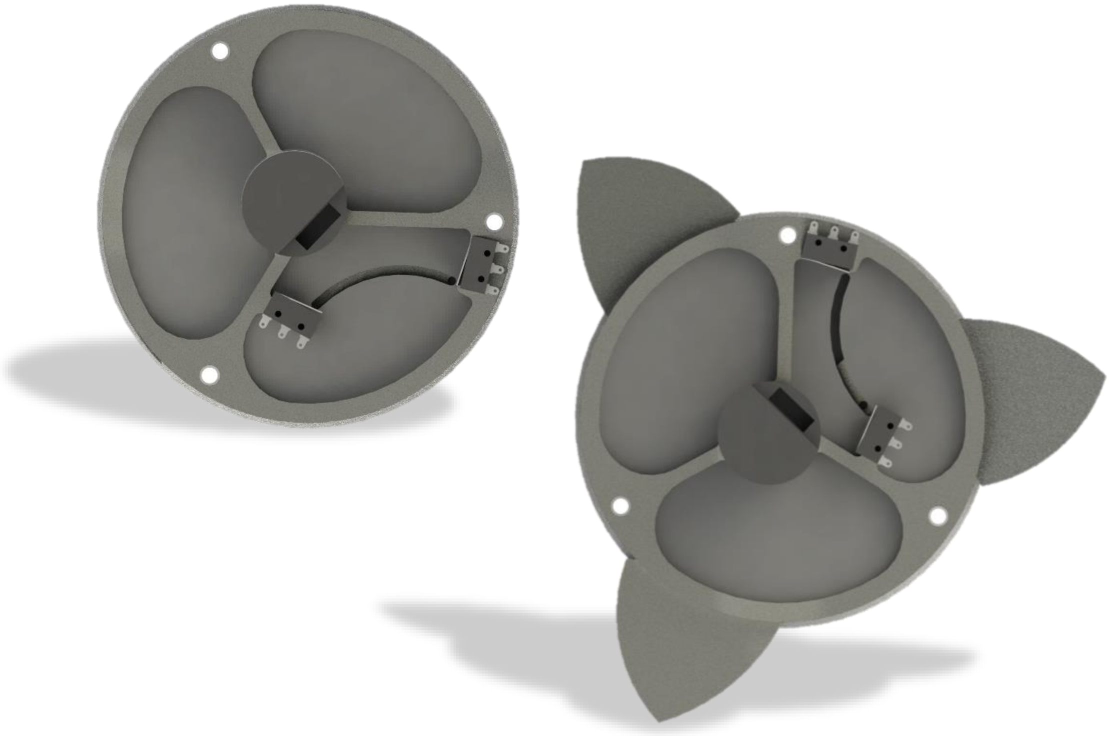
VDS Agenda:

- General Design of the VDS
- Current testing and prototyping progress
- Simulations and mission performance prediction
- Integration and Interfacing plans

Basic Design

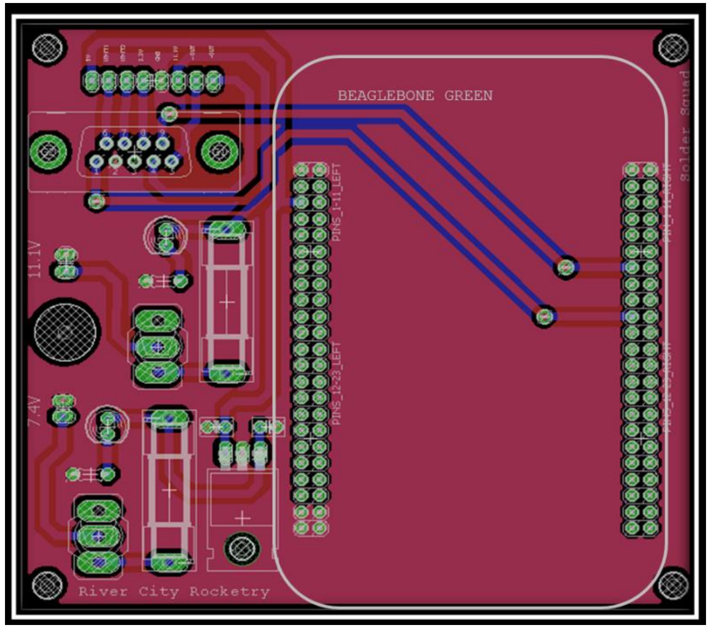
VDS Construction:

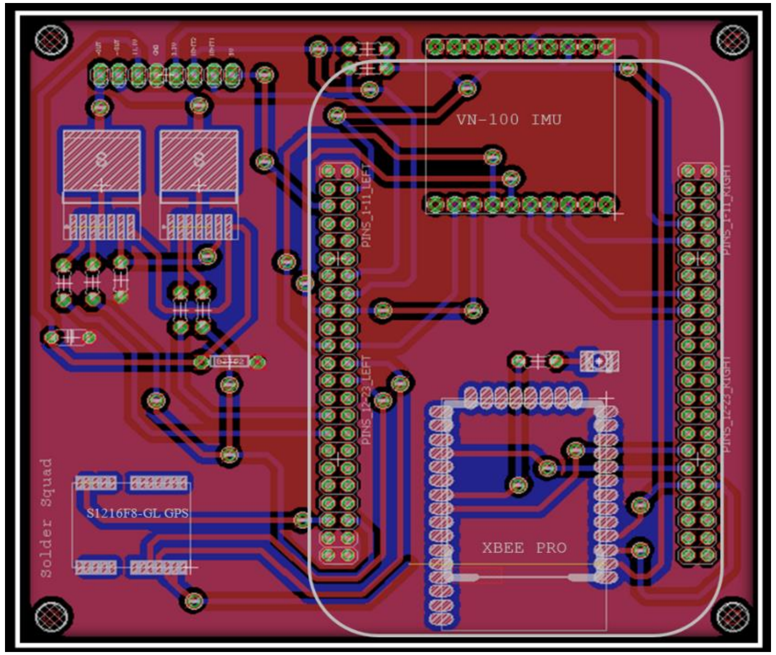
- Designed to reduce apogee from 5,462 ft. to 5,280 ft.
- Three water jetted 6061-T6 aluminum drag blades, delrin plates provide a low friction bearing surface.
- Simultaneously actuated by central DC motor
- Three configurations; non actuating, full actuation, and full performance



Electronics Hardware

- Two printed circuit boards
- Top board power controls
- Prototyping Sponsored by Advanced circuits
- Bottom board DAQ
- System runs on BeagleBone green computer
- Major components:
    - VN-100 IMU
    - Skytraq GPS module
    - Xbee Pro SX telemetry module
    - H-bridge motor control circuit





Full-Scale Launch Testing

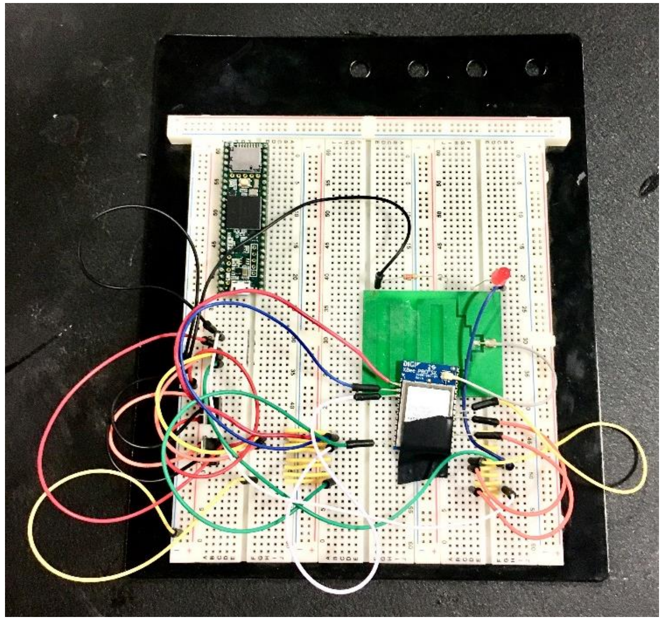
Test	Criteria	Requirements verified	Test Date
First Launch	Verifying VDS software operation and data acquisition. Non actuation launch	V.1.2	2/10/2018
Second Launch	Finalization of software and full actuation	V.1.5.1	2/17/2018
Third Launch	Full performance testing/debugging	V.1.5, V.1.5.1, V.1.6, V.1.6.1, V.1.6.2	2/24/2018
Fourth Launch	Full performance and finalization	V.1.5, V.1.5.1, V.1.6, V.1.6.1, V.1.6.2	3/10/2018

Telemetry signal testing

Procedure Overview: Place modules at varying distances on independent battery power and evaluate the signal.

- Operational at 902-928MHz – will automatically scan for lowest noise frequency.

Test	Status	Requirements verified	Date
Telemetry signal and fidelity with patch antennae	Fail– will retest with whip antennae an re-evaluate	V.1.2, V.1.5	1/6/2018
Power consumption of telemetry module	Pass- 900mA current draw at highest data setting of 30dBm. Power loss over 1 hour was 2%.	V.1.2, V.1.5	1/6/2018
Telemetry signal and fidelity test with whip antenna	Incomplete	V.1.2, V.1.5	1/18/2018



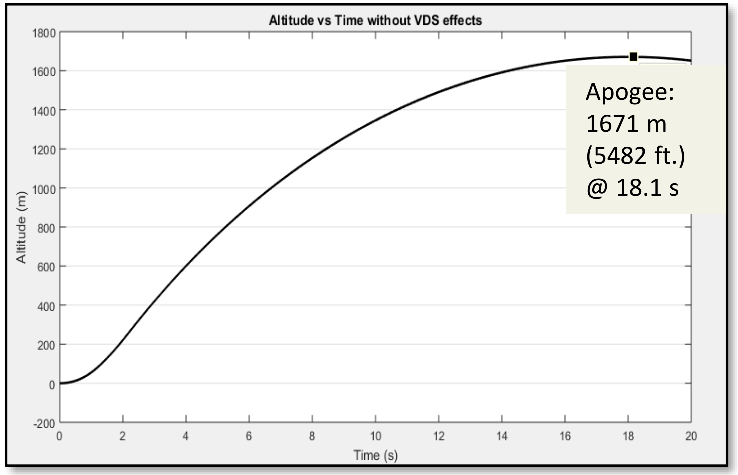
Mission Performance Prediction

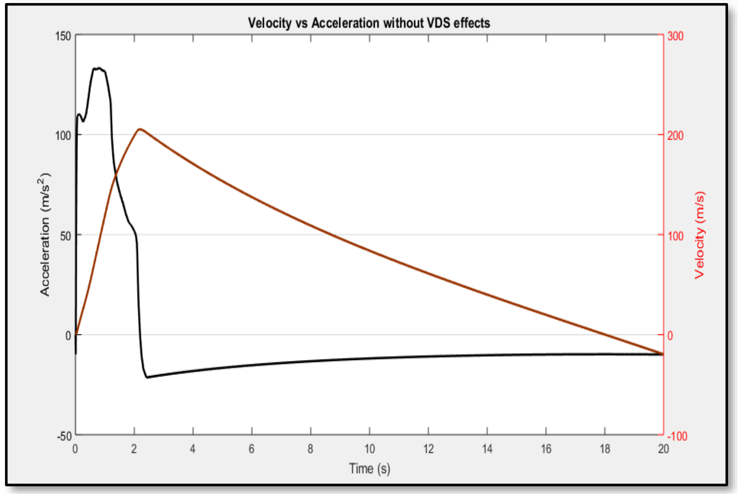
Updated simulation parameters prediction based on values derived from subscale model

- Updated C_d
- Updated vehicle mass and thrust curve

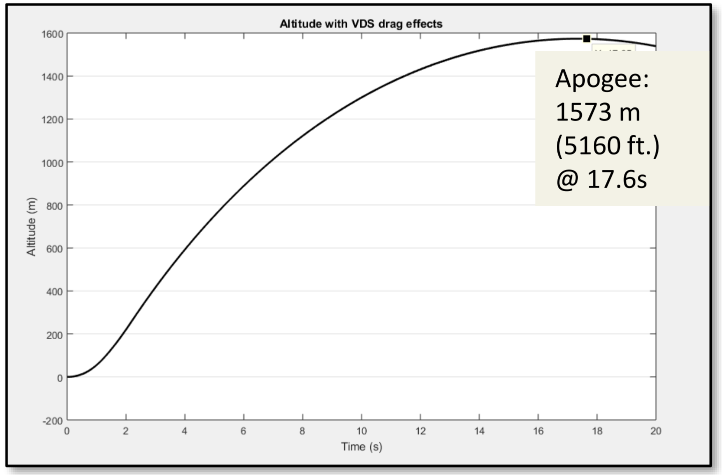
- Graphs simulate first and second launches

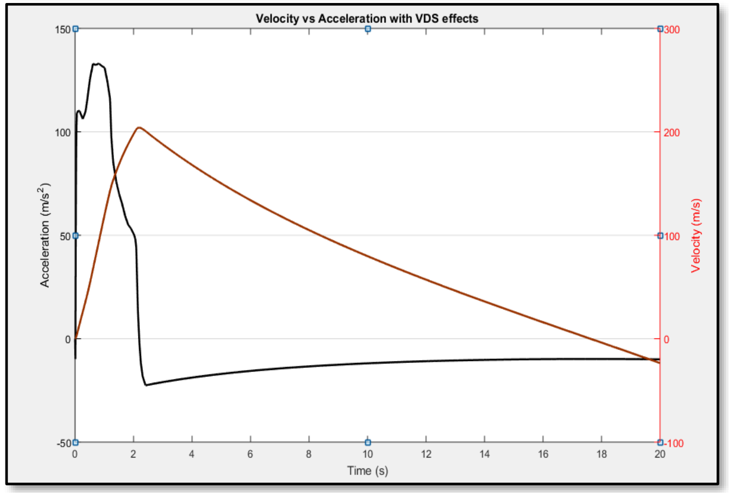
Full Scale Launch One – Control with no actuation





Full Scale Launch Two- Control with full actuation





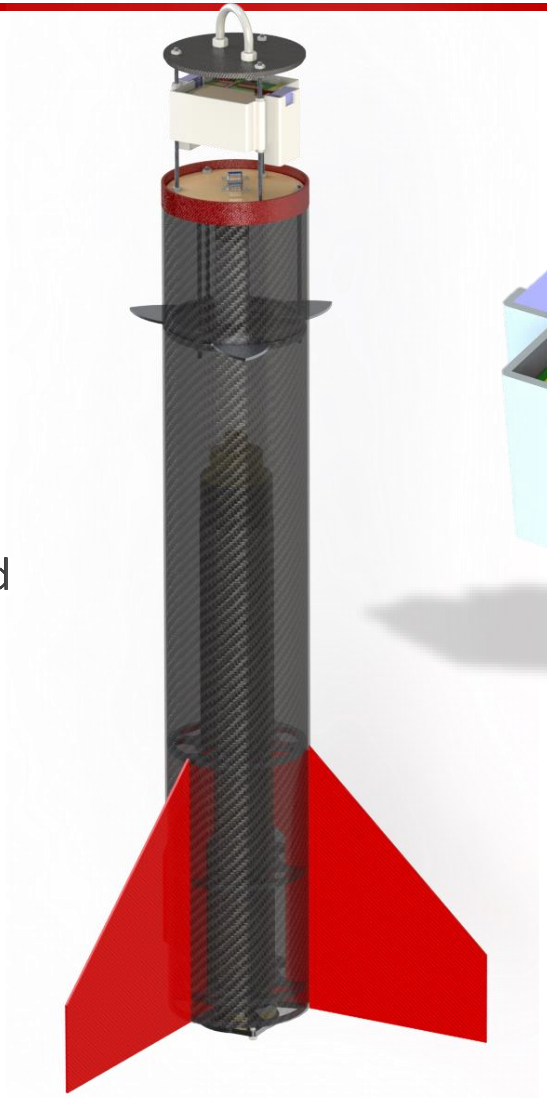
Integration

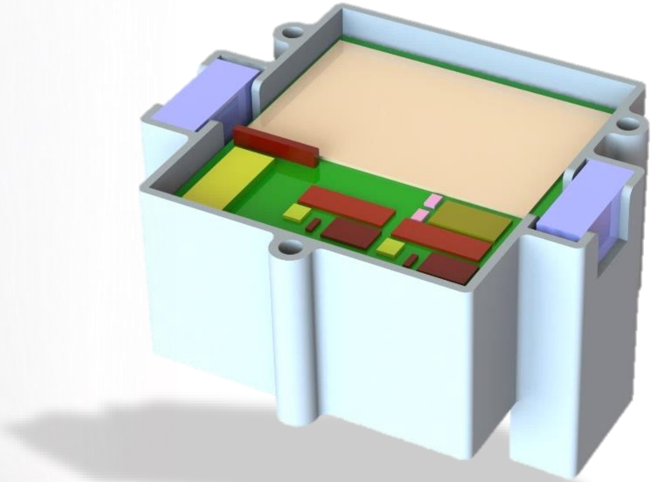
Integration:

- Custom designed avionics sleds
- External power connection through body of vehicle

Interfacing:

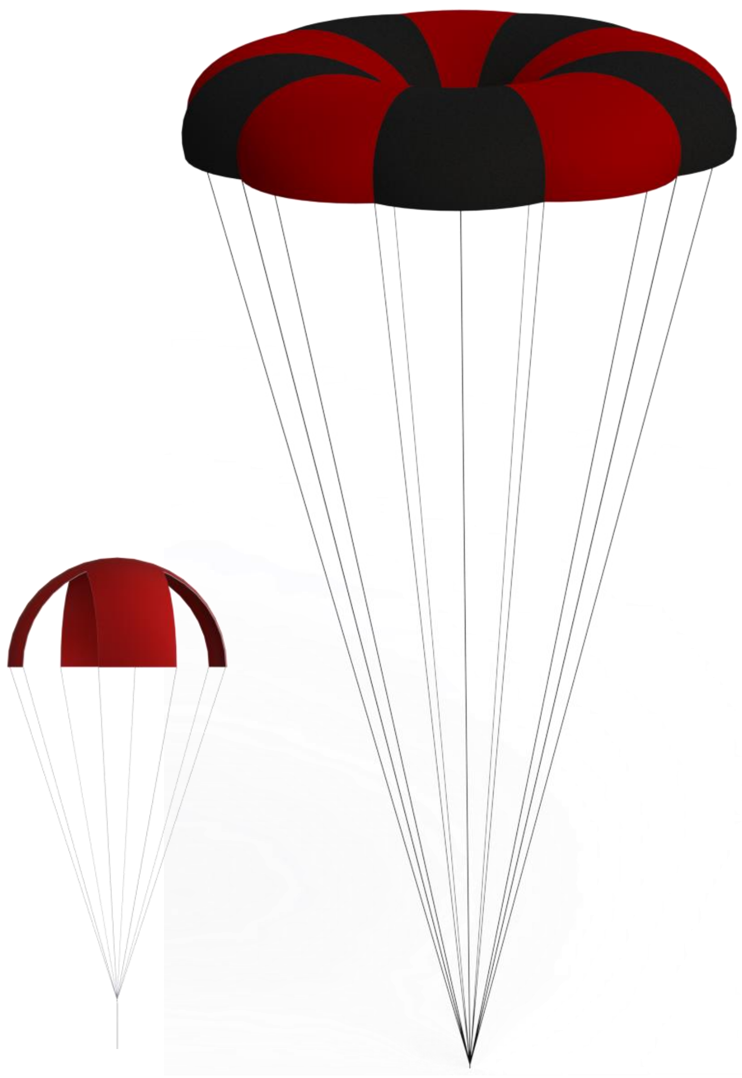
- Antenna wired external down through booster and secured to fins of vehicle
- Wire through bulk plate for connection with blade configuration





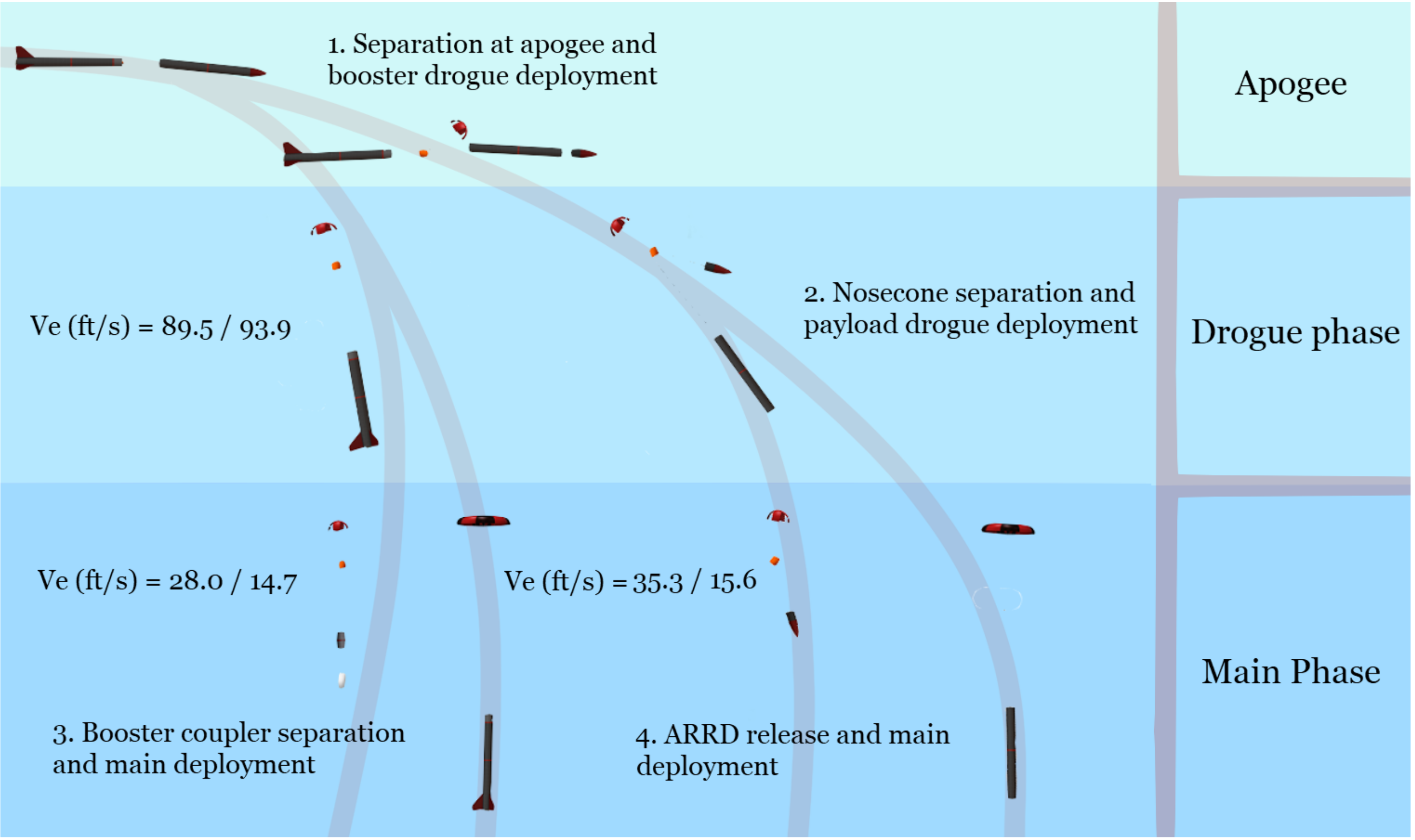
CDR Presentation Agenda

- Launch Vehicle
- Variable Drag System
- Recovery
- Subscale Vehicle
- Safety
- Payload
- Educational Outreach
- Budget



Recovery Agenda

- Sequence of events
- Parachute parameters
- Rigging parameters
- Opening force
- Drift



Sequence of Events

Apogee: 5280 ft.
Separation of midsection and nosecone after delay.

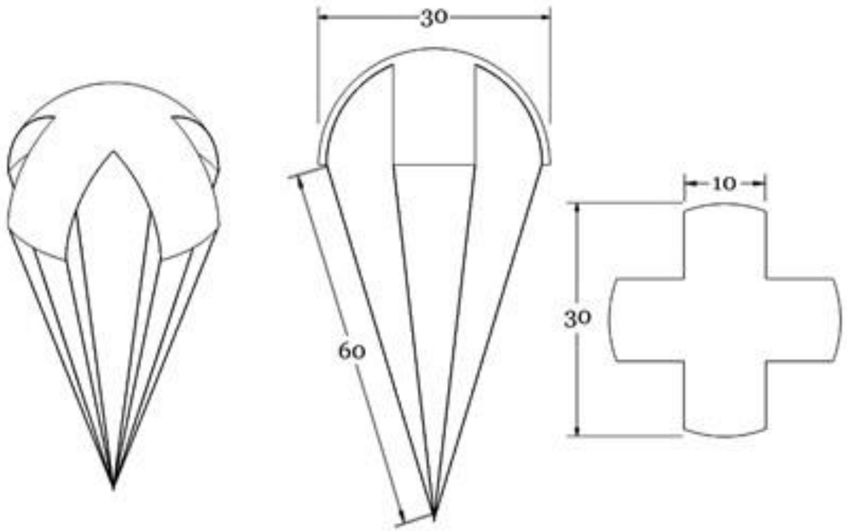
Drogue phase: Apogee – 500 ft.
Booster decent at 89.5 ft./s
Payload decent at 93.9 ft./s

Main phase: 500 ft.
Booster decent at 14.7 ft./s
Payload decent at 15.6 ft./s
Nosecone decent at 35.3 ft./s
Coupler decent at 28.0 ft./s

Drogue Parachute

Section	Mass (lbs.)	Terminal Velocity (ft./s)	Kinetic Energy (ft.-lbs.)	Size Boundaries (in.)	Size (in.)
Payload	20.24	89.5	238.3	25 - 35	30
Booster	21.27	93.9	169.9	16 - 36	30

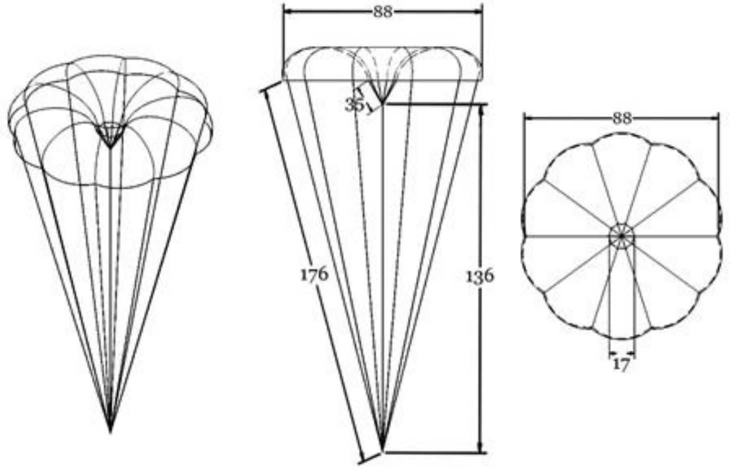
- Cruciform design
- Designed for KE and Drift
- Both sections have same diameter for ease of integration
- Laser cut single panel



Main Parachute

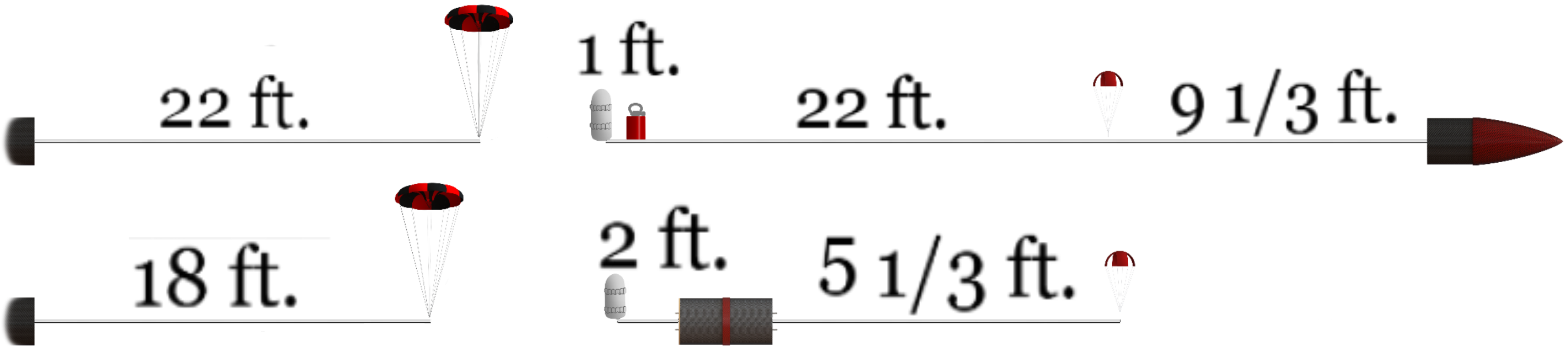
Section	Mass (lbs.)	Terminal Velocity (ft./s)	Kinetic Energy (ft.-lbs.)	Size (in.)
Payload	17.09	15.6	65	88
Booster	19.29	14.7	65	99
Coupler	1.98	28.0	17.47	30
Nosecone	3.14	35.3	43.8	30

- Toroidal design
- Laser cut gores sewn in house
- Drogues act as main for coupler and nosecone



Rigging Parameters

Linkage	Material	Length (ft.)	Break Strength (lbs-f)
Nosecone - Drogue	9/16 in. Tubular Nylon Shock Cord	9 1/3	1500
Drogue - ARRD	9/16 in. Tubular Nylon Shock Cord	22	1500
ARRD - Deployment Bag	Paracord	1	320
Payload Main - Bulkplate	9/16 in. Tubular Nylon Shock Cord	22	1500
Drogue - Coupler	9/16 in. Tubular Nylon Shock Cord	5 1/3	1500
Coupler – Deployment Bag	Paracord	2	320
Booster Main - Bulkplate	9/16 in. Tubular Nylon Shock Cord	18	1500



Opening Force

Section	Opening force (Lbs.-f)	Acceleration (ft/s/s)	Factor of safety
P. Drogue	1.4	0.4	>10
P. Main	323.1	608.4	3.7
B. Drogue	6.4	3.2	>10
B. Main	411.8	686.9	2.9

Opening forces are found using

$$F_x = \frac{(C_D S)_P \rho v^2 C_x X_1}{2}$$

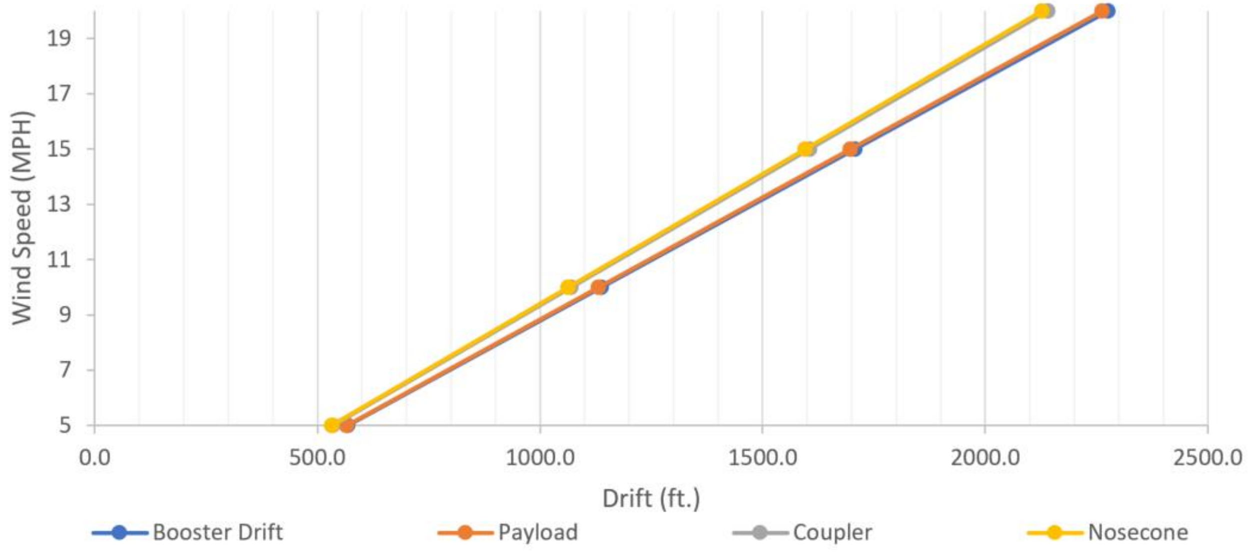
using data from subscale flights and scaled to the full scale launch vehicle

- Drogue opening force relatively small due to low opening speed
- Quick link is lowest rated linkage AT 1200 LBS.
- Lowest factor of safety of 2.9

Drift

MPH	ft./s	Booster (ft.)	Payload (ft.)	Coupler (ft.)	Nosecone (ft.)
5	7.3	622.6	604.8	504.3	474.3
10	14.7	1245.2	1209.6	1008.7	948.6
15	22.0	1867.8	1814.4	1513.0	1423.0
20	29.3	2275.3	2204.1	2017.4	1897.3

- Calculated mathematically using decent times
- Drogue parachutes designed to not exceed drift restriction
- Booster drifts furthest under worst case 20 mph winds due to slow decent under main



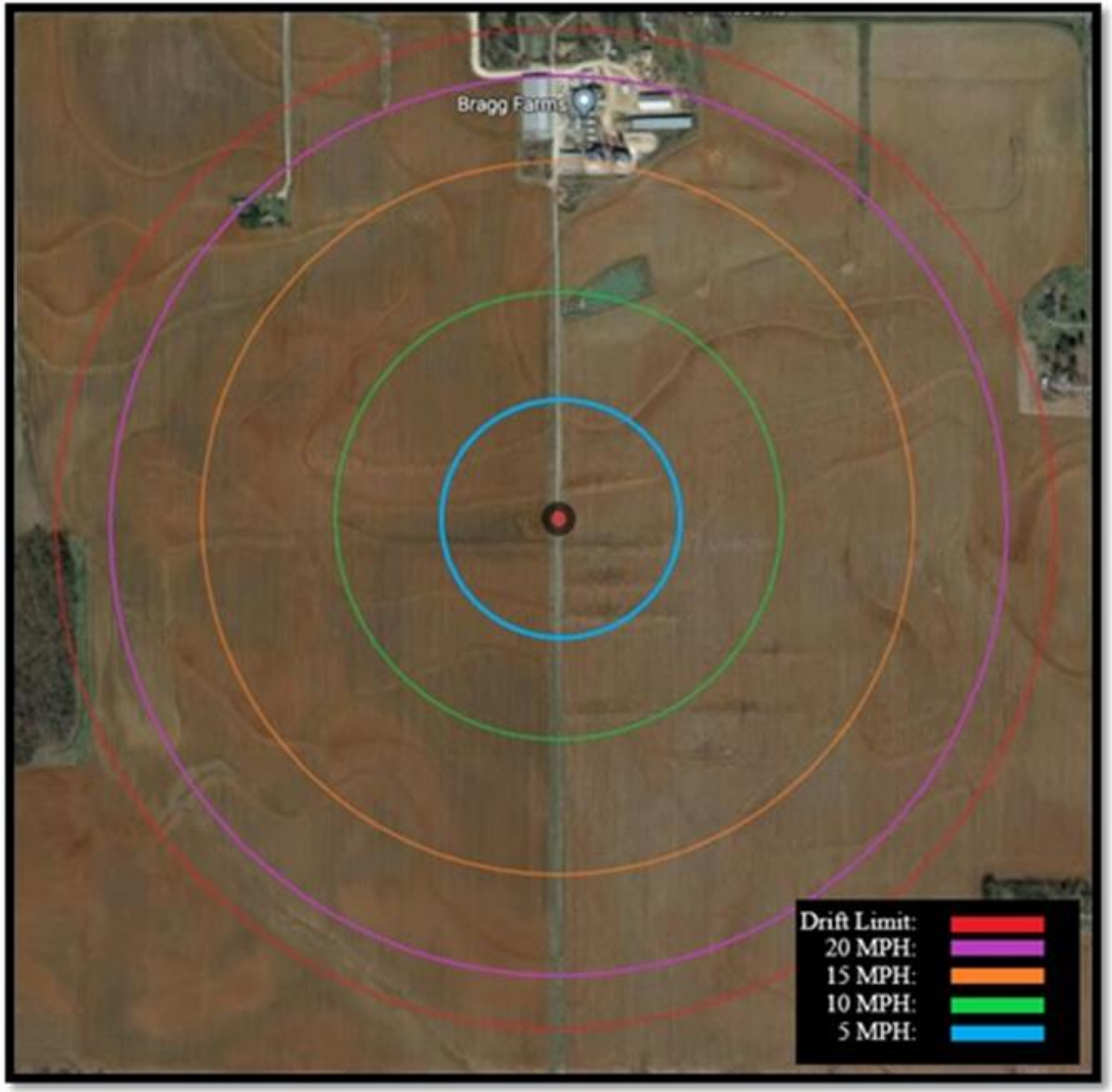
Visualized drift and Mission Elapsed Time

Ascent: 17.8s

Drogue decent: 53s

Main decent: 24s

Total: 94.8s



Recovery Test Campaign

- Payload protection from BP separation
- Nomex cloth square to contain BP residue and reduce concussive forces
- Separation pressure within the vehicle unchanged

Control recovery flight → Payload protection dummy test → Payload protection test → Full recovery system test

Control recovery flight	Payload protection dummy test	Payload protection test	Full recovery system test
2/10/18	2/17/18	2/24/18	3/10/18

Requirement Verifications

- 17/21 Requirements verified
- Remaining requirements scheduled to be verified during full scale campaign
- All requirements will be verified by FRR
- All tests are based upon SOW or team derived requirements

TDR 1
The sections of the launch vehicle will not interfere with each other or each other's recovery systems during the descent phase of the flight profile.

TDR 2
The opening force of the main parachutes will not exceed the structural capability of the launch vehicle or the rigging which attaches it to the vehicle.

TRD 3
The drogue parachute must have a larger drag force than the launch vehicle while horizontal.

TDR 4
The Advanced Retention and Release Device (ARRD) will perform properly during the official flight of the launch vehicle.

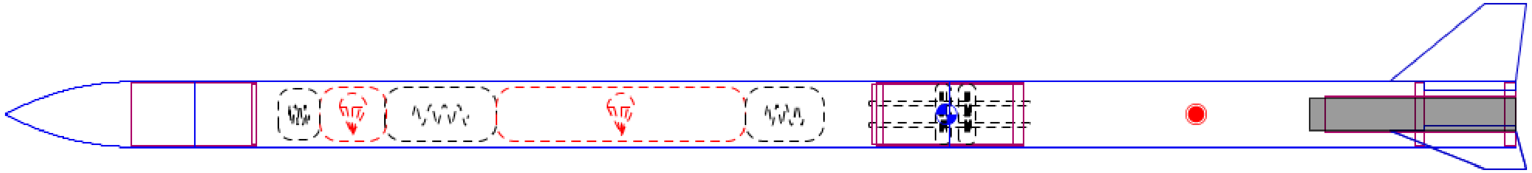
TDR 4.1
The ARRD will not release prematurely during the recovery process.

CDR Presentation Agenda

- Launch Vehicle
- Variable Drag System
- Recovery
- Subscale Vehicle
- Safety
- Payload
- Educational Outreach
- Budget

Subscale Vehicle Overview

- Half scale model of the full scale vehicle
- Designed in OpenRocket
- Aerotech I300 motor
- Launched twice
  - 11/11 in Elizabethtown, KY
  - 12/2 in Cedarville, OH



Subscale Vehicle Recovery

Parachute	Diameter (in)	KE at landing (ft-lbs)	Velocity during decent (ft/s)
Main	30	61	26.25
Drogue	20	440	60.53

- Single recovery bay.
- Utilized toroidal main parachute and cruciform drogue parachute.
- Utilized ARRD for main deployment.
- Verified opening force calculations and drag coefficient.

November 11th Subscale Flight

- Stable ascent
- Failed main parachute deployment
- Damage to fins, recovery bay, and nose cone

Vehicle Mass on Pad	5.703 lbs.
Temperature (°F)	46
Wind Speed	3 mph
Wind Direction	NE
Air Density at Ground Level (kg/m^3)	1.2850
Apogee Altitude/ % Difference to Simulation	2,353 ft./2.14%

Recovery Failure Analysis

- Drogue failure caused by asymmetry
- Cruciform parachutes now one panel cut from CNC laser cutter
- Reduces chance of error due to manufacturing

December 2nd Subscale Flight

- AIM XTRA added
- Stable ascent
- Successful recovery

Vehicle Mass on Pad	5.978 lbs.
Temperature (°F)	50
Wind Speed	4 mph
Wind Direction	NW
Air Density at Ground Level (kg/m^3)	1.2853
Apogee Altitude/ % Difference to Simulation	2,258/2.48%

CDR Presentation Agenda

- Launch Vehicle
- Variable Drag System
- Recovery
- Subscale Vehicle
- Safety
- Payload
- Educational Outreach
- Budget

Hazard Risk Assessment Matrix

Probability Level	Severity Value			
	1 - Catastrophic	2 - Critical	3 - Marginal	4 - Negligible
A–Almost Certain	1A	2A	3A	4A
B – Likely	1B	2B	3B	4B
C – Moderate	1C	2C	3C	4C
D – Unlikely	1D	2D	3D	4D
E – Improbable	1E	2E	3E	4E

- Redesigned to match NASA SL Handbook
    - Evaluated before and with mitigations
- Severity and Probability matrices maintained
- Risk Level Approval Matrix added

Risk Level and Approval Matrix	
Risk Level	Level of Approval Required
High Risk	Highly undesirable. Documented approval of NASA SL team, RSO, team sub-team leads, team safety officer, and team co-captains required.
Moderate Risk	Undesirable. Documented approval of all team sub-team leads, team safety officer, and team co-captains required.
Low Risk	Acceptable. Documented approval from team sub-team lead overseeing the component's development.
Minimal Risk	Acceptable. Documented approval is not required. Sub-team lead will ensure that sub-team members are familiar with the hazard.

Example Assessment

Hazard	Cause	Effect	RBM	Mitigation	Verifications	RWM
Obstructed rover path.	Field debris, launch vehicle, or rough terrain prevent the rover from being able to drive in a straight line.	The rover will not be able to drive 5 feet away from the vehicle resulting in a failed payload mission.	2B	The OAS will select the least obstructed path within the 156° field of view and the RDS will be designed to transverse different terrains and inclines of at least 20 degrees from horizontal.	Team derived OAS requirements, requirement CES-5, and requirement CES-6 will respectively test and demonstrate the selection of the least obstructed path.	2D
SAS panel support arms are not able to fully deploy.	Panel support arm(s) or tower assembly are damaged by contacting the airframe during flight or contacting launch field debris following rover deployment.	Rover is unable to deploy solar panels, leading to a failed payload mission.	2C	The panel support arms will be locked in a stowed position until the rover reaches its final destination. The deployed panel support arms were designed to fit inside the footprint of the RDS to avoid contact with debris at any point during panel deployment.	Requirement SAS-1 and requirement SAS-4 will verify complete SAS tower actuation from the stowed configuration through inspection and demonstration. Actuation will also be checked in the payload launch procedure checklist.	2E

From **Table 77: Payload Equipment Hazard Risk Assessment.**

Launch Operations

Full Scale Launch Safety Checklists

The following checklists were written to prepare the team for a safe and successful launch. Each checklist includes the following features to ensure that assemblers are well equipped, safe, and able to recognize all existing hazards:

- Required hardware, equipment, and PPE for each process
- Labels to indicate explicit safety precautions:

CAUTION -label used to identify where PPE must be used
WARNING -label used to signify importance of procedure by clearly identifying a potential failure and the result if not completed correctly
DANGER -label to signal the use of explosives and to indicate specific steps that should be taken to ensure safety

7.1.1. General Material Safety Checklist

To be checked and signed by a River City Rocketry team member and co-captain.	
1. ______________________	2. ______________________
Prior to leaving for launch site	
Equipment to Pack	
☐ Clear black powder capsules (x4)	☐ Drill
☐ E-matches (x4)	☐ Drill bit set
☐ Black powder	☐ Electrical tape
☐ Black powder measuring kit	☐ Black Gorilla Tape
☐ Paper towels	☐ Paper towels
☐ Hot glue gun	☐ Hot glue gun
☐ Scissors	☐ Allen wrench set
☐ Garbage bag (x2)	☐ Tent (x2)
☐ Large tarp	☐ Folding table (x3)
☐ Folding chair (x3)	☐ Dremel bit kit
☐ Dremel	☐ 5-minute epoxy
☐ Assorted zip tie container	☐ Red supply tackle box (x2)

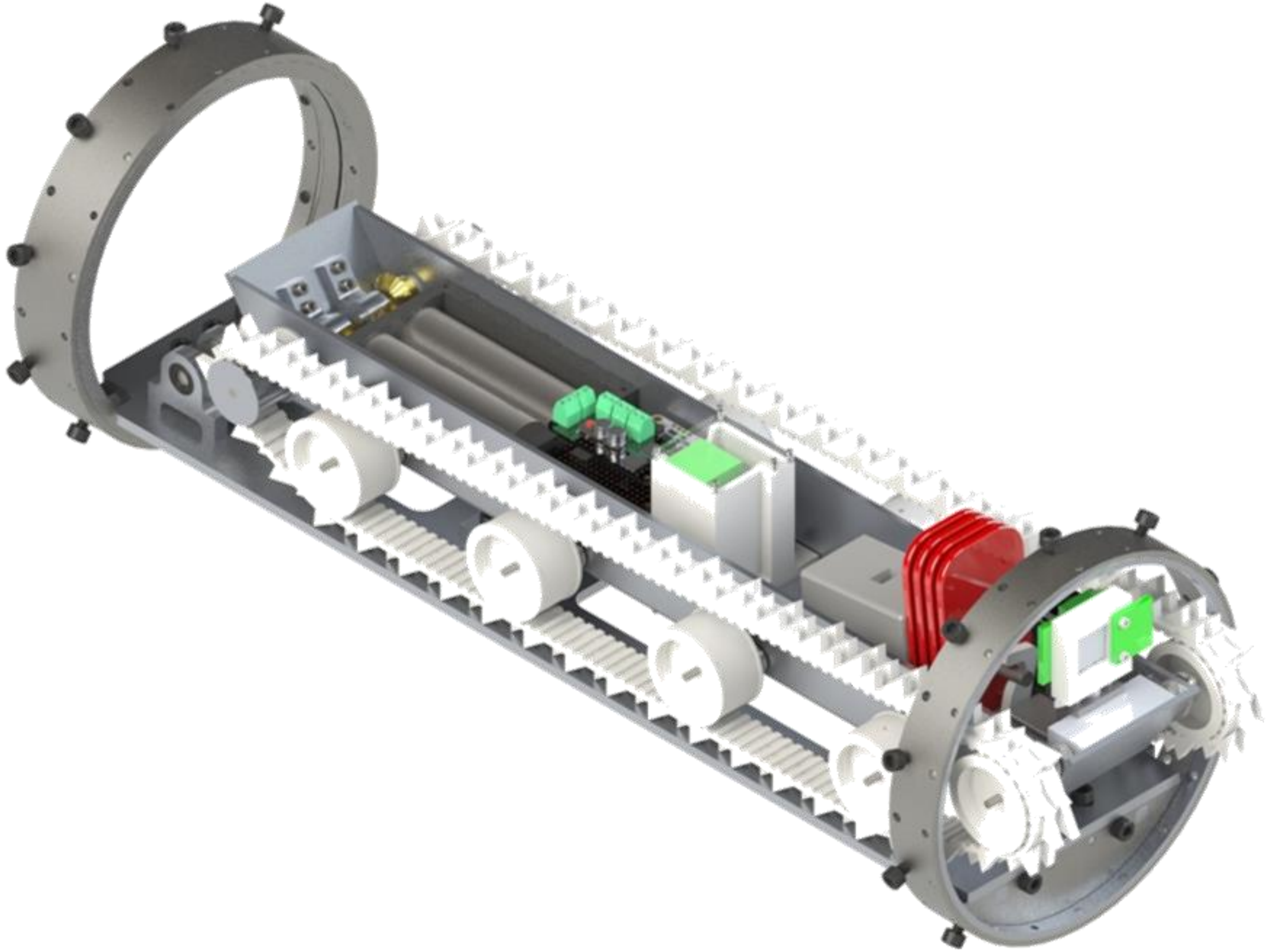
Vehicle Setup on Launch Pad		
Equipment to Pack or Prepare		
☐ Assembled vehicle ☐ Philips head screw driver ☐ Level ☐ Pencil		☐ Rocket perch ☐ Launch box ☐ Checklist ☐ Level 2 certification card
____	1. Verify flight card has been properly filled out and launch permission has been granted by RSO.	
CAUTION	Safety glasses are required to be worn at the launch pad.	
____	2. Select 3 team members to transport the assembled vehicle from the preparation area to the launch pad	
WARNING	Confirm the members can comfortably carry the vehicle together to eliminate the risk of a dropped vehicle.	
Note:	Only required personnel should accompany the rocket to the launch pad to eliminate distraction	
____	2. Slide the vehicle onto the rail. If the section of airframe does not slide freely up and down the entire length of the launch rail, see the trouble shooting section.	
WARNING	This step cannot be considered completed until the airframe moves freely. If the airframe is caught on the launch rail, the vehicle will experience too much friction, jeopardizing successful flight.	

CDR Presentation Agenda

- Launch Vehicle
- Variable Drag System
- Recovery
- Subscale Vehicle
- Safety
- Payload
- Educational Outreach
- Budget

Payload Agenda

- Overview of Final Design
- Integration
- Internal and External Interfaces
- Requirement Verification Schedule
- Testing Plans



Overview of Final Design

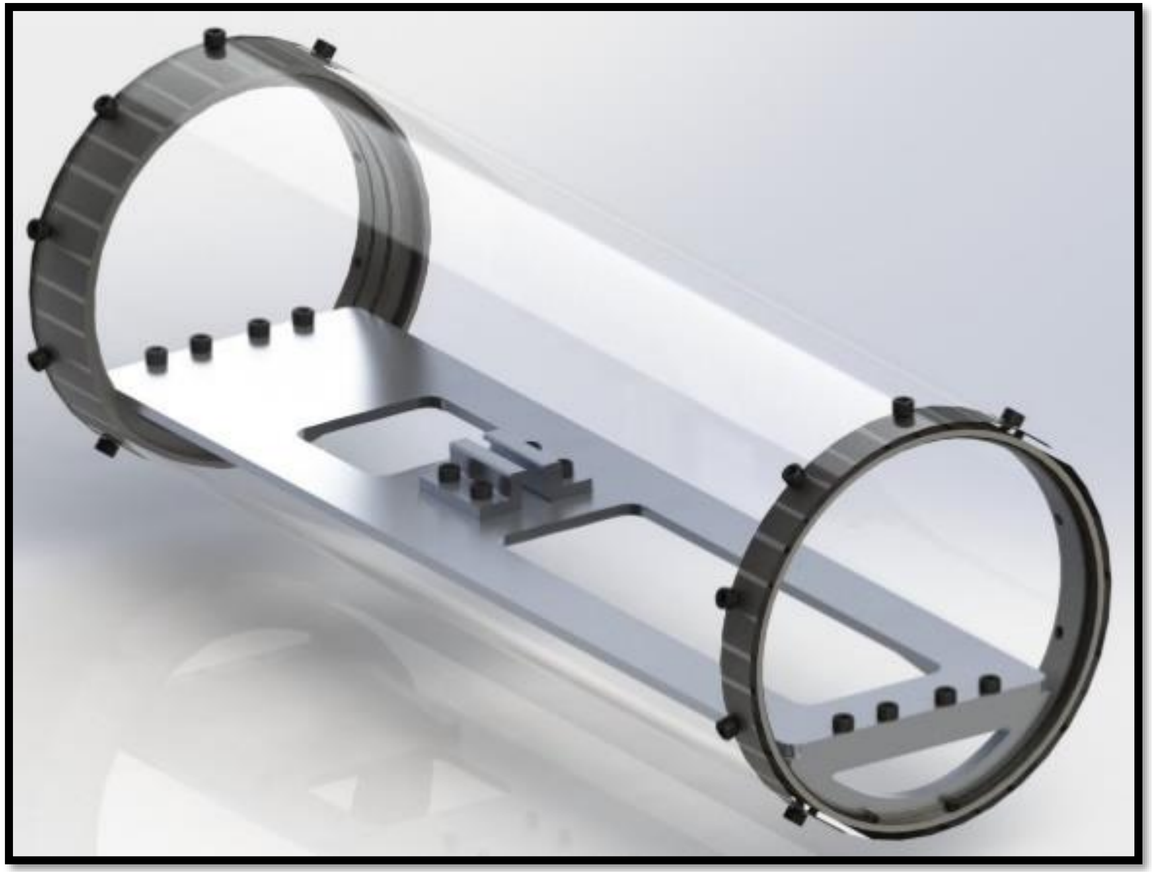
- "The payload" refers to all subassemblies and subsystems of the entire experimental payload onboard the launch vehicle

- "The rover" refers to only the subassemblies and subsystems onboard the autonomous rover vehicle

ROCS/RLM	
Dimension	**Value**
Diameter	Ø6.0 in.
Length	17.9 in.
Weight	4.78 lbs.
ROVER	
Dimension	**Value**
Stowed Length x Width x Height	16.82 x 4.73 x 3.73 in.
Deployed Length x Width x Height	16.82 x 4.73 x 4.05 in.
Weight	3.51 lbs.
PAYLOAD	
Total Weight (including DTS)	8.29 lbs.

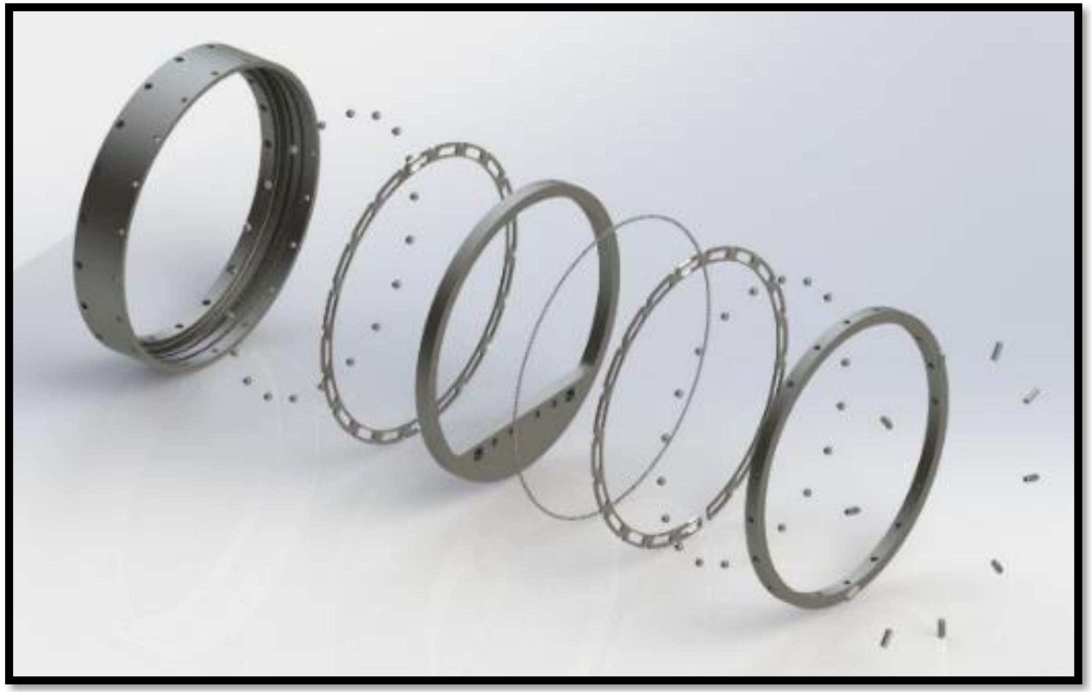
Rover Orientation Correction System (ROCS)

- Supports rover throughout flight
- Ensures upright orientation of the rover at landing
- Quick integration and removal



ROCS Cont….

- AFT End Thrust Bearing
  - Absorbs critical forces
  - Allows free rotation of the rover

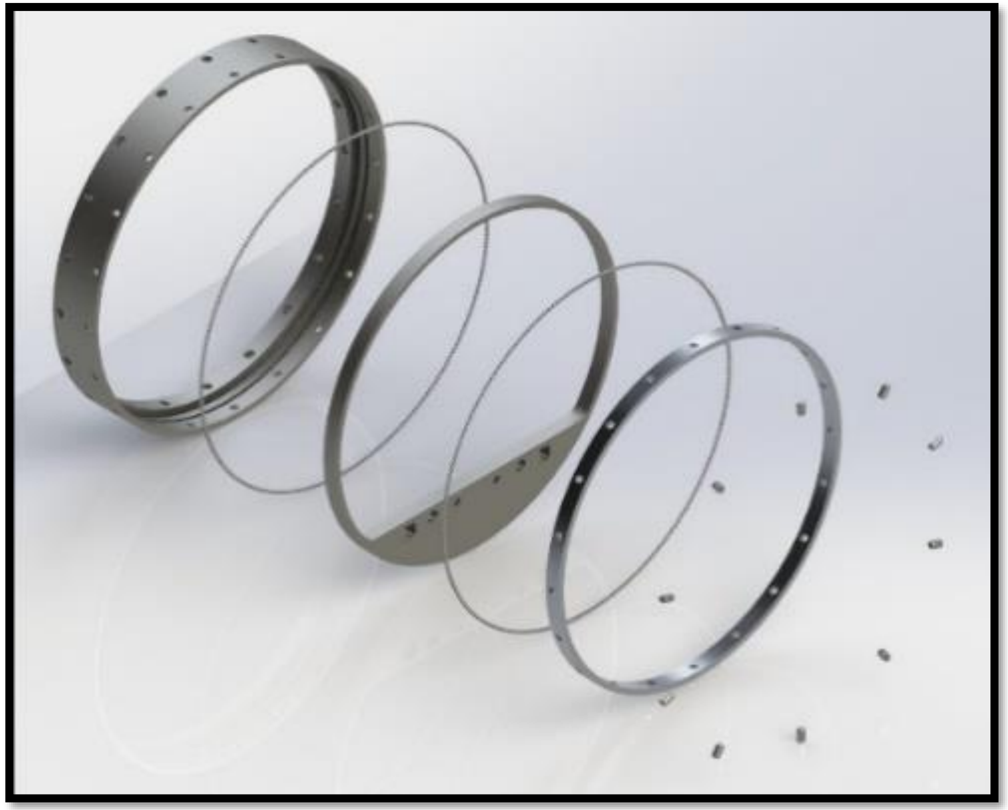


Component	Material
Outer Ring, Primary Inner Ring, Secondary Inner Ring	D2 tool steel
0.1575 in. Ball Bearing	Si_3N_4 Silicon Nitride
0.0625 in. Ball Bearings	AISI 52100 Chromium Steel
Ball Bearing Retention Ring	316 Stainless Steel
0.1250 Dowel Pin	Fully Hardened Alloy Steel

ROCS Cont….

- FWD End Support Bearing
  - Support the rover throughout flight
  - Allow free rotation of the rover

- Similar materials used to build both bearings



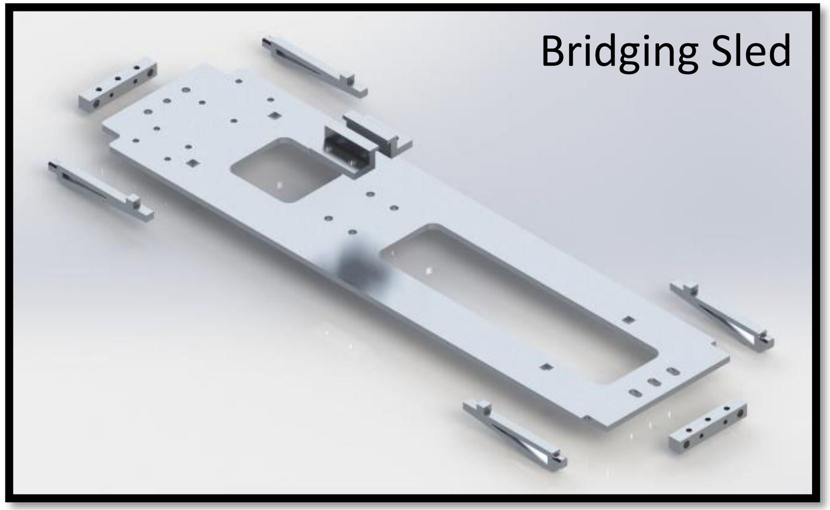
ROCS Cont….

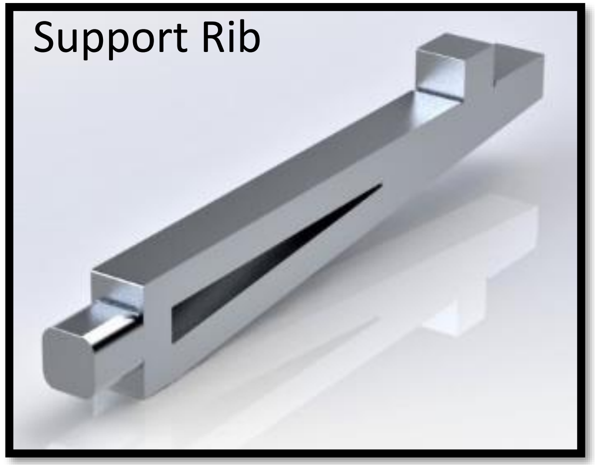
- Bridging Sled
  - Support rover throughout flight
  - Bridge and connect the two bearings

- Support Ribs
  - Reduce deflection
  - Reduce single-point bending

- Crescent Mounting Bracket
  - Mount Bridging Sled to bearings

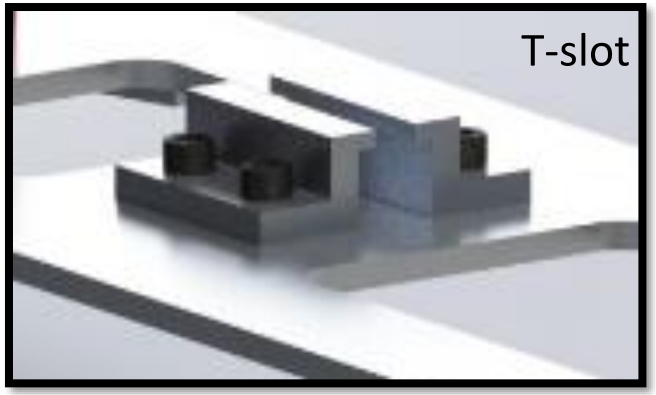
- 6061-T6 Aluminum
  - Light weight and high strength

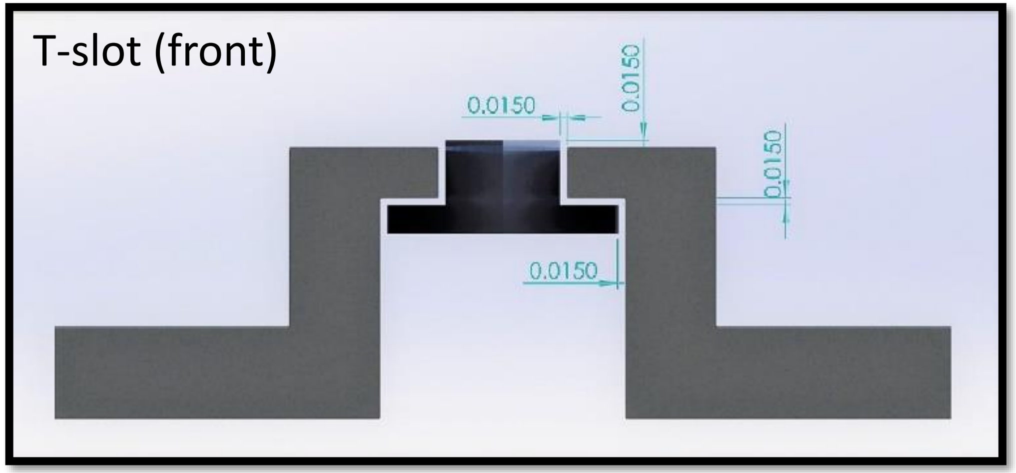




ROCS Cont....

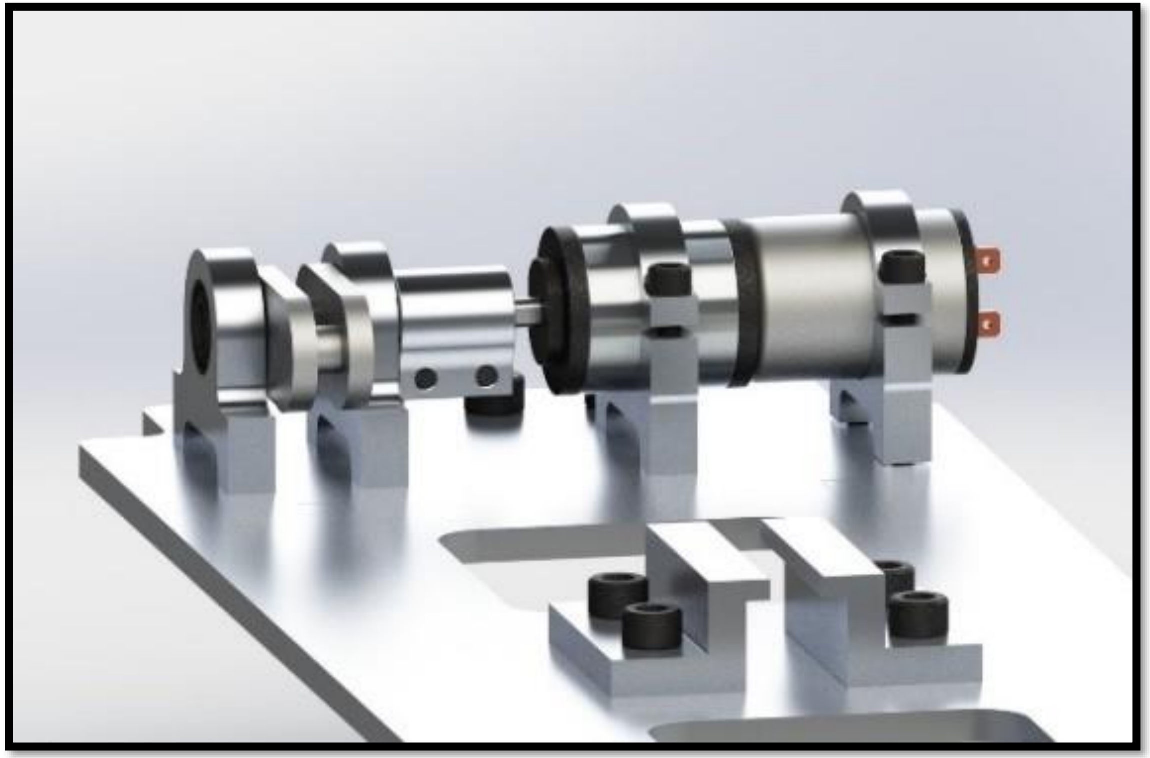
- Female T-slot on bridging sled
- Male T-slot on bottom side of rover
- Restricts motion relative to the ROCS in the axes perpendicular to the central axes of the launch vehicle





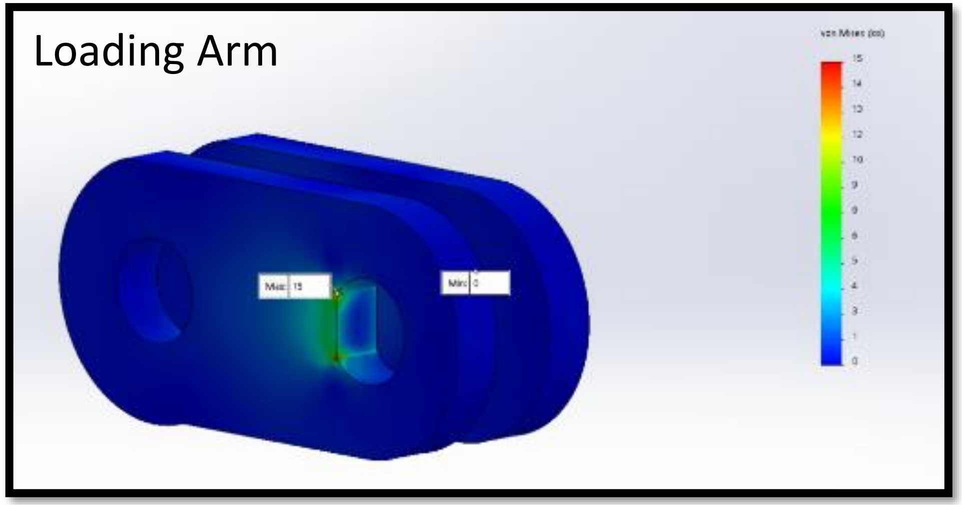
Rover Locking Mechanism (RLM)

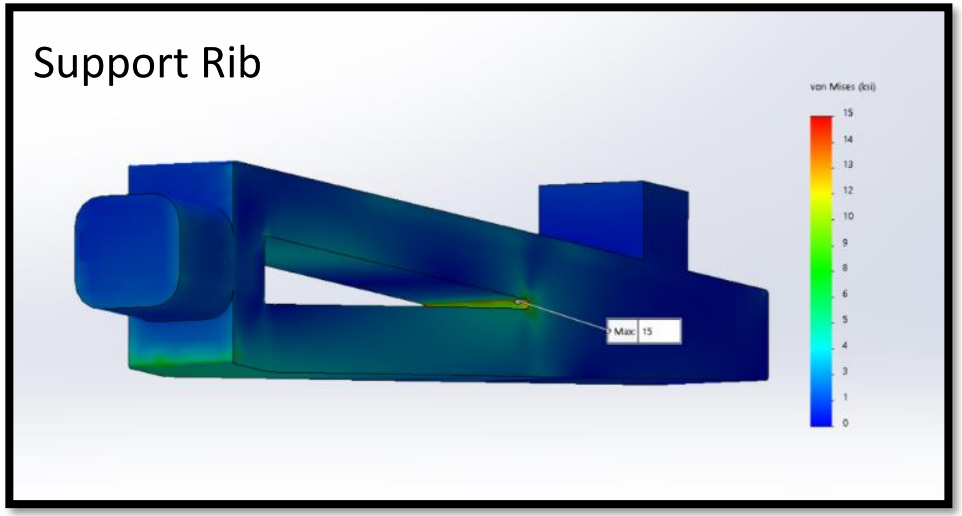
- Purpose: prevent premature deployment
- Unlock after deployment signal
- Configured to be locked while unpowered
- Design change to be more robust and reliable



Rover Locking Mechanism (RLM) Cont…

- 3.04 ft.-lb. Planetary Gearmotor
- Loading arm matches with bracket on rover
- FEA to ensure factors of safety





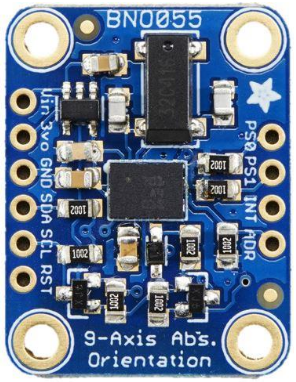
Rover Locking Mechanism (RLM) Cont…

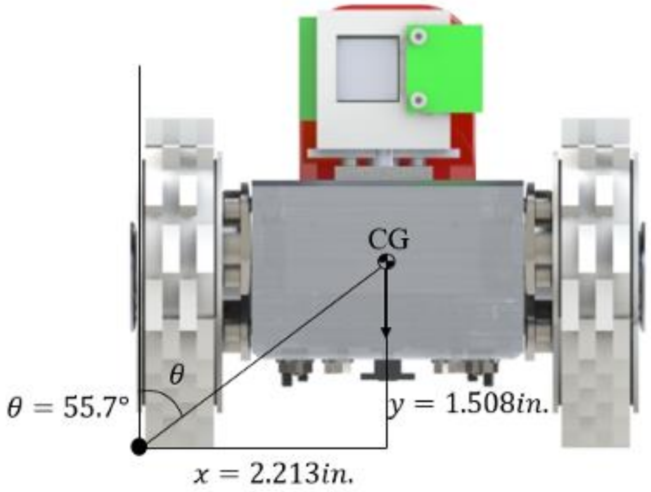
Component	Yield Strength (psi)	Von Mises Stress (psi)	Factor of Safety
Loading Bracket	55,000	15,000	3.67
		5,500	10.0
D-Shaft	40,000	13,000	3.08
		5,500	7.27

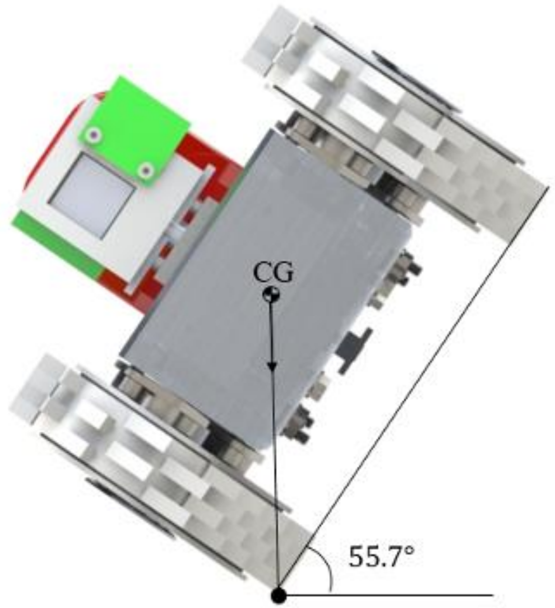
Component	Factor of Safety
Pillow Blocks	2.33
26 RPM, 36.4 lb-in stall torque, Planetary Gearmotor	8.67
BSS – RLM Interface	4.0
Support Rib	2.67
Crescent Mounting Bracket	8.0

Rover Locking Mechanism (RLM) Cont….

- Roll axis: < 50° (alpha in the figure below)
- Pitch axis: < 30°
- Further mitigates possibility of premature deployment

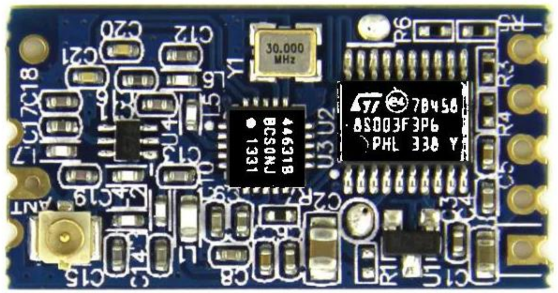


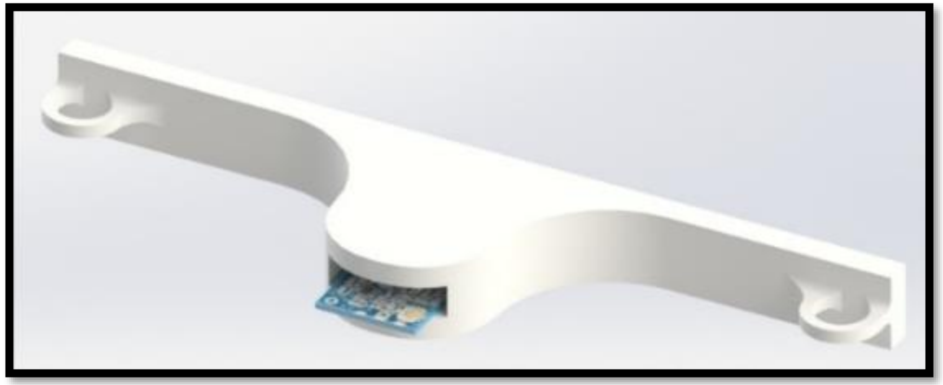




Deployment Trigger System (DTS)

- Unique packet of data
- HC-12 Transceiver module
- 100 available channels for comm
- 473 MHz, 100 mW





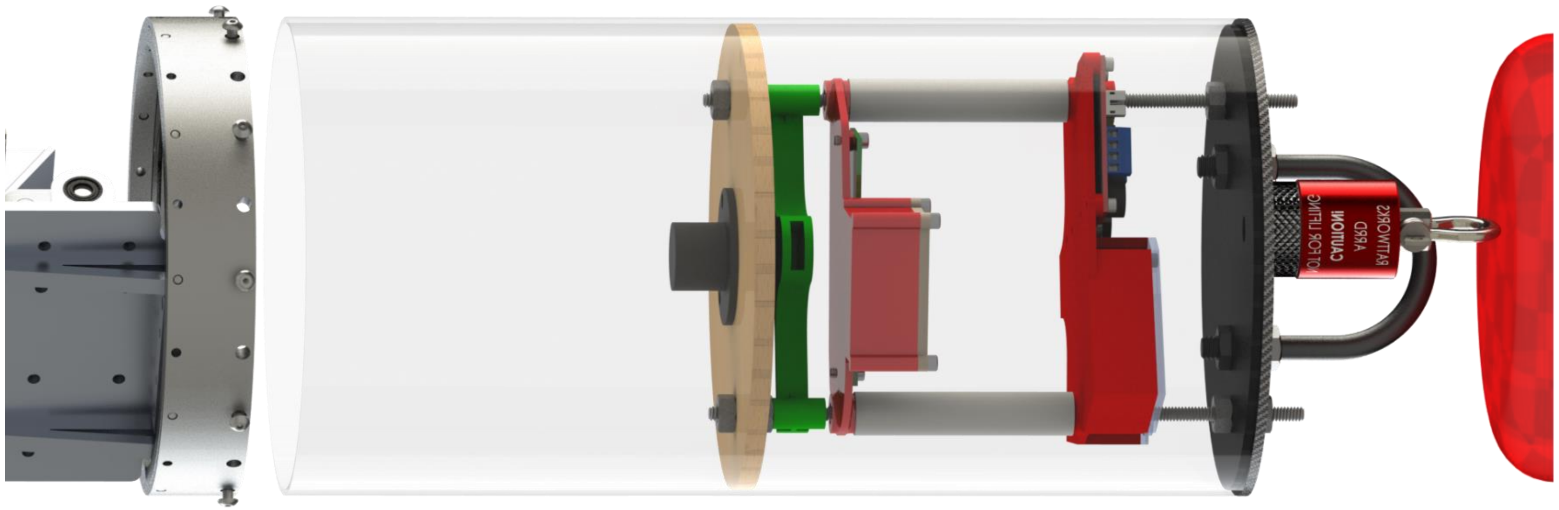
DTS Receiver Side

- Mud-flap antenna
- Connected to Control Electronics System using magnetic connector

DTS Receiver Side Cont….

- Slip ring flange for wiring

- Allows free rotation on the rover without tangling wires



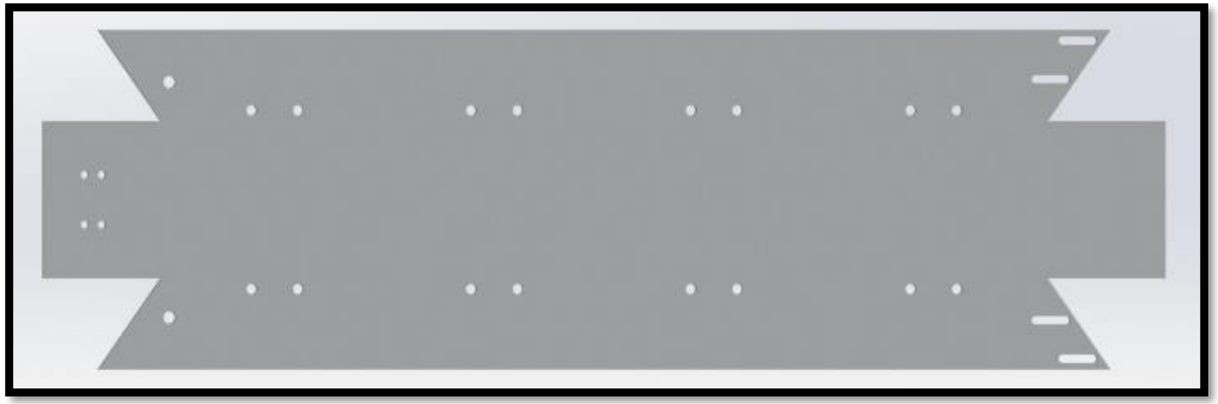
DTS Transmitter Side

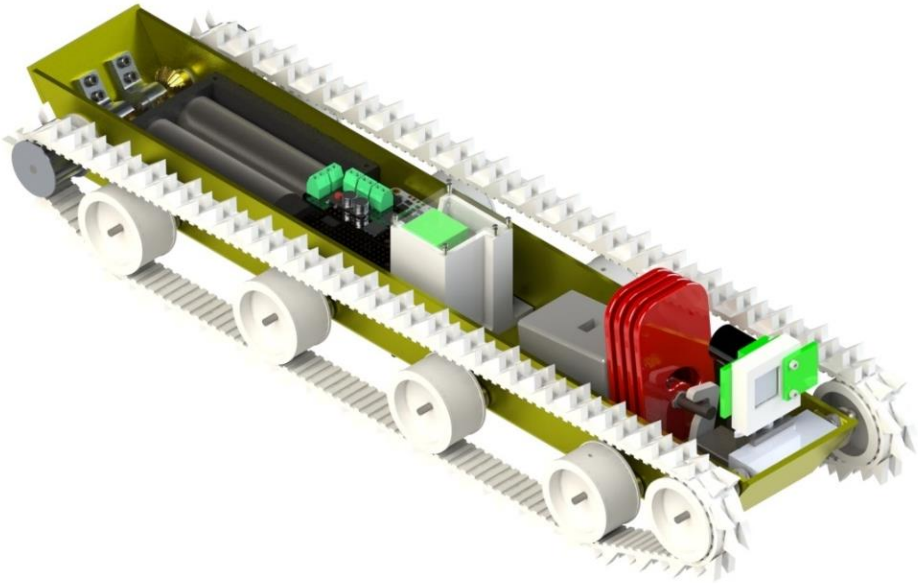
- Yagi antenna with 473 MHz in its operating range

- System has been successfully tested at a range of over 3200 ft.

Rover Body Structures (RBS)

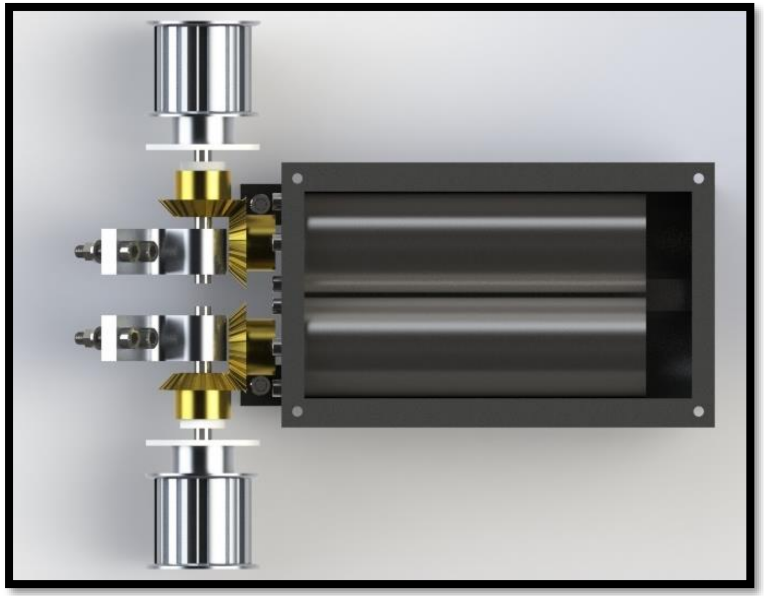
- Acts as main support for all systems and electronics bay
- Material: Aluminum
- Water-jet for precision
- Formed with a finger break
- TIG Weld corners after bending for strength

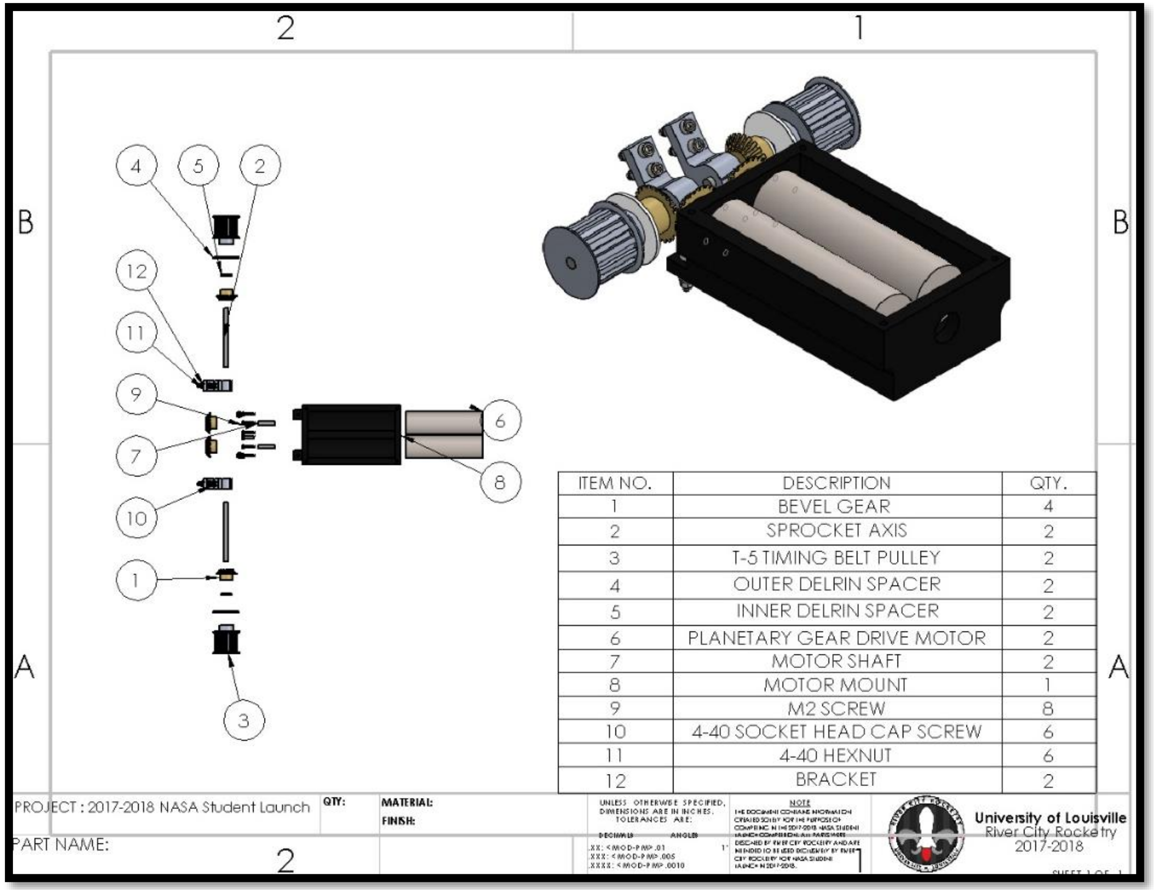




Rover Drive System (RDS)

- 2 main drive motors
- 90 degree bevel gears





Rover Drive System (RDS) Cont...

- Custom tread design

- Compatible with pulley discussed in PDR

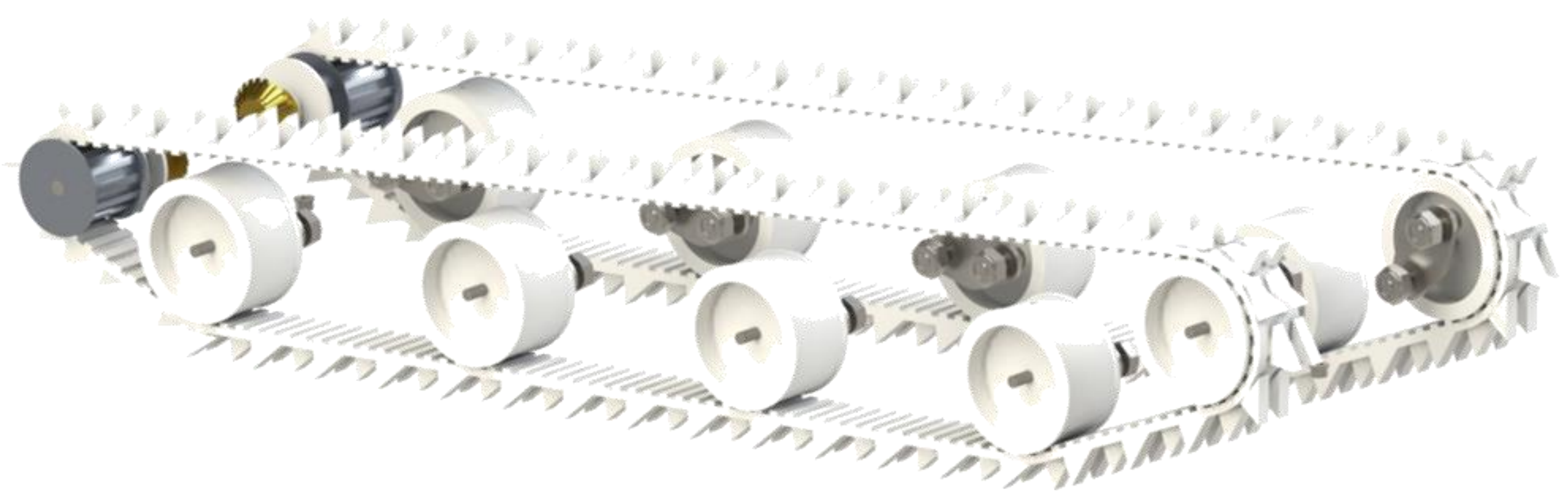
Pitch: 0.197 in.

Width: 0.63 in.

Depth: 0.25 in.

Material: Polyurethane

Coating: High friction

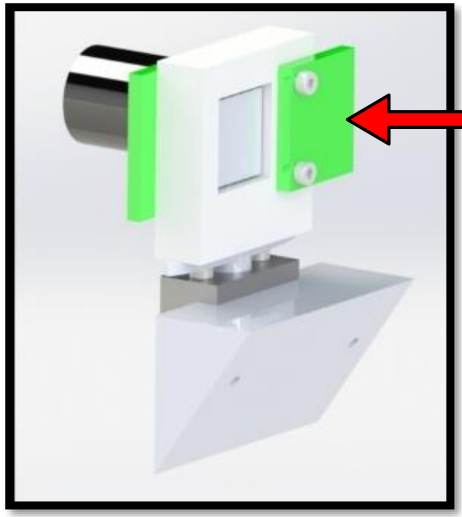


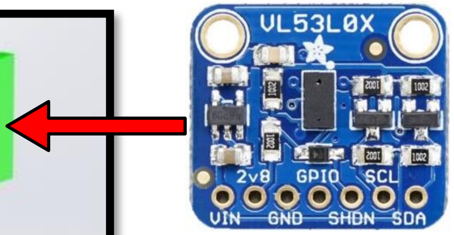
Rover Drive System (RDS) Cont….

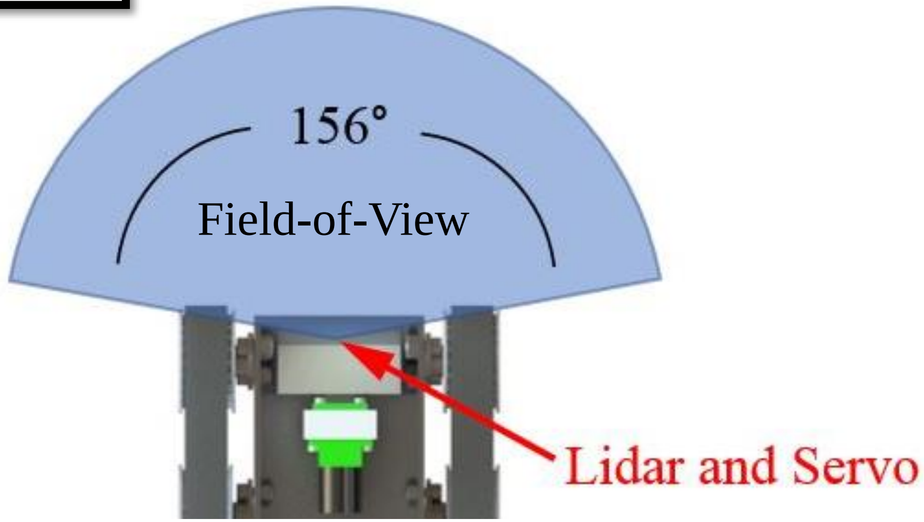
Actobotics Planetary Gear Motor	
Characteristics	
Technical Dimensions	
Total Weight	0.22 lbs
Shaft Dimensions (in.)	Ø0.157 x 0.602
Motor Dimensions (in.)	Ø0.866 x 2.95
Operation	
Nominal Operative Voltage	12V
RPM	52
Stall Torque (ft-lb)	1.52
No Load Current	210 mA

Obstacle Avoidance System (OAS)

- Lidar sensor
- Mounted to servo
- Rolling average to determine best path







Solar Array System (SAS)

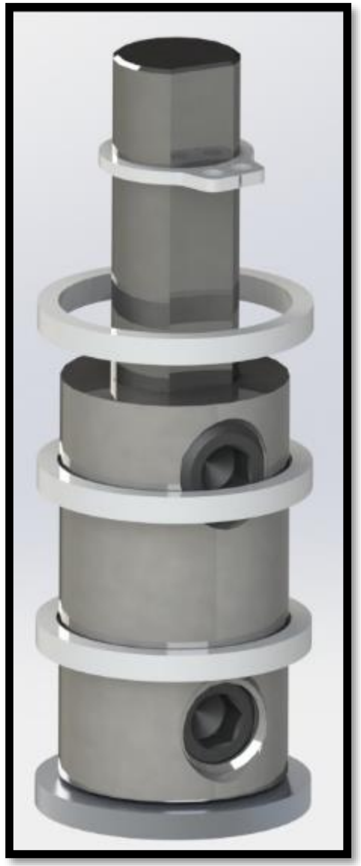
- 4 solar panel support arms
- Locking motor to keep the panels stowed
- Spring hinge actuation of tower assembly

Stowed

Deployed

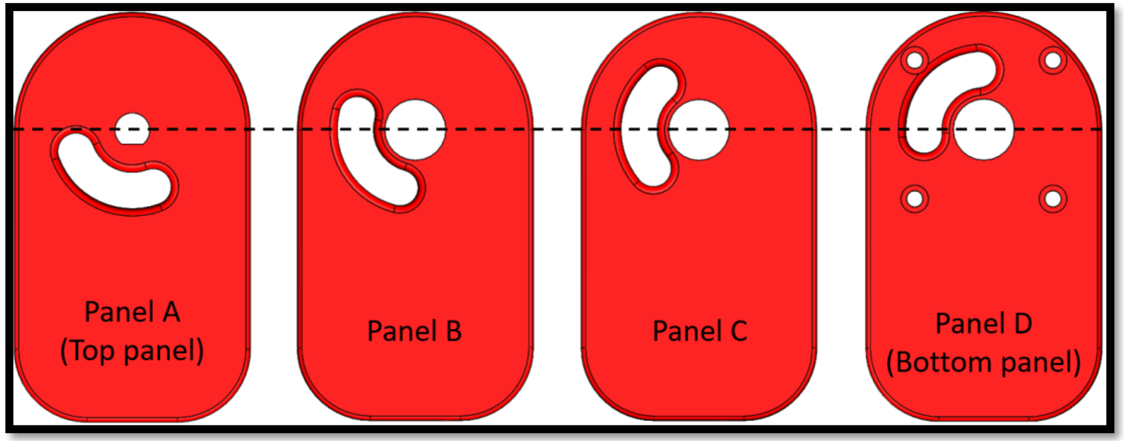
Solar Array System (SAS) Cont…

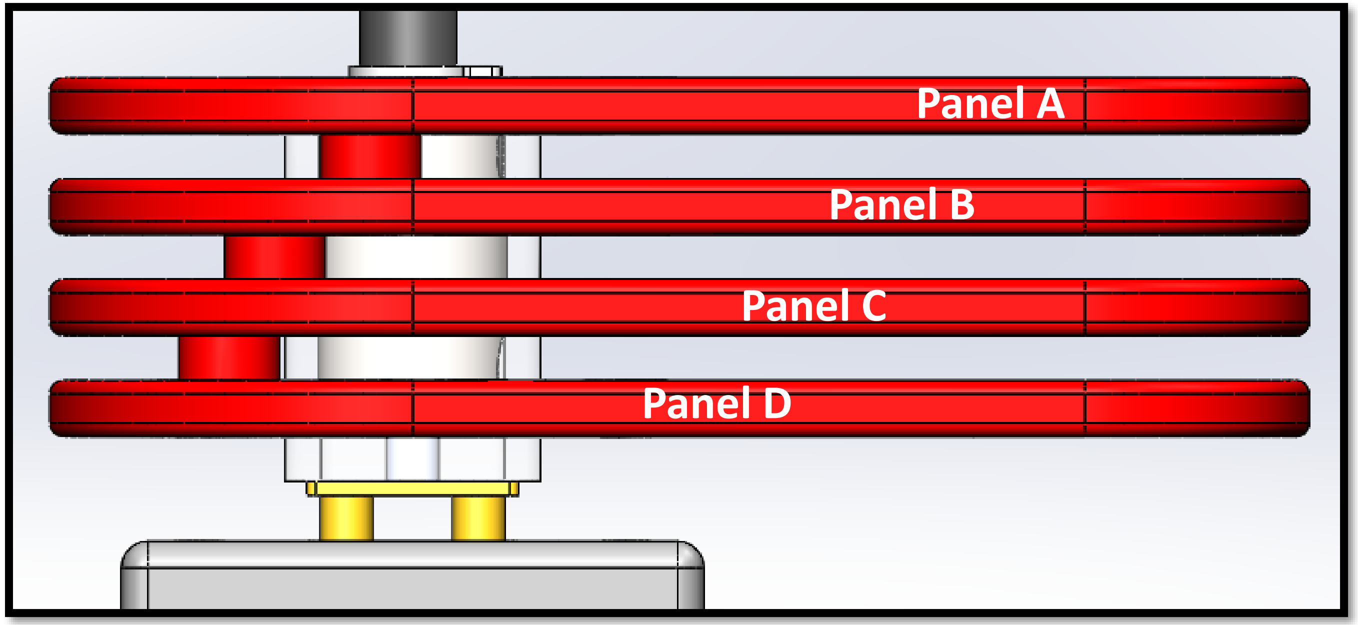
- Rotational deployment method
- Support arms mounted to deployment motor shaft coupler and shaft extension
- Acrylic spacers to separate panels



Solar Array System (SAS) Cont…

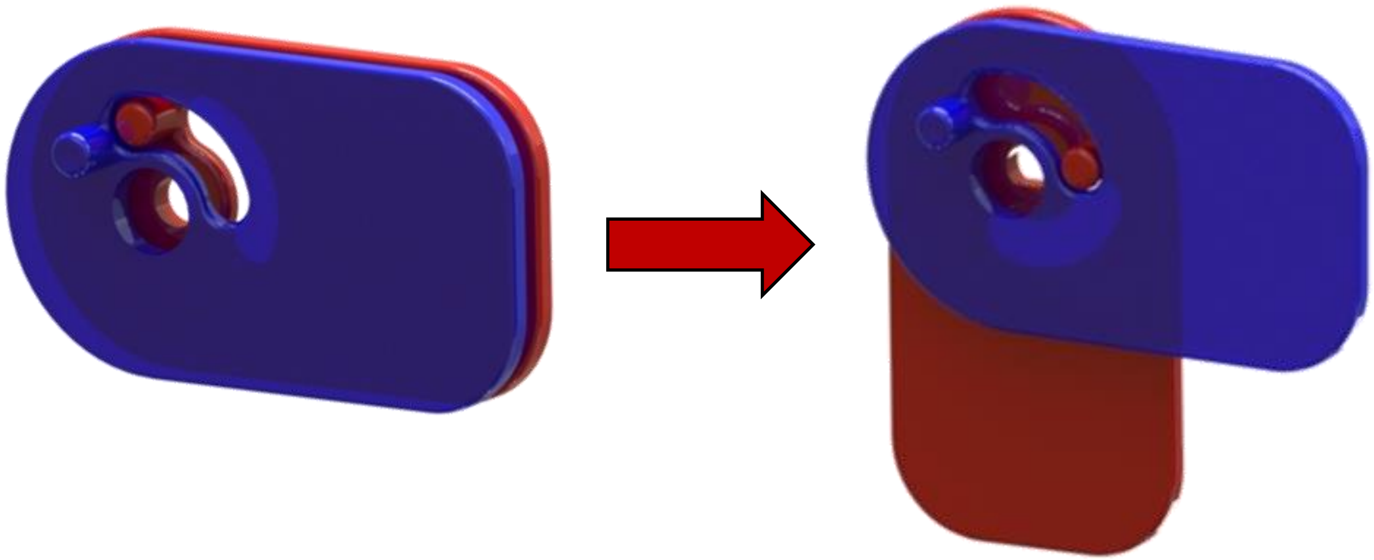
- Center hole used for mounting to shaft
- Towing peg protrudes from bottom of support arm
- Slot for towing peg

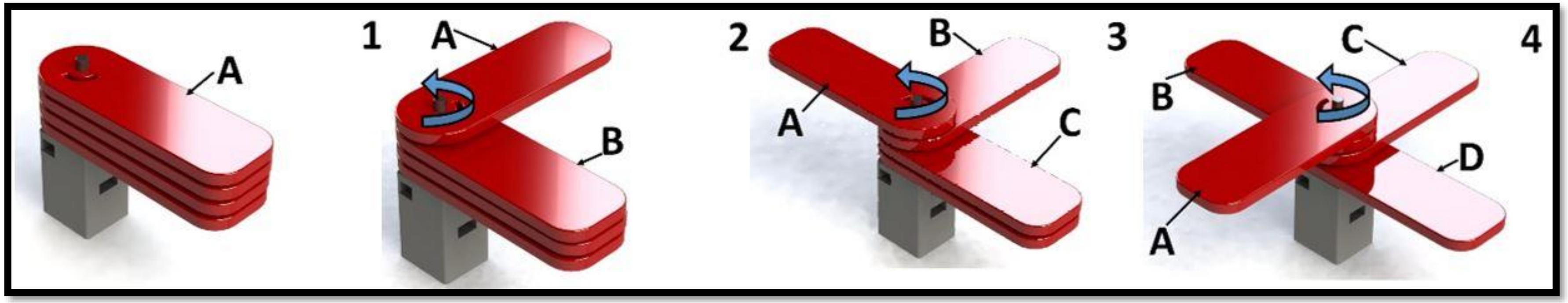




Solar Array System (SAS) Cont….

- Top support arm is driven
- After 90°, towing peg makes contact with next lower panel support arm
- Cascade deployment until all panels are deployed





Surface Imaging System (SIS)

- Secondary mission of the payload
- Take images of payload and surrounding area
- Store images on microSD card for analysis after retrieval of rover

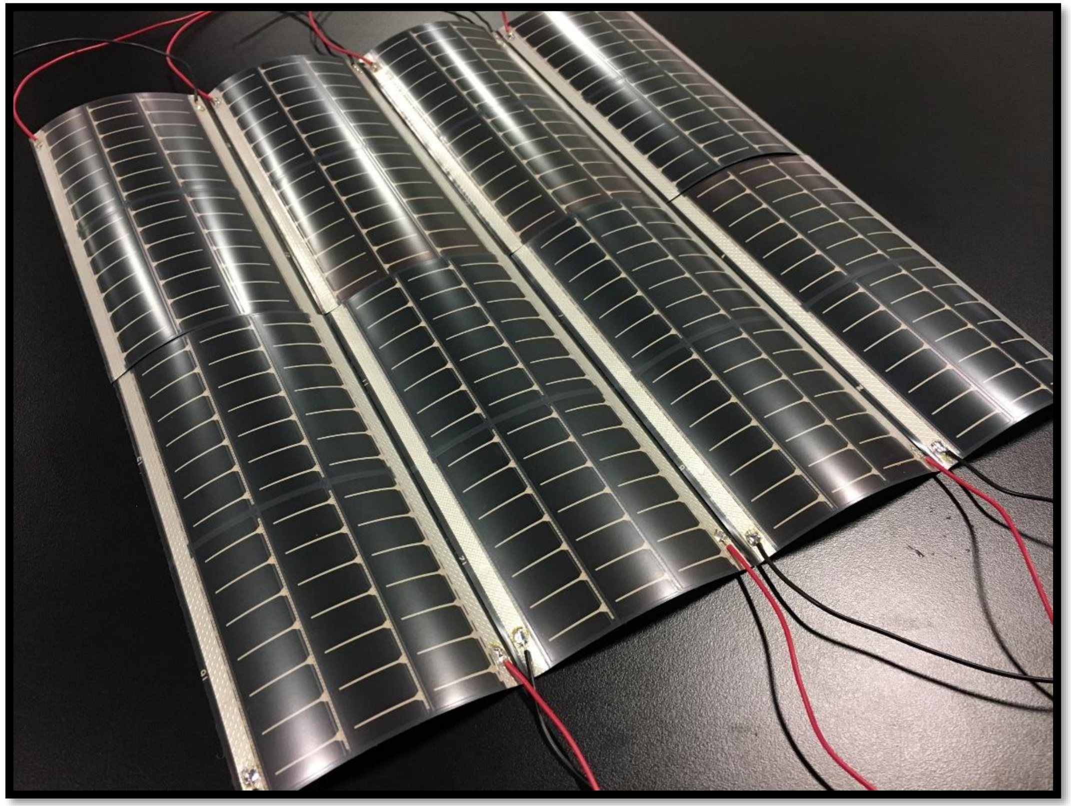
1280 x 960

Surface Imaging System (SIS) Cont…

- Solar power generated will act as a trigger

- Panels will be connected in parallel

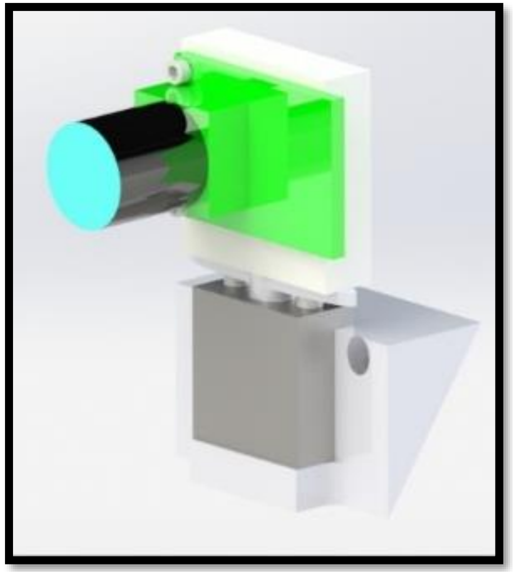
```
Voltage = 87988.28 LOW
Voltage = 88183.59 LOW
Voltage = 87890.63 LOW
Voltage = 87792.97 LOW
Voltage = 91503.91 HIGH
Voltage = 99902.34 HIGH
Voltage = 99902.34 HIGH
Voltage = 99902.34 HIGH
```

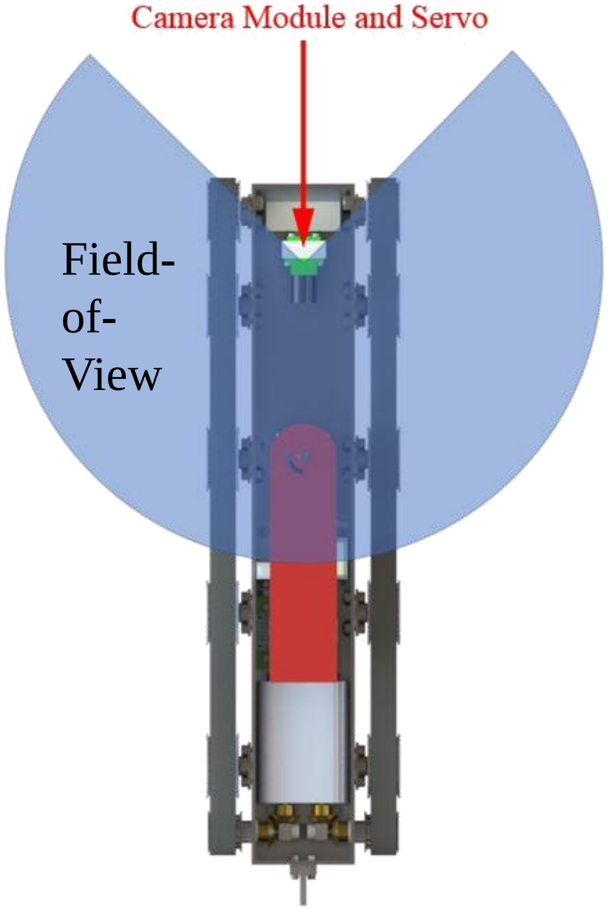


Surface Imaging System (SIS) Cont….

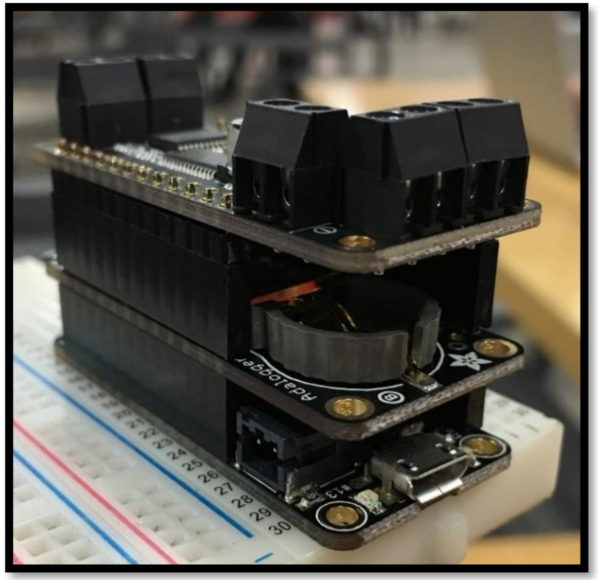
- Mounted to rear of Lidar mount on servo motor

- Increase field-of-view and therefor increase in scientific data collected

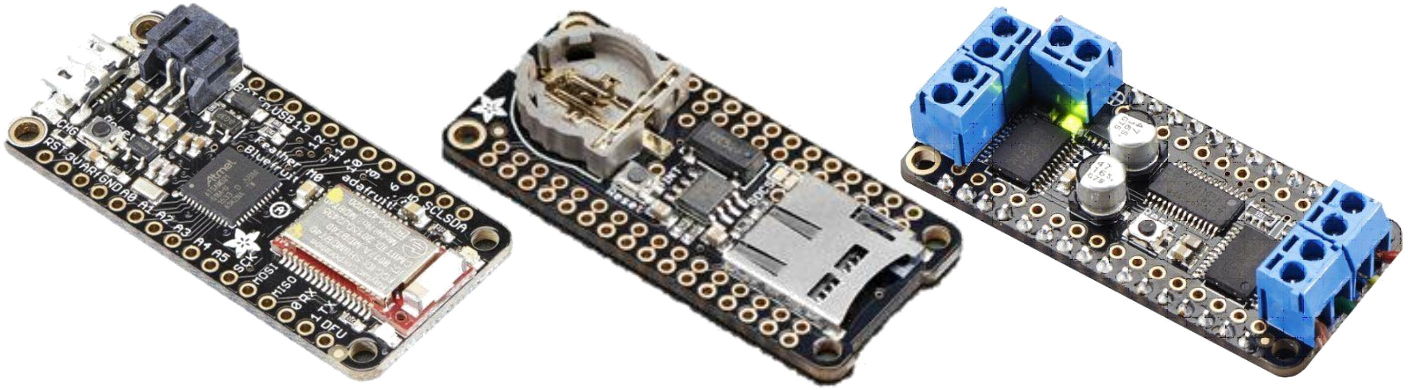




Control Electronics System (CES)

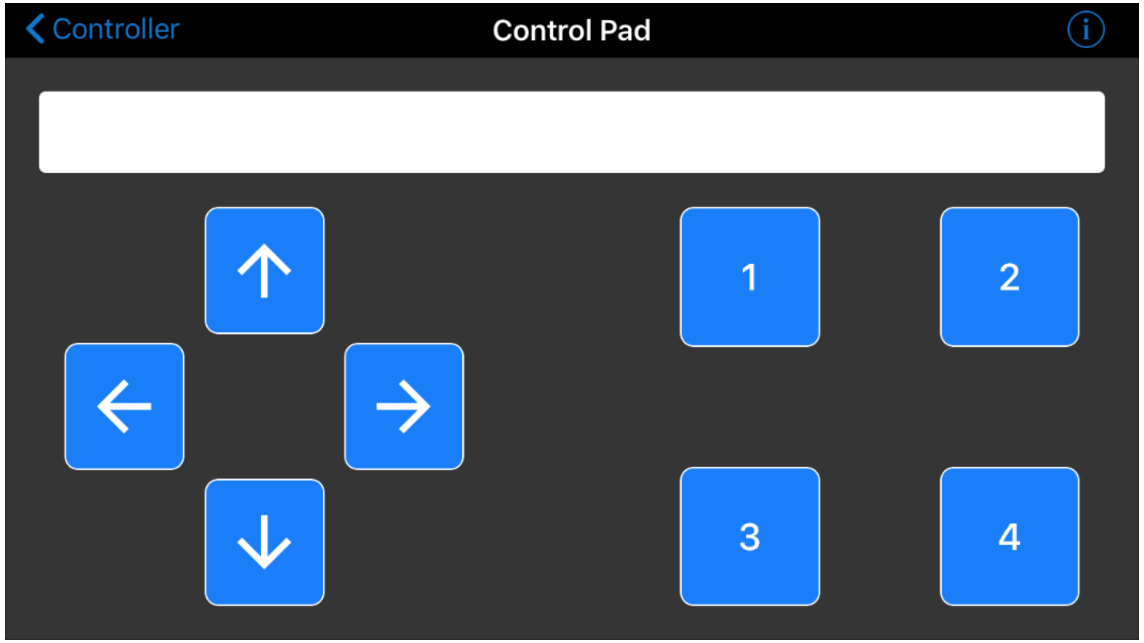


- Feather M0 Bluefruit LE microcontroller
  - Run the control scheme for the rover
- FeatherWing Adalogger data logging board
  - Record data collected throughout the flight
- FeatherWing Motor Shield
  - Drive two main drive motors, RLM Locking Motor, and SAS Deployment Motor



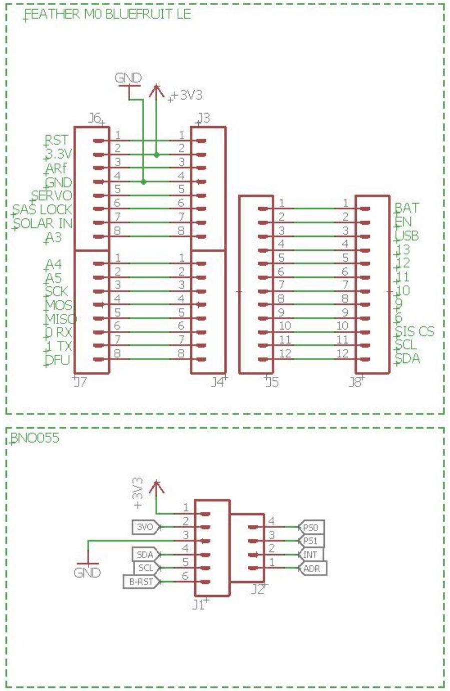
Control Electronics System (CES) Cont…

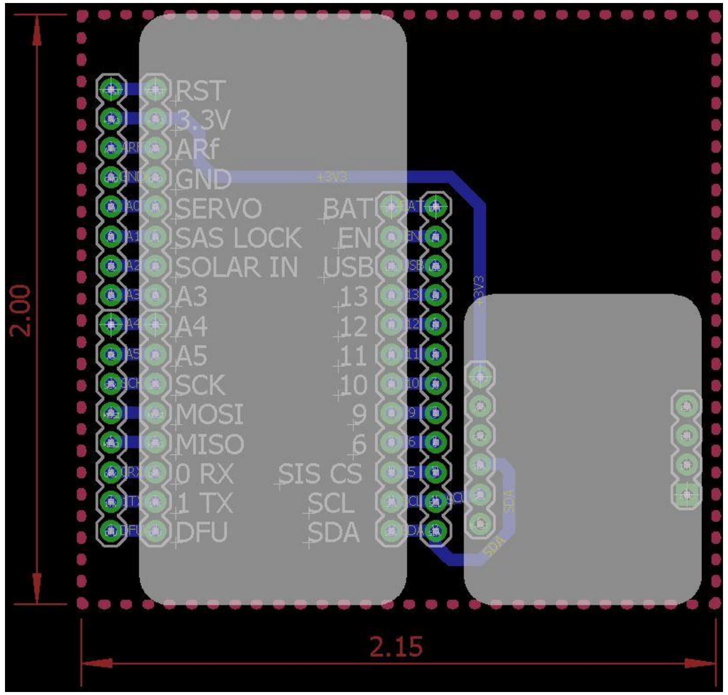
- Test scripts have been written for Bluetooth control of systems
  - Provides hands-off, autonomous testing environment
  - maintain full override control



Control Electronics System (CES) Cont…

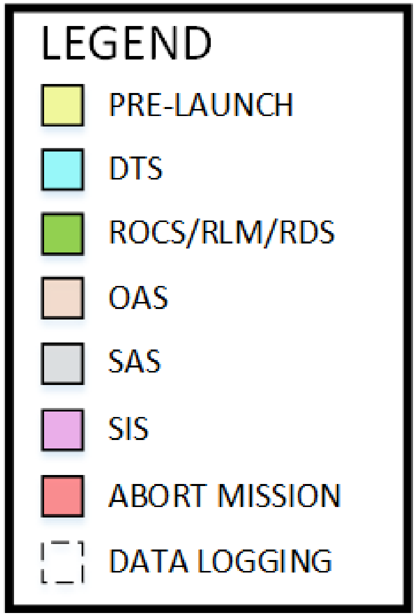
- PCB design for easy of integration
- Headers extend board I/O to handle sensors
- Board dimensions are 2 in. x 2.15 in.

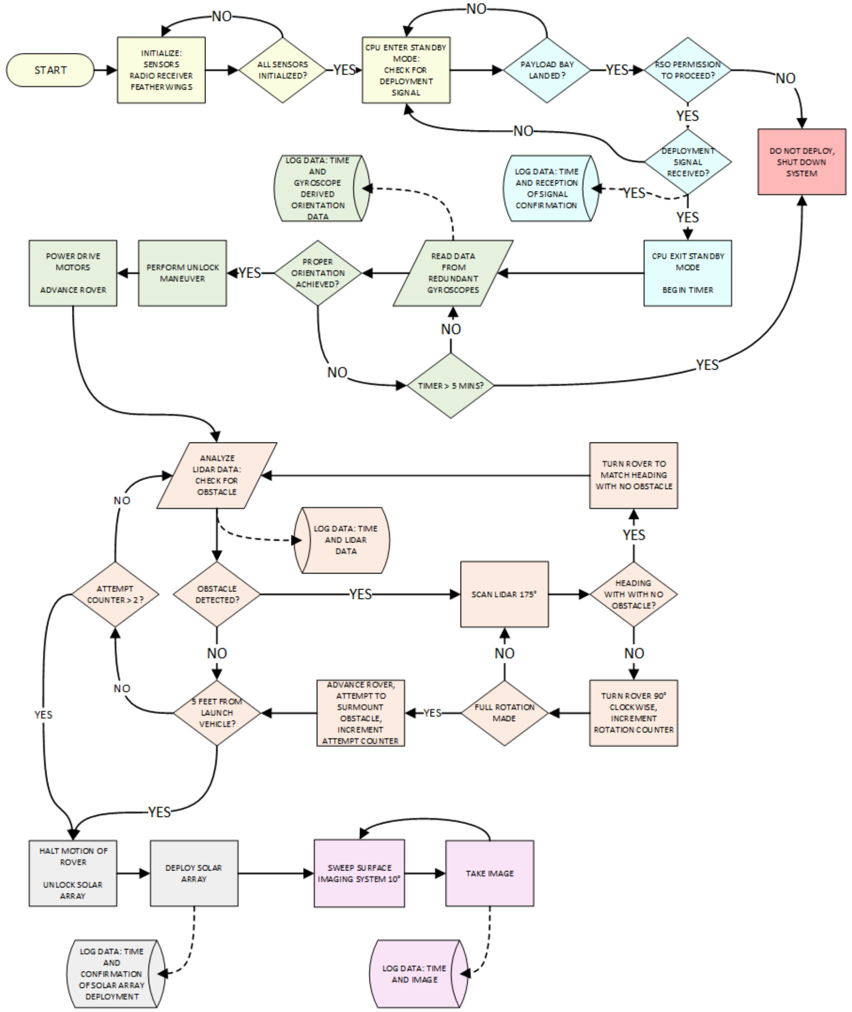




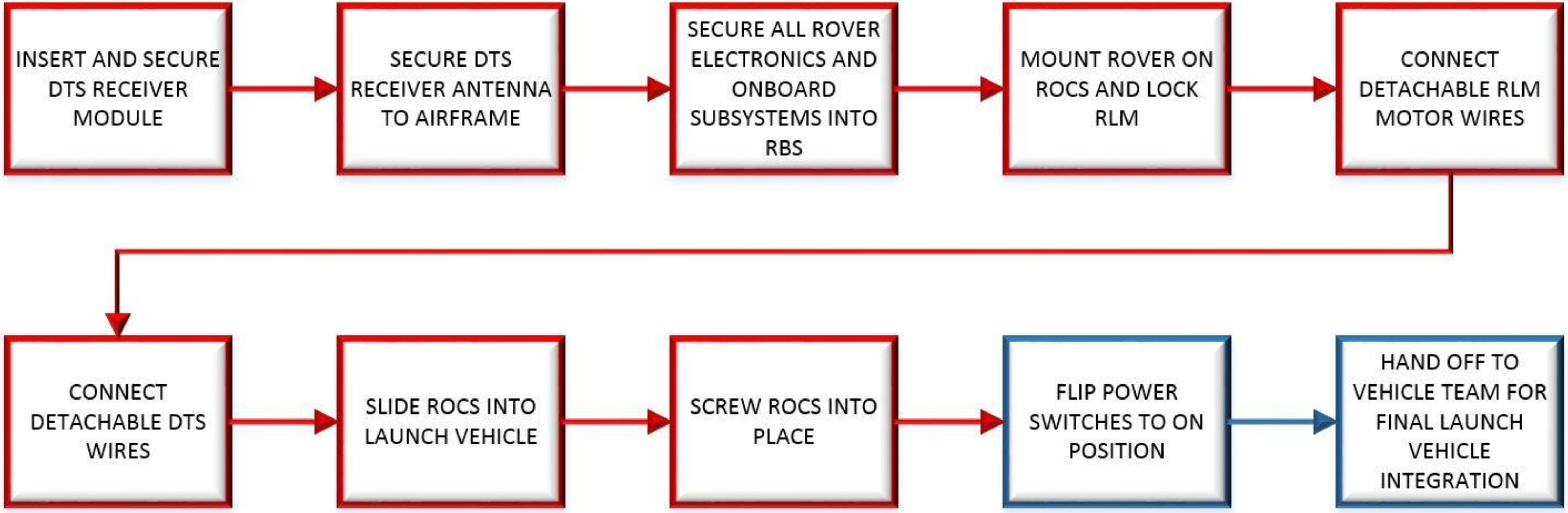
Control Electronics System (CES) Cont….

- Control Scheme broken into phases
- Will be tested thoroughly to ensure mission success



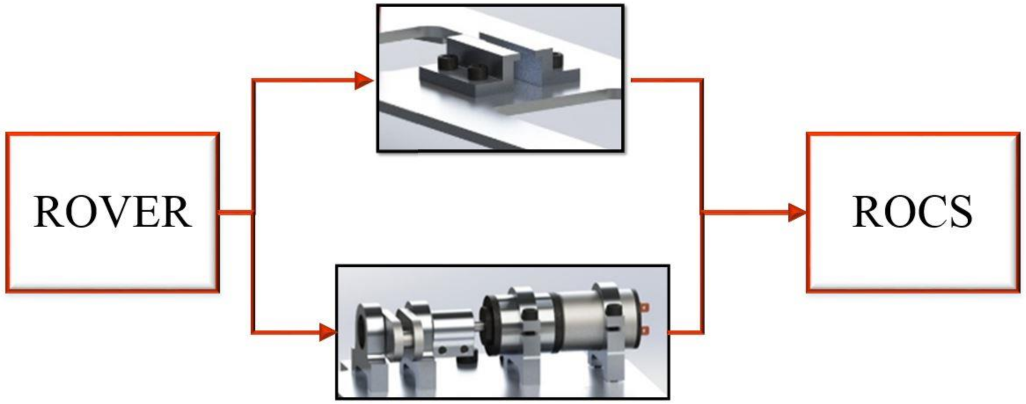


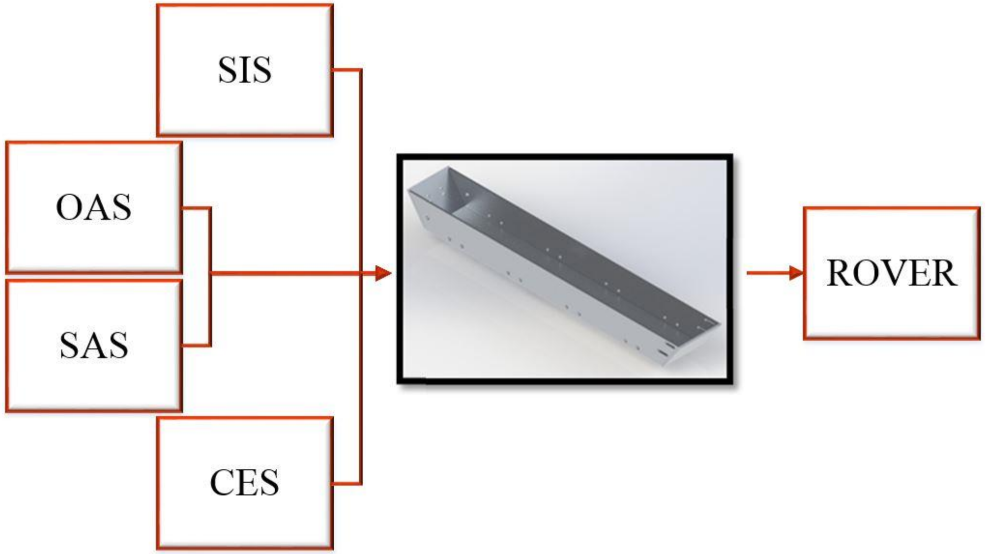
Integration



Internal Interfaces

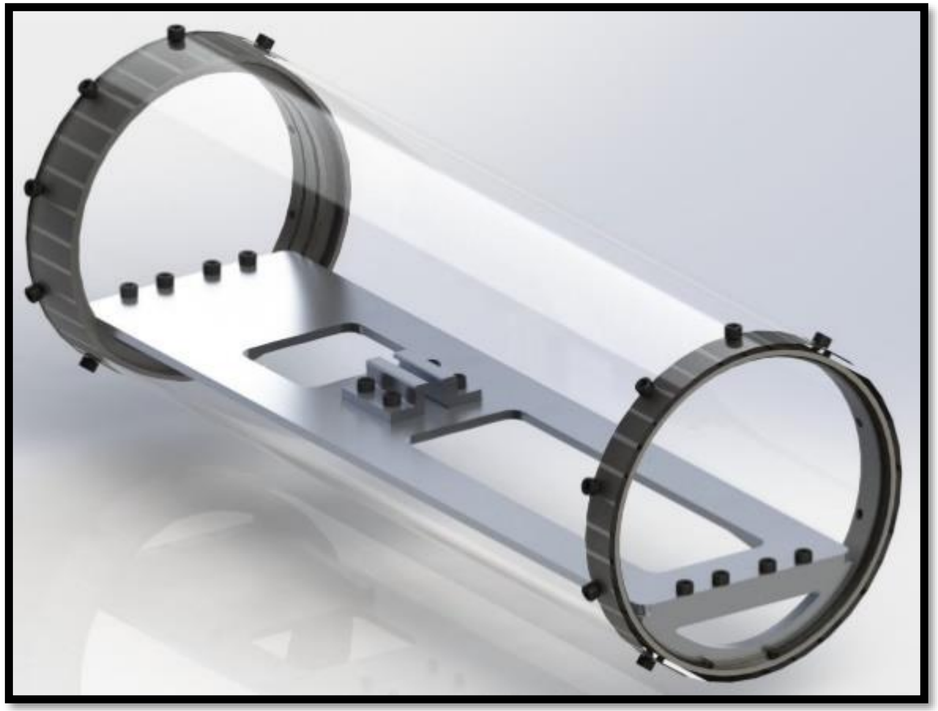
- Loctite will be used to secure bolts and screws where possible
- All electrical wires will be routed to the CES PCB
- PCB has been designed to extend I/O pins for interfacing with all sensors
- System has been designed to maintain clearance for all subsystems of the payload





External Interface

High strength adhesive tape



20 Socket Head Cap Screws

Requirement Compliance Plan

Req. ID	Requirement	Verification Method	Status
Payload SIS-3	The SIS shall be triggered to begin taking images by the amount of energy produced by three of the four SAS solar panels being exposed to full and direct sunlight.	<u>Demonstration</u> The SIS ArduCAM OV5642 camera module and four SAS solar panels will be connecetd to the Feather M0 Bluefruit LE microcontroller. Software will be configured to begin taking images with the camera once the power level of the input from the solar panels exceeds 4 mW which is experimentally the case when three of the four panels are fully exposed in direct light. The Solar panels will begin covered and one by one will be fully uncovered in a well-lit place. After the third panel is fully revealed the camera will be commanded to begin taking pictures by the microcontroller. If this does not occur, the trigger power level will be adjusted and the trial restarted. After five consecutive trials without need for adjustment, the verification will be complete and considered successful.	Incomplete - Scheduled for January 24th, 2018
Payload CES-1	The CES shall obtain the 3-axis orientation of the rover with an minimum accuracy of +/- 0.1°.	<u>Test</u> Two BNO055 9DOF IMUs with documented accuracy of +/- 0.05° will be connected to the Feather M0 Bluefruit LE microcontroller. Software will be configured to receive 3-axis gyroscope data from the two IMUs. An RGB LED will be illuminated green if the sensor data reflects less than 50° of inclination in the pitch and roll directions with a base point of the sensor being flat on the surface. The LED will be turned red if the inclination exceeds 50°. The electronics will be fixed inside a tube and rolled in all possible pitch and roll angles. After 10 consecutive trials of the LED correctly indicating the angle of inclination within 0.1° error and with a drift of less than 1° over the testing period, the verification will be complete and considered successful. See <u>CES Orientation Accuracy Test</u>	Incomplete - Scheduled for January 31st, 2018

Testing Plans

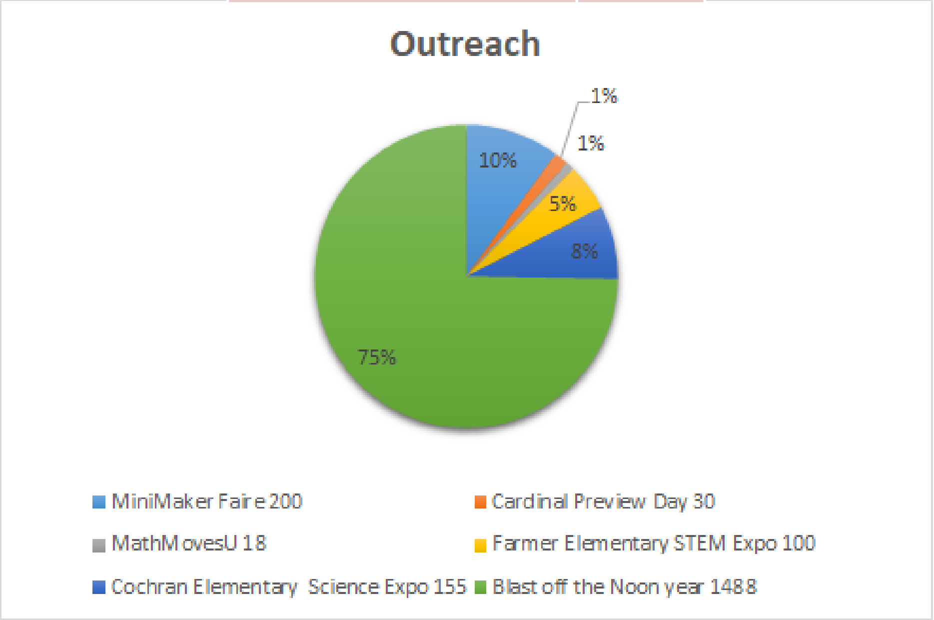
Test	Requirement to be Verified	Scheduled Date
Rover Performance Test	4.5.3 of the NASA SOW	February 23rd, 2018
ROCS Roll Test	ROCS-3	February 10th, 2018
DTS 50 foot Radius Test	DTS-4	January 18th, 2018
RDS Sloped Driving Test	RDS-3	January 27th, 2018
OAS Accuracy Test	OAS-2	January 13th, 2018
CES Orientation Accuracy Test	CES-1	January 31st, 2018
CES Autonomous Control Testing Series	4.5.3 of the NASA SOW CES-2 CES-3 CES-4 CES-5 CES-6	February 18th – February 23rd, 2018
Battery Life Tests	CES-8 CES-9	February 25th, 2018
Flight Load Tests	ROCS-4 RLM-4 RBS-3 SAS-5	February 17th February 24th
Full Flight Performance Tests	DTS-6 CES-7	February 10th (DTS-6) February 24th (CES-7)

CDR Presentation Agenda

- Launch Vehicle
- Variable Drag System
- Recovery
- Subscale Vehicle
- Safety
- Payload
- Educational Outreach
- Budget

Educational Outreach

Outreach Event	Number
First Lego League	25
Louisville Area Math Circle	21
MiniMaker Faire	200
Cardinal Preview Day	30
MathMovesU	18
Farmer Elementary STEM Expo	100
Cochran Elementary Science Expo	155
Blast off the Noon year	1488
Total	2037



CDR Presentation Agenda

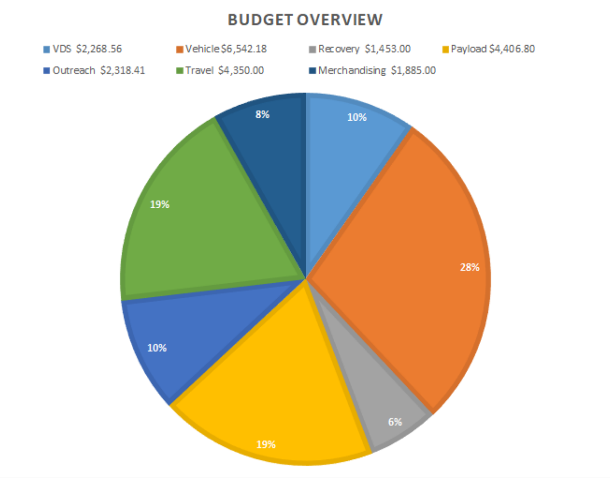
- Launch Vehicle
- Variable Drag System
- Recovery
- Subscale Vehicle
- Safety
- Payload
- Educational Outreach
- Budget

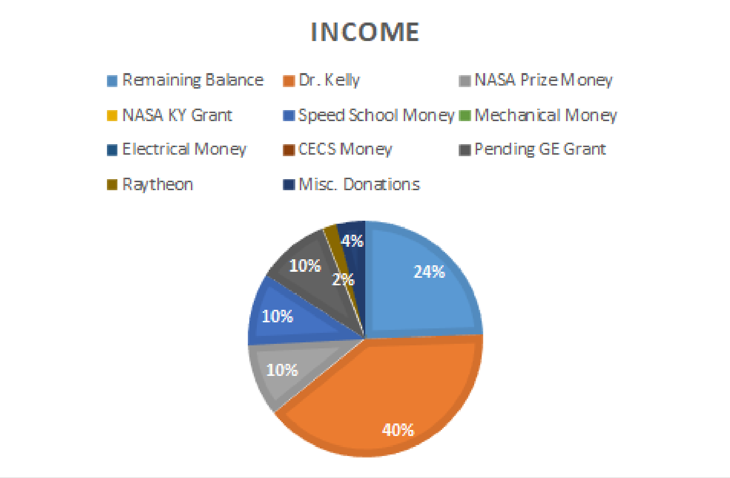
Budget

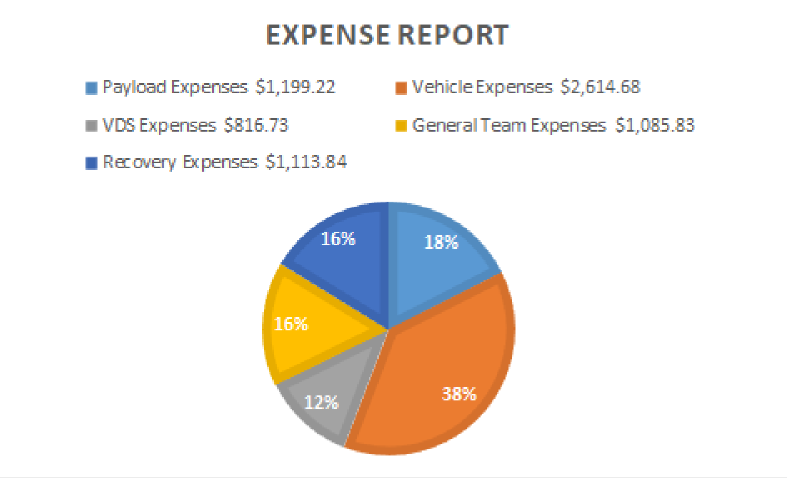
Budget Overview	
VDS	$ 2,268.56
Vehicle	$6,542.18
Recovery	$1,453.00
Payload	$4,406.80
Outreach	$ 2,318.41
Travel	$ 4,350.00
Merchandising	$ 1,885.00
Team Improvements	$ 6,200.00
Total Projected Expenses	$ 29,423.95
Total Projected Carryover	$ 20,876.05
Total Projected Income	$ 50,300.00
Total Received Income	$ 45,300.00
Total Unrecieved Income	$ 5,000.00

Income Overview	
Remaining Balance	$ 12,300.00
Alumni Donations	$ 20,000.00
NASA Prize Money	$ 5,000.00
Speed School Money	$ 5,000.00
Pending GE Grant	$ 5,000.00
Raytheon	$ 1,000.00
Misc. Donations	$ 2,000.00
Total	**$ 50,300.00**

Expenses	
Payload Expenses	$ 1,199.22
Vehicle Expenses	$ 2,614.68
VDS Expenses	$ 816.73
General Team Expenses	$ 1,085.83
Recovery Expenses	$ 1,113.84
Total Expenses	**$ 6,830.30**







RIVER CITY ROCKETRY

UNIVERSITY of LOUISVILLE