River City Rocketry

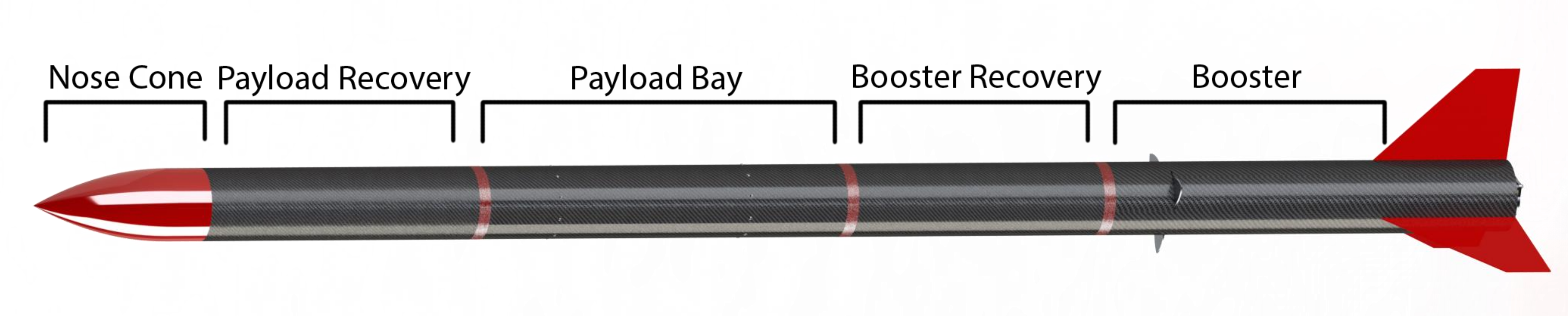
FLIGHT READINESS REVIEW (FRR) PRESENTATION

CDR Presentation Agenda

- Launch Vehicle
- Full Scale Test Flights
- Variable Drag System
- Recovery
- Safety
- Payload
- Educational Outreach
- Budget

Launch Vehicle Overview

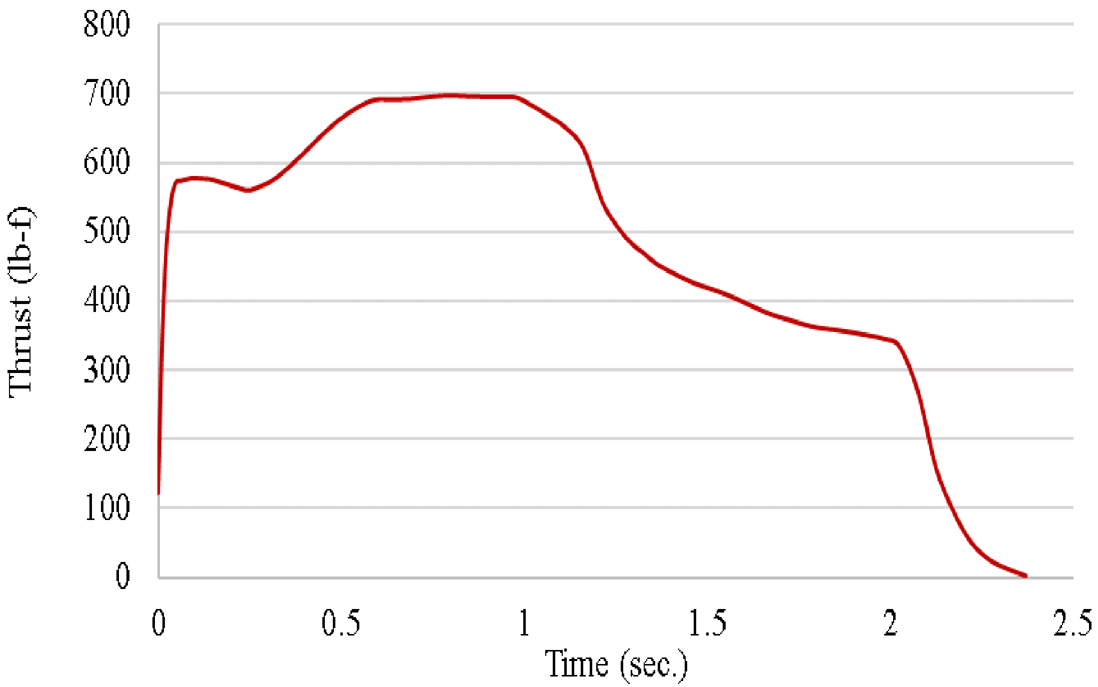
- 6.25 in. Diameter
- 4 Independent Sections
- Custom Carbon Fiber Airframe
- Custom 12in. Parabolic Nose Cone
- 3 Carbon Fiber Fins
- Variable Drag System
- Removable Fin System
- Aerotech L2200-G Motor



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

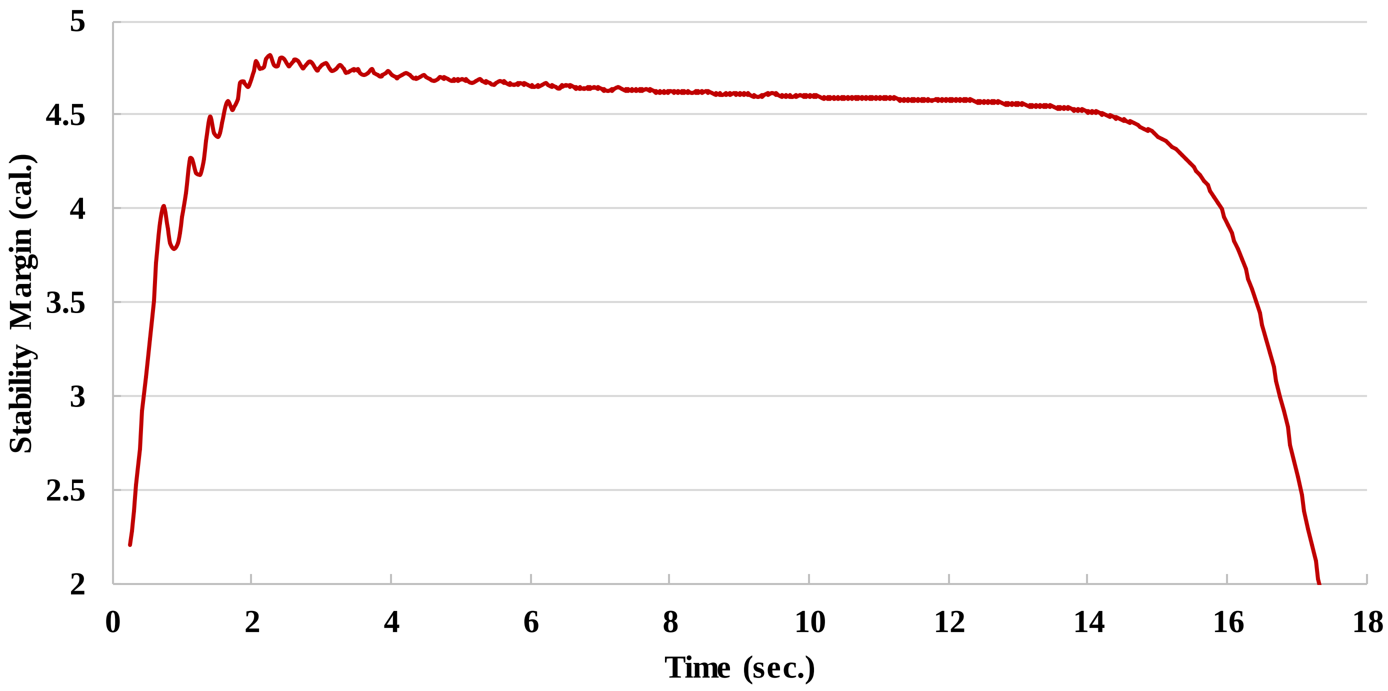


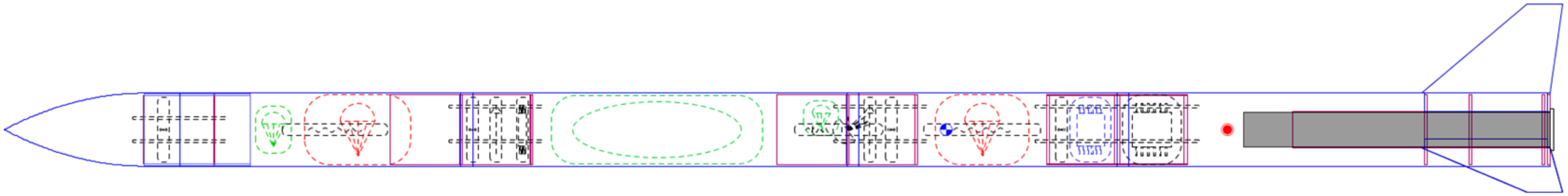
Flight Characteristics

Maximum Acceleration (ft./s^2)	428
Maximum Velocity (ft./s)	664
Thrust to Weight Ratio	13.9
Predicted apogee in 10mph wind (ft.)	5,363
Time to Apogee (sec.)	18
Exit Rail Velocity from a 141-inch rail (ft./s)	91.6
Center of Pressure Location at Rail Exit (in. from nose cone tip)	98.5
Center of Gravity Location at Rail Exit (in. from nose cone tip)	83.0
Stability Margin at Rail Exit (cal.)	2.48

As-Built Stability Margin

- Diameter: 6.25 in.
- CP location at rail exit: 98.5 in.
- CG location at rail exit: 83.0 in.
- Stability margin at rail exit: 2.48





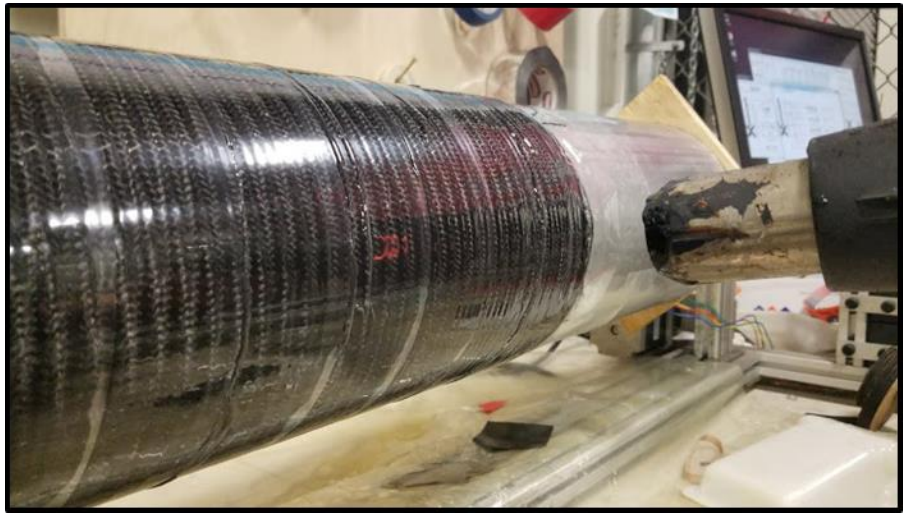
Vehicle Sections, Dimensions, and Mass

- 4 independent sections
- Dimensions dictated by payload, motor, and recovery hardware size
- Recovery bays lengthened since CDR

Section	Length (in.)	Wet Mass (lbs.)
Booster	37	26.149
Booster Recovery Bay	24	
Coupler	-	1.791
Payload Bay	33	17.818
Payload Recovery Bay	30	
Nose Cone	15	3.465
Total	**139**	**49.3**

Airframe

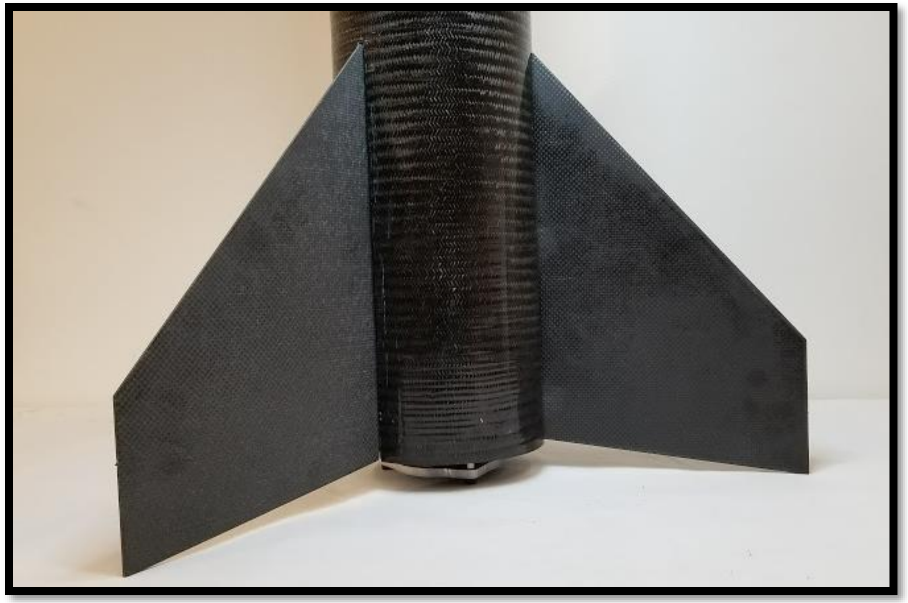
- Quasi-isotropic carbon fiber airframe material impregnated with Aeropoxy PR2032 resin and PR3660 Hardener
- Manufactured using “lay-up” method
- Curing expedited by applying heat and removing excess epoxy with heat shrink tape



Fin Material

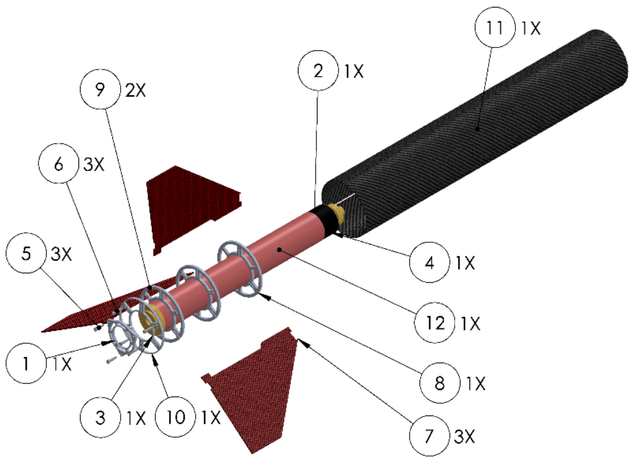
- Custom layup replaced with DragonPlate carbon fiber sheet due to time constraints and results of first test flight
- DragonPlate carbon fiber sheet used on previous launch vehicle of similar size
- Material Properties:

Property	Value
Young's Modulus	5 Msi
Tensile Strength	50 Ksi

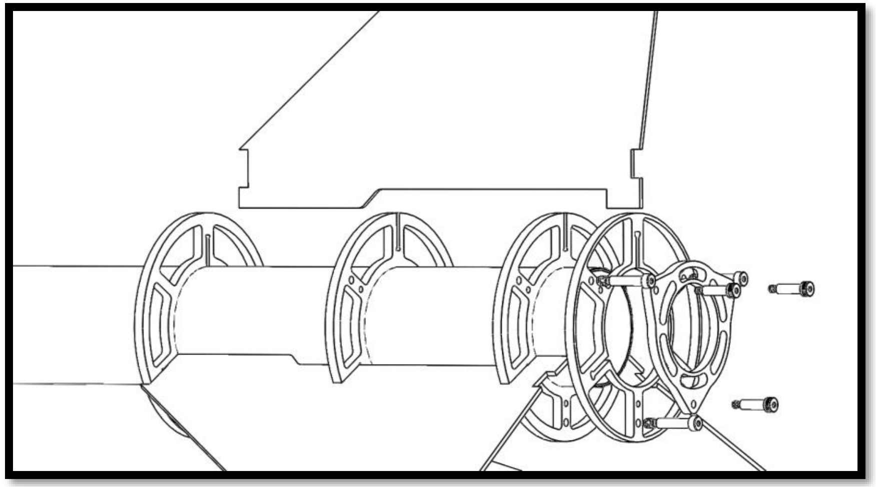


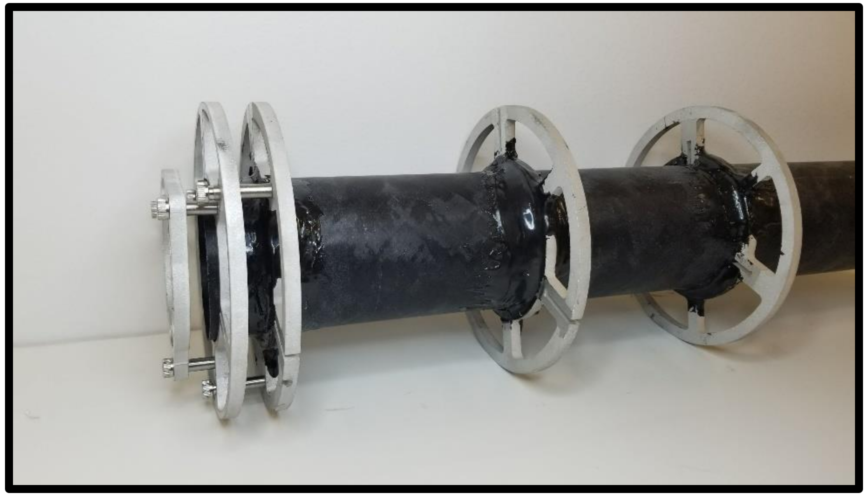
Removeable Fin System

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



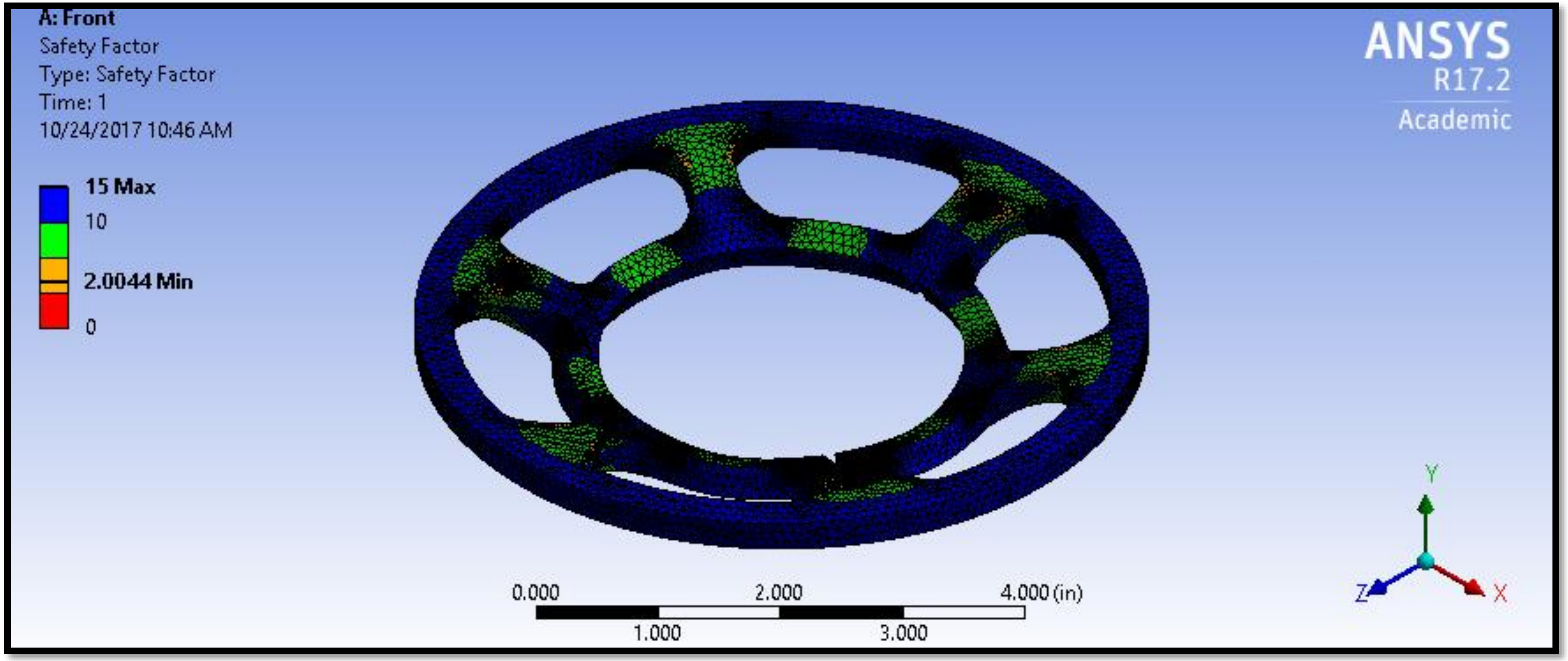
ITEM NO.	PART NUMBER	QTY.
1	Motor Retainer	1
2	Motor Casing	1
3	Aft Closure	1
4	Forward Closure	1
5	#10-32 Shoulder Bolt	3
6	1/4" - 20 Shoulder Bolt	3
7	Swept Cropped Delta Fin	3
8	Fore Centering Ring	1
9	Mid Centering Ring	2
10	Fin Retainer	1
11	Booster Tube	1
12	Motor Mount Tube	1





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



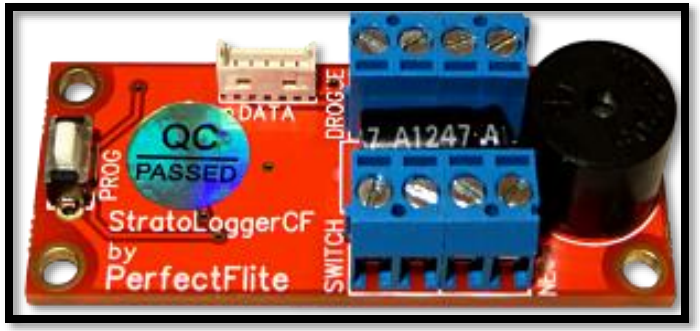
Nose Cone

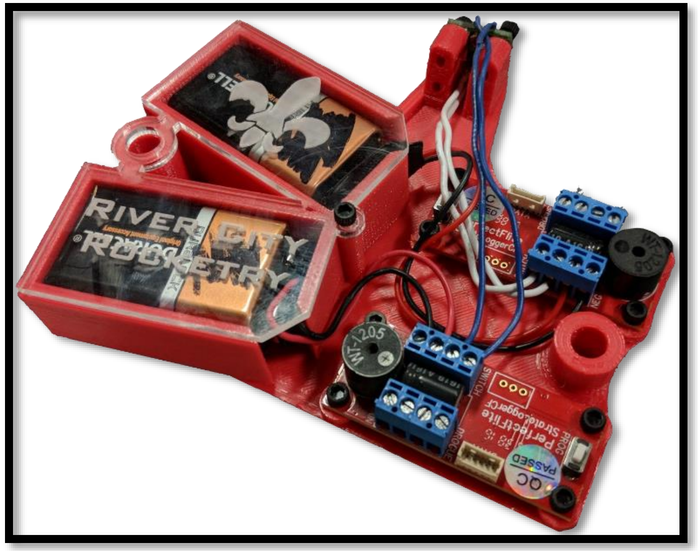
- 12-inch long parabolic nose cone with a 3-inch transition section
- Additively manufactured from Nylon 12 using a SinterStation 2500+
- Carries a Stratologger altimeter and AIM XTRA GPS device
- Material Properties:

Mechanical Property	Value
Elongation at Break	15%
Tensile Modulus (ksi)	246
Tensile Strength (Psi)	6,815
Density (lb/in^3)	0.034

Avionics

- Total of Five StratoLogger CF altimeters
  - Two carried in payload coupler for separation event
  - Two carried in coupler between booster recovery and payload bay for separation event
  - One carried in nose cone for altitude scoring





GPS Tracking

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

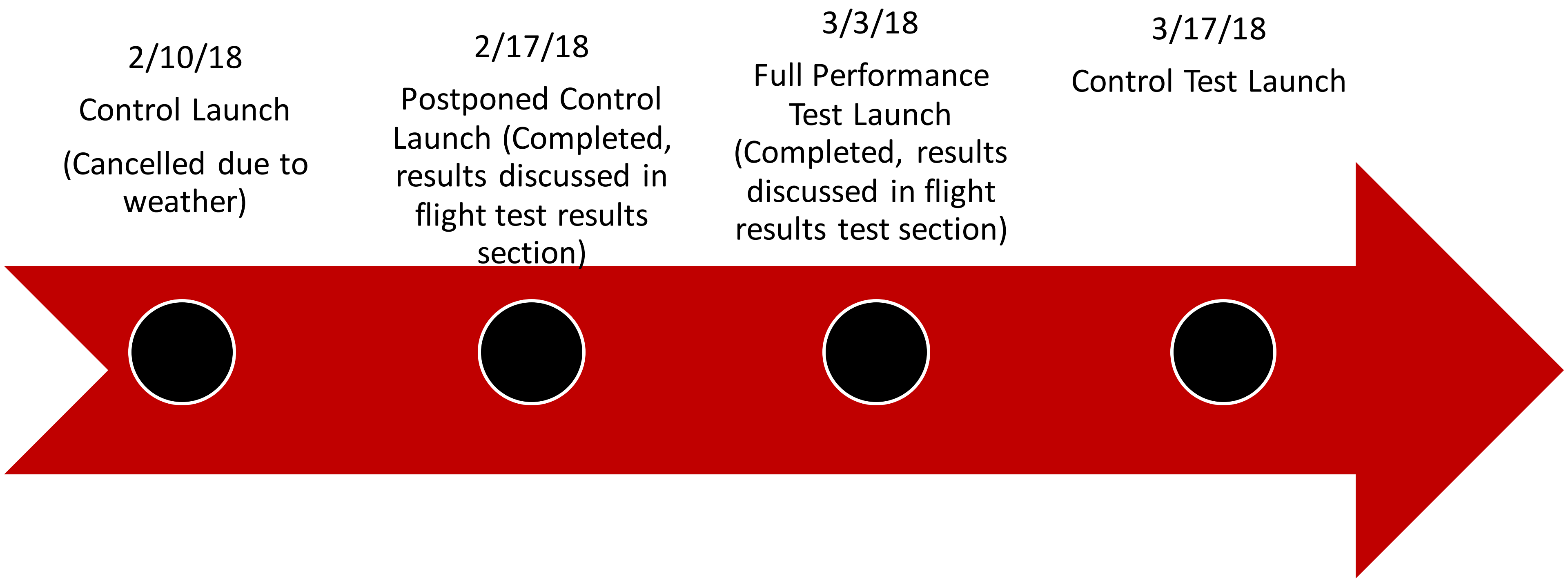
- **Payload Bay**: Eggfinder (900 MHz)

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

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

Vehicle Verification Progress

- 55/74 Requirements verified
- Remaining requirements to be verified with successful full scale flight



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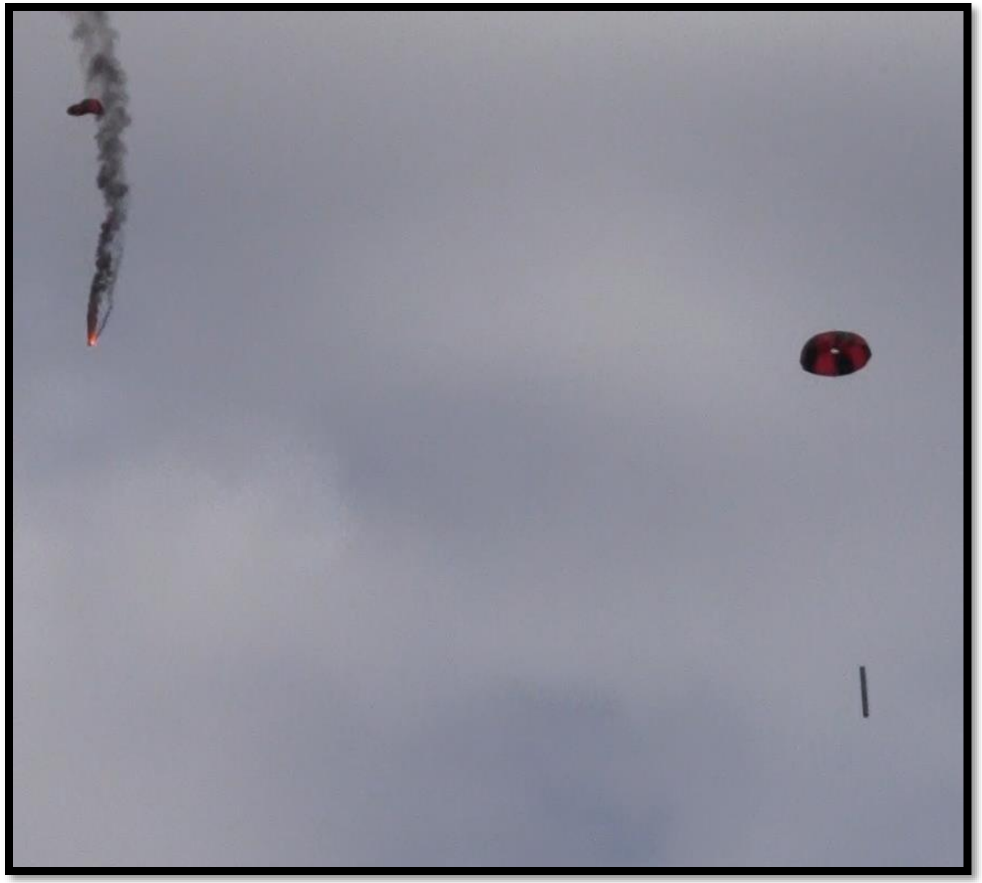
Flight Results Overview

- February 17th:
- Catastrophic motor failure approximately two seconds after ignition
- Apogee: 1,835ft.

- March 3rd:
- Successful vehicle ascent
- Failed separation at apogee led to ballistic impact
- Apogee: 5,114ft.

February 17th Flight Analysis

- Cause of motor failure determined to be a forward motor enclosure rupture
- Flames swept upward severely damaging centering rings and VDS
- All sections except booster recovered successfully



March 3rd Flight Analysis

- Stable ascent to apogee of 5114ft. AGL
- Minimal spinning, no fin flutter
- Failed separation at apogee
- Booster main separation event occurred at 500ft. AGL
- Shock cord zippered at high velocity
- Ballistic impact at over 400ft/s
- Majority of flight data lost

March 3rd Flight Damage Assessment

- Catastrophic damage to nearly all vehicle components, payload, and VDS
- Fins and motor hardware only surviving components

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VDS Agenda

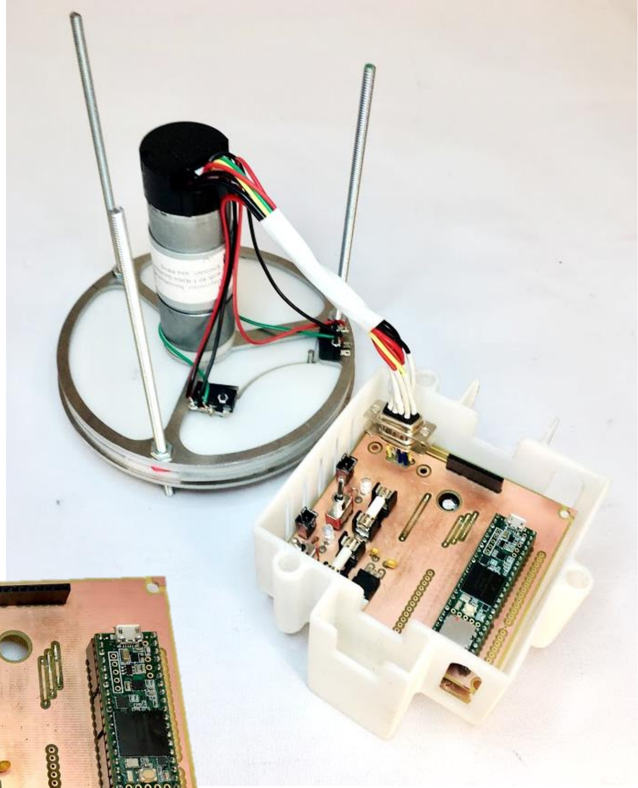
The Variable Drag System (VDS) has been fully manufactured and ground tested. All safety, integration and breaking power requirements have been demonstrated. Today, the following will be discussed.

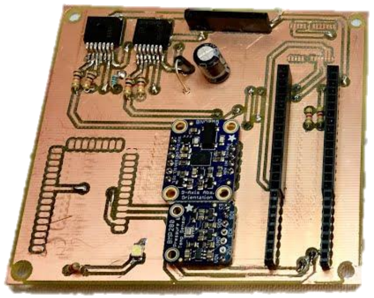
- Complete Manufactured system
- Testing and Demonstration
- Completed Simulation
- Verifications

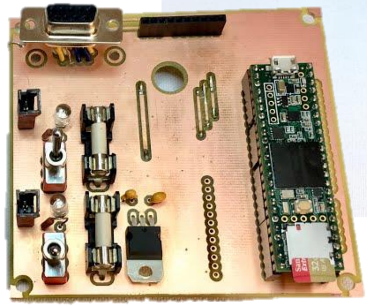
Manufacturing

The VDS has completed full manufacturing of all components, including;

- Dual-layered FR-4 copper plated Printed Circuit boards
  - Fully assembled with Teensy 3.6, BNO055, BMP280, BTN7960, connectors, fuses, and switches.
- 3 Aluminum 6061-T6 drag blades with middle spur gear, and delrin space plates.
- Motor configuration with D-sub connection, encoders, and 2 normally open limit switches.
- 3D printed ABS electronics sled.





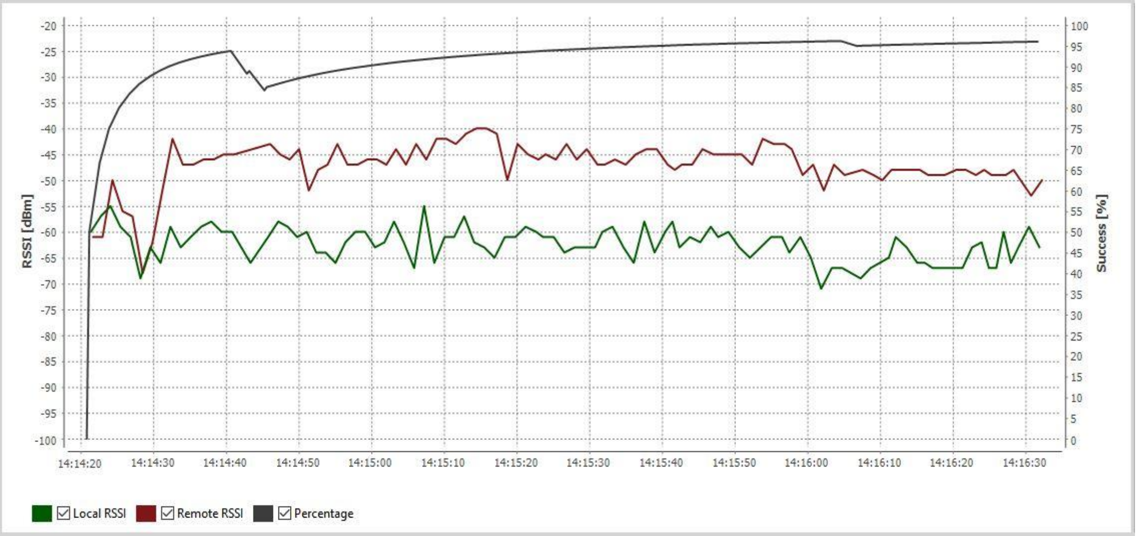


Telemetry Testing

A successful telemetry test was completed on 3-3-18.

- This test confirmed the hypothesized power and transmission ability of this unit
- The average packet delivery success rate at a distance of 1 mile was 95%.

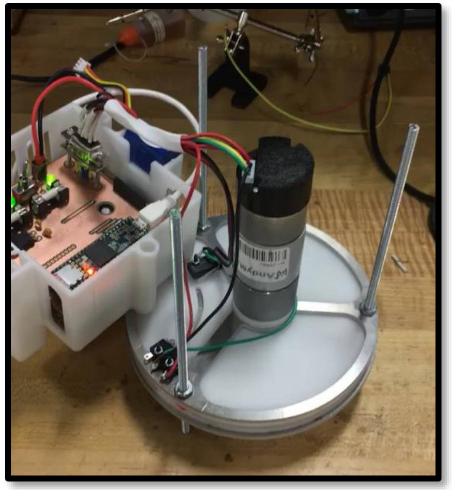
XBee SX Pro Relevant Specifications	
Operation	
Supply Voltage (VDC)	2.6 to 3.6
Current (mA) : VCC = 3.3 V	40
Transmit Current (mA) : VCC = 3.3 V	900 @ 30 dBm; 640 @ 27 dBm; 330 @ 20 dBm
Parasitic Drain (µA) : VCC = 3.3 V	2.5
Performance	
Frequency Range (Mhz)	902 to 928 (decided autonomously on field)
Transmit Power (dBm)	0 to 30
Channels	10 Hopping Sequences share 50 Frequencies
Max Data Throughput (kb/s)	120

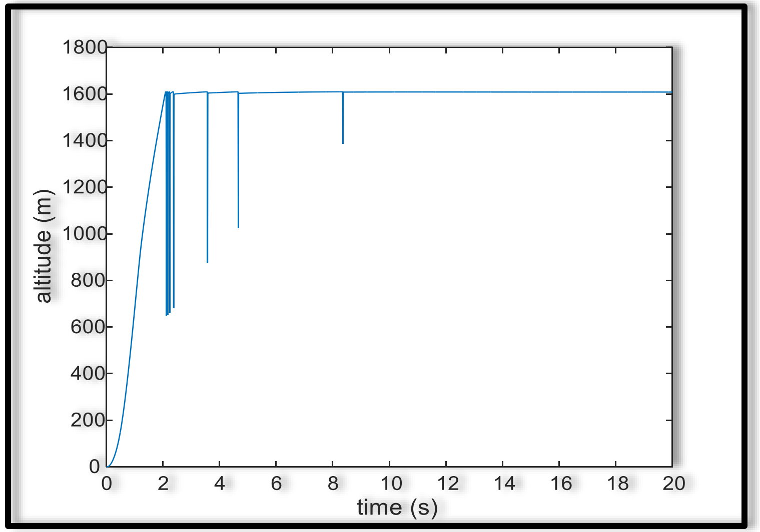


Blade testing

The motor controls were found to have been successful while performing a ground motor calibration test on 3-2-18.

- The graph shown displays the ability for the blades to actuate fully within 1.2 seconds.
- The blades are tested under various force and pressure conditions to ensure they are able to actuate with the anticipated are resistance on the brushless DC motor.





Verifications

All 17 VDS team derived requirements have been verified with the exception of the 2 shown in the table below;

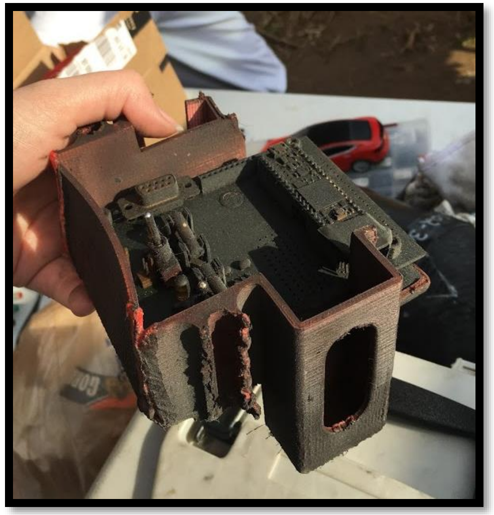
- Due to the unexpected catastrophe at takeoff and launch anomaly, all data logging systems were destroyed. For this reason, the current data is not adequate to say that these have been verified. These will be verified before the submission of an approved re-flight via the addendum.

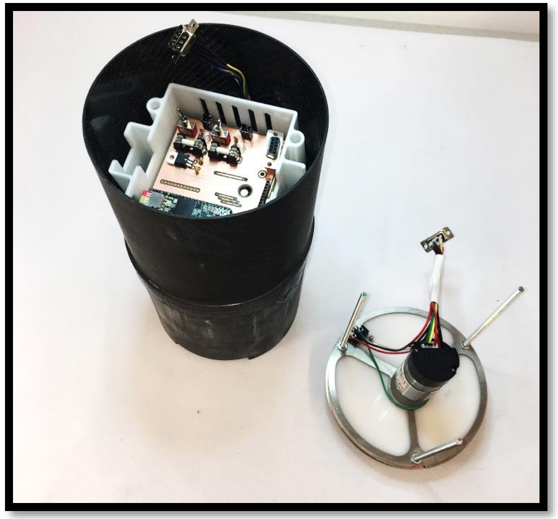
Requirement number	Requirement	Verification Status
V.1.1	The VDS will autonomously actuate it's drag blades, and alter the drag of the rocket to achieve an altitude of ±23 feet of the target altitude.	Test: The actuation method will be tested independently of the launch vehicle, as well as through several test launches to verify the system.
V.1.2	The VDS will telemetrically communicate its current state to a ground station during flight, without altering the path of the vehicle	**Test:** This requirement will be verified in sub scale flight testing. The tests will verify whether the range and data transmission rates are of acceptable standards for the needs of the VDS.

Outlook

Before competition, the VDS will be completely remanufactured, and will have achieved;

- Performed a Full-Break launch with full DAQ and verification of breaking power
- Performed a Full-performance launch with Telemetry and successful DAQ.





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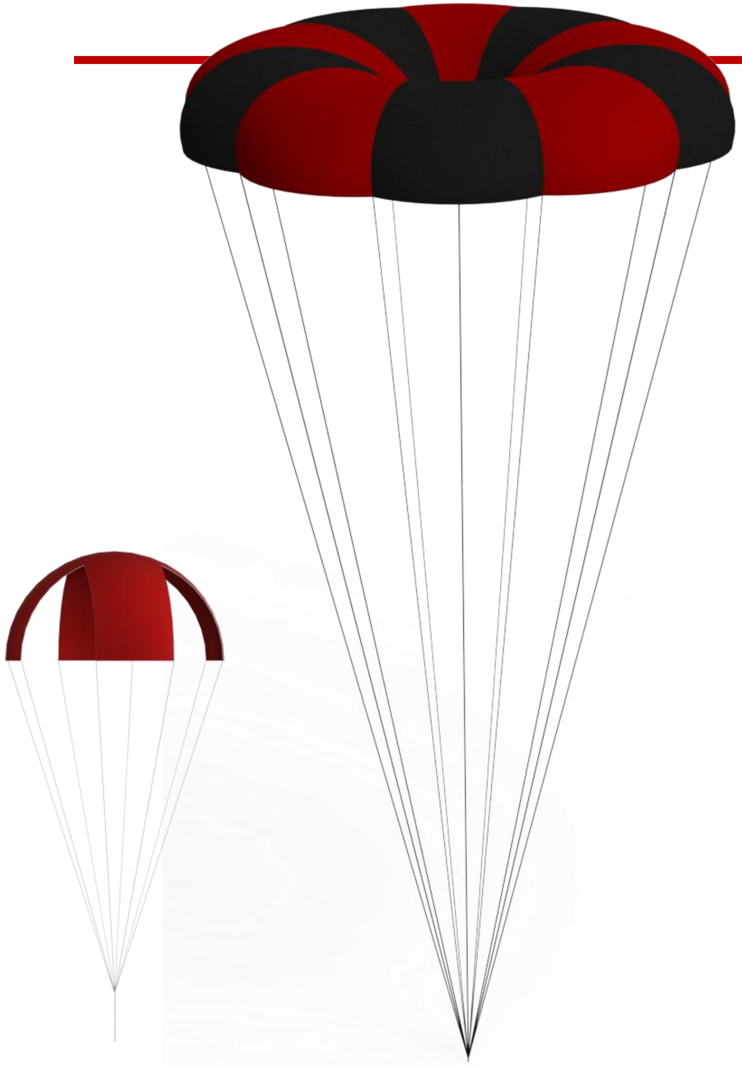
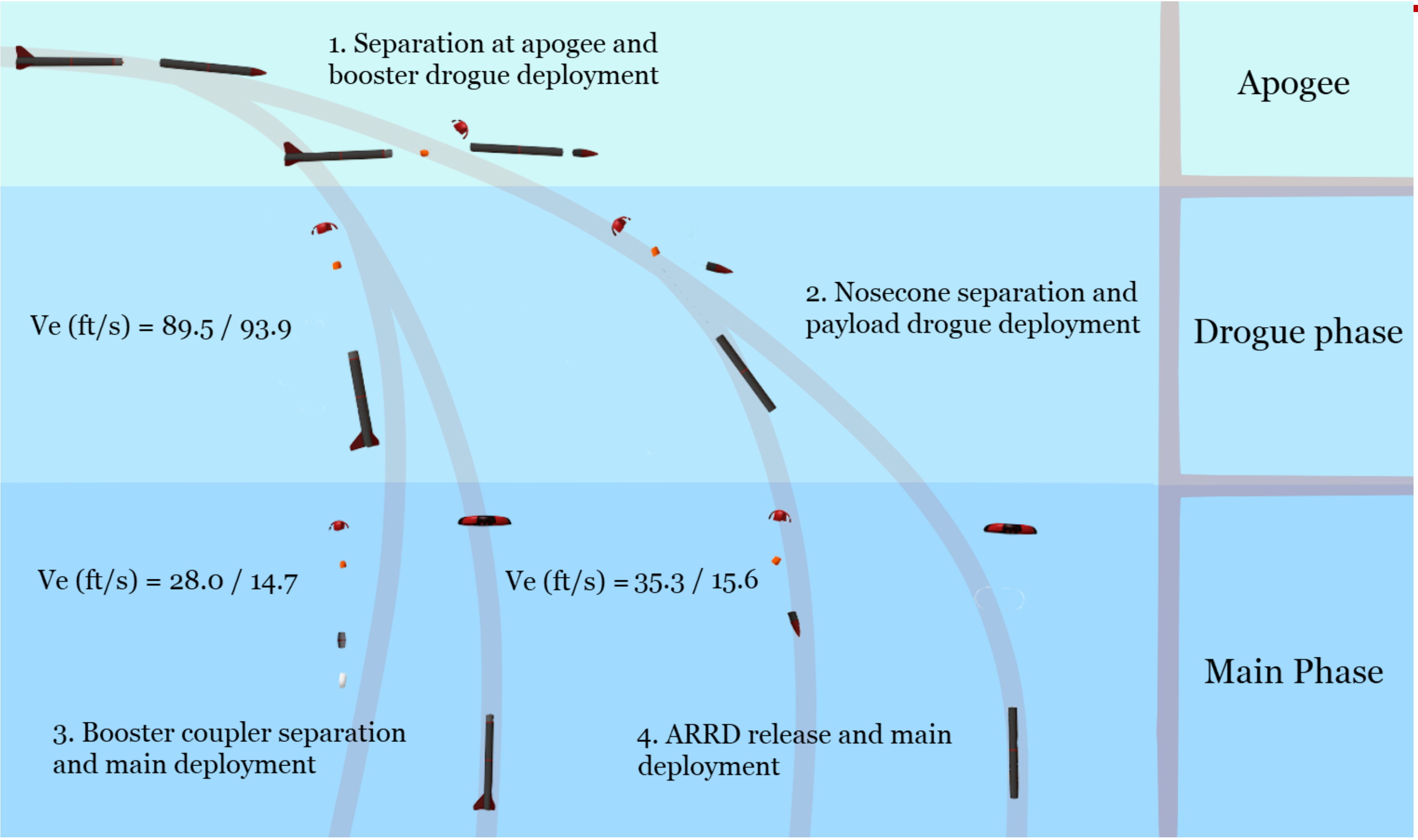


Recovery Agenda

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



Sequence of Events

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

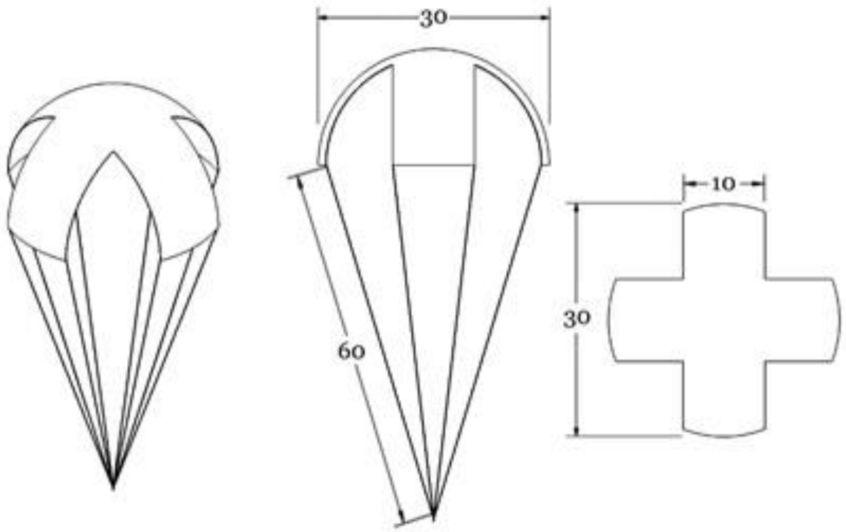
Drogue phase: Apogee – 500 ft.
Booster decent at 89.5 ft./s
Payload decent at 93.9 ft./s

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

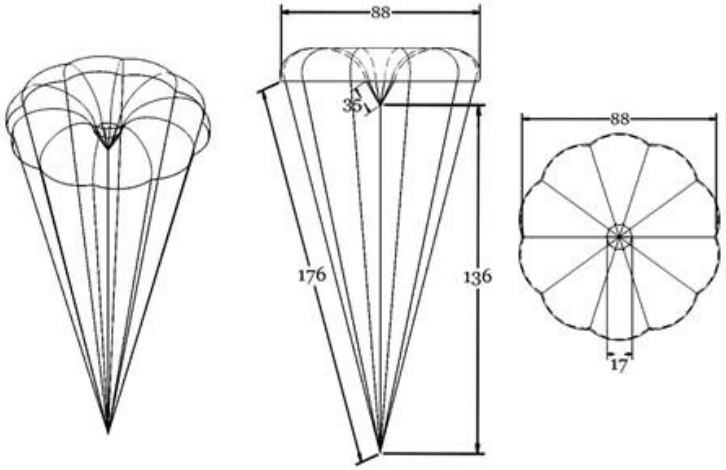
- Cruciform design
- Designed for KE and Drift
- Both sections have same diameter for ease of integration
- Laser cut single panel



Main Parachute

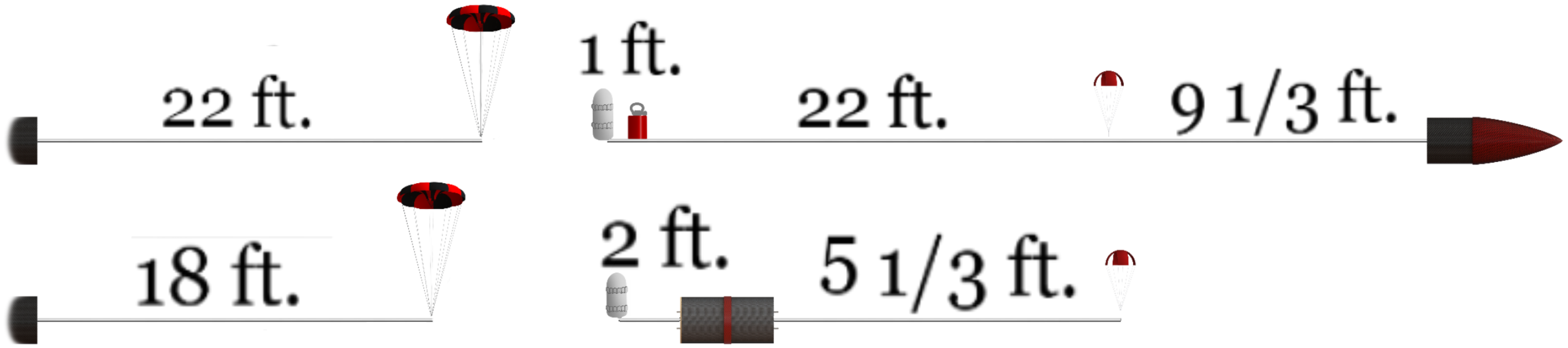
Section	Mass (lbs.)	Terminal Velocity (ft./s)	Kinetic Energy (ft.-lbs.)	Size (in.)
Payload	17.09	15.6	65	88
Booster	19.29	14.7	65	99
Coupler	1.98	28.0	17.47	30
Nosecone	3.14	35.3	43.8	30

- 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

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

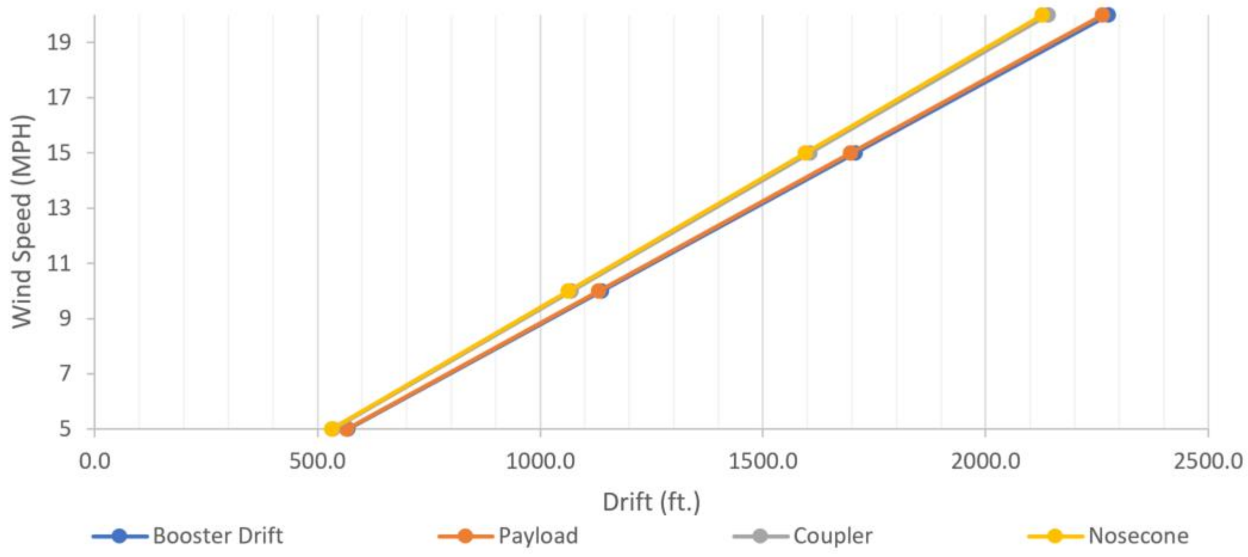
using data from subscale flights and scaled to the full scale launch vehicle

- 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



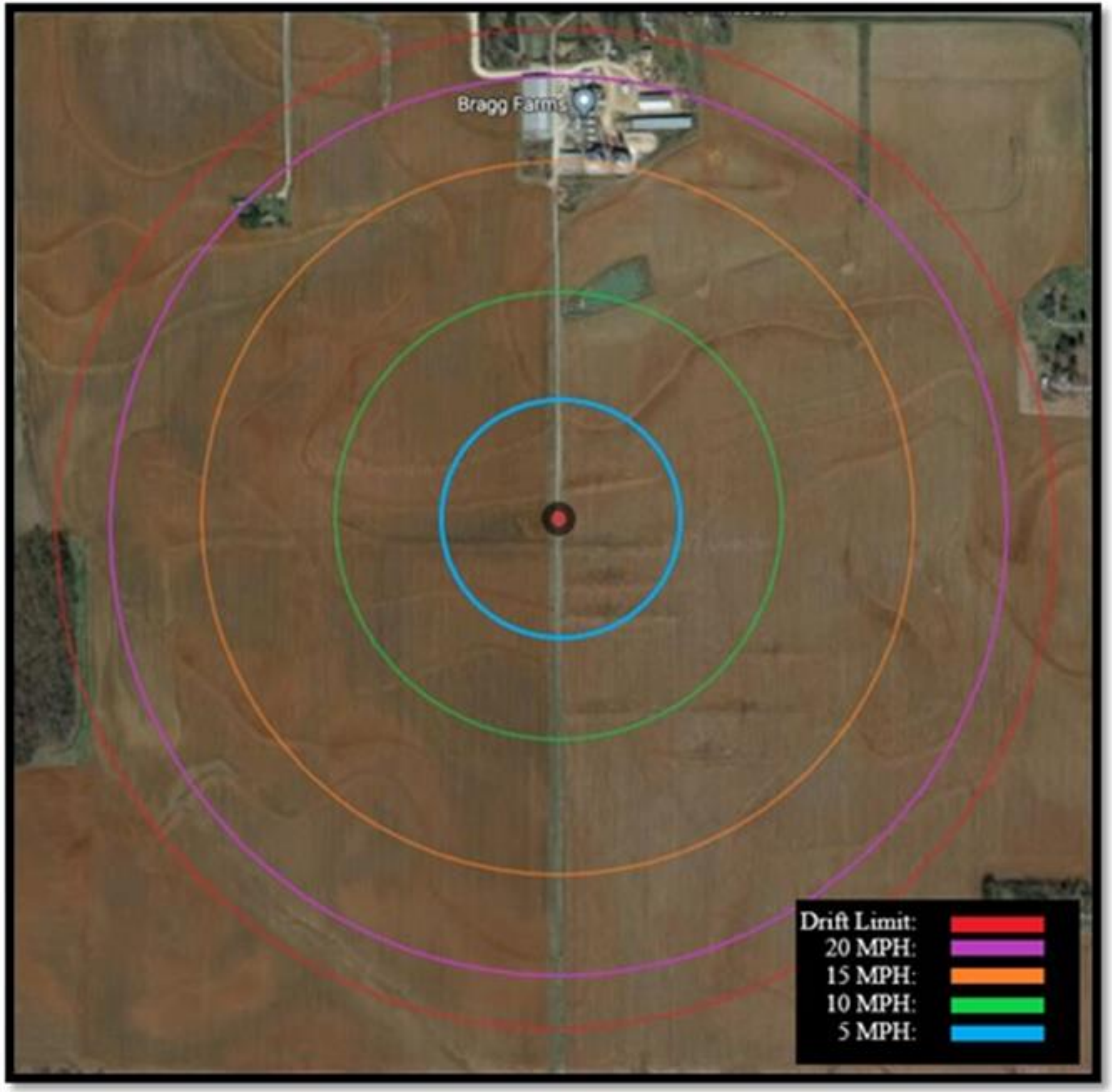
Visualized drift and Mission Elapsed Time

Ascent: 17.8s

Drogue decent: 53s

Main decent: 24s

Total: 94.8s



Recovery Test Campaign

- Protection of payload from BP separation charges
- Fire retardant 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
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.

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Hazard Risk Assessments

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.

- Mitigations and Verifications have been finalized
- Approval from sub-team leads, safety officer, and co-captains obtained for the necessary risks.
- Updated personal hazards based on full scale preparation observations

Launch Operations

- Additional materials such as sunscreen
- Additional preparations like checking fire extinguisher level

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

FRR Presentation Agenda

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- Subscale Vehicle
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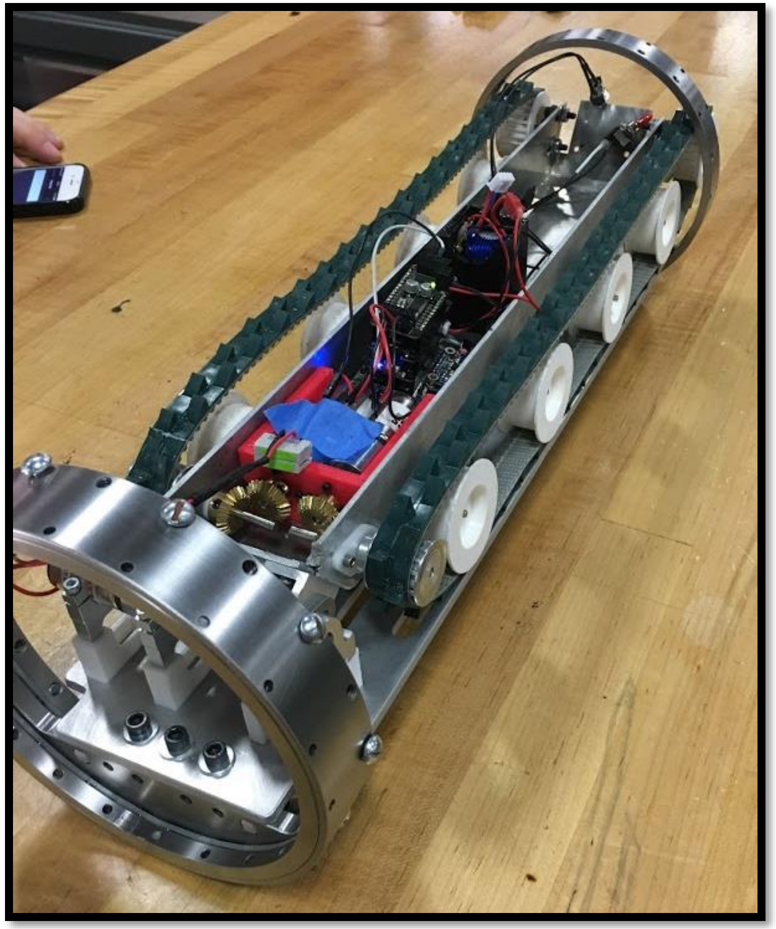
Payload Agenda

- Overview of Constructed Payload
- Integration
- Interfaces with Ground Systems
- Summary of Requirements Verification



Dimensional Overview

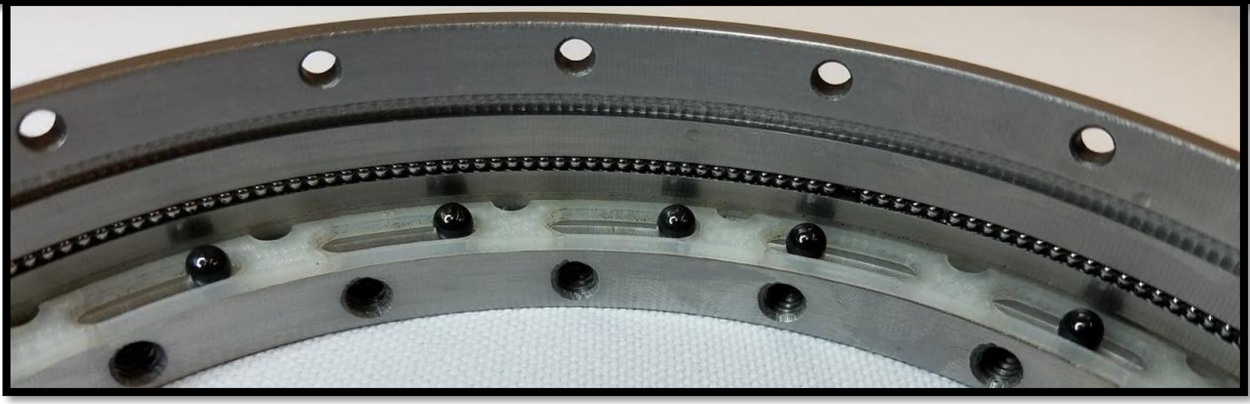
ROCS/RLM	
Dimension	**Value**
Diameter	Ø6.0 in.
Length	17.9 in.
Weight	4.495 lbs.
ROVER	
Dimension	**Value**
Stowed Length x Width x Height	16.82 x 4.73 x 3.73 in.
Deployed Length x Width x Height	16.82 x 4.73 x 4.05 in.
Weight	3.20 lbs.
PAYLOAD	
Total Weight (including DTS)	7.695 lbs.

Rover Orientation Correction System (ROCS)

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

ROCS Cont….





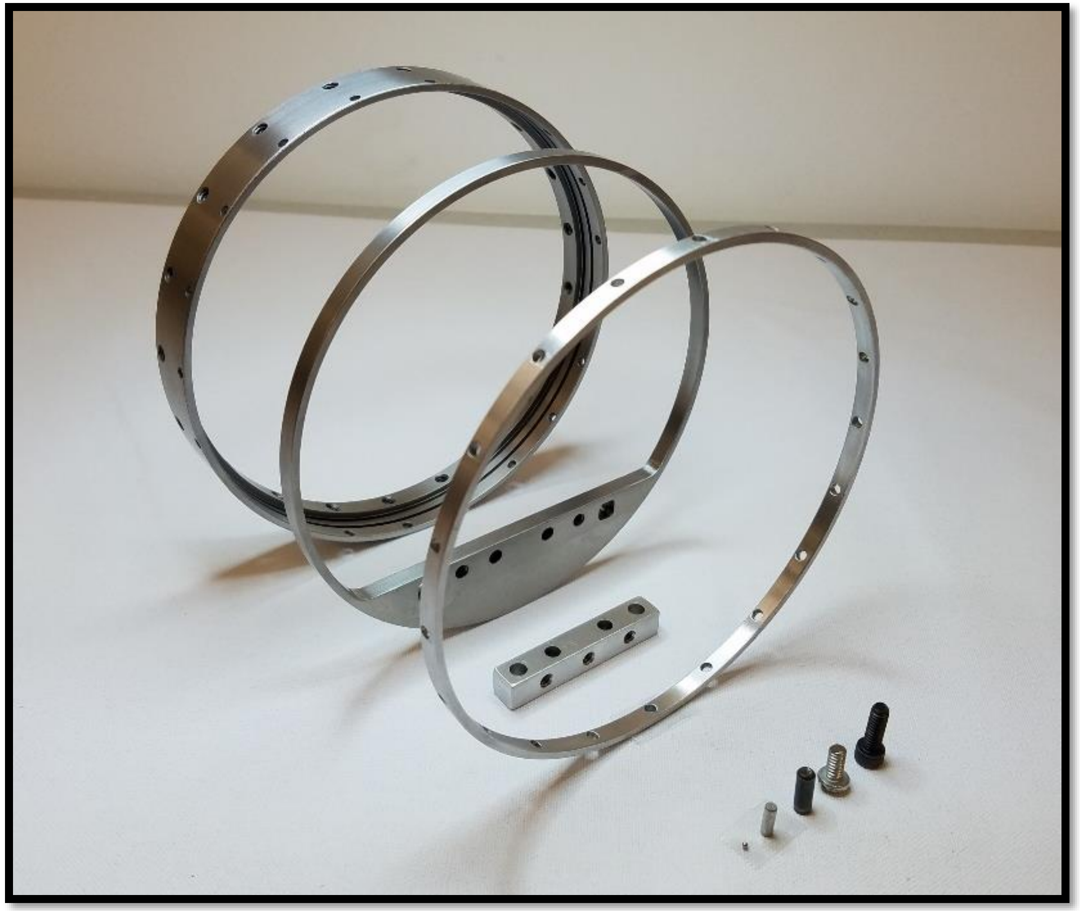
- Machined and assembled by team member

- Equipment used:
  - CNC Vertical Milling Center
  - CNC Horizontal Table Grinder
  - Manual Lathe
  - Horizontal Ban Saw
  - 3D Printer

- Ball bearings in each raceway

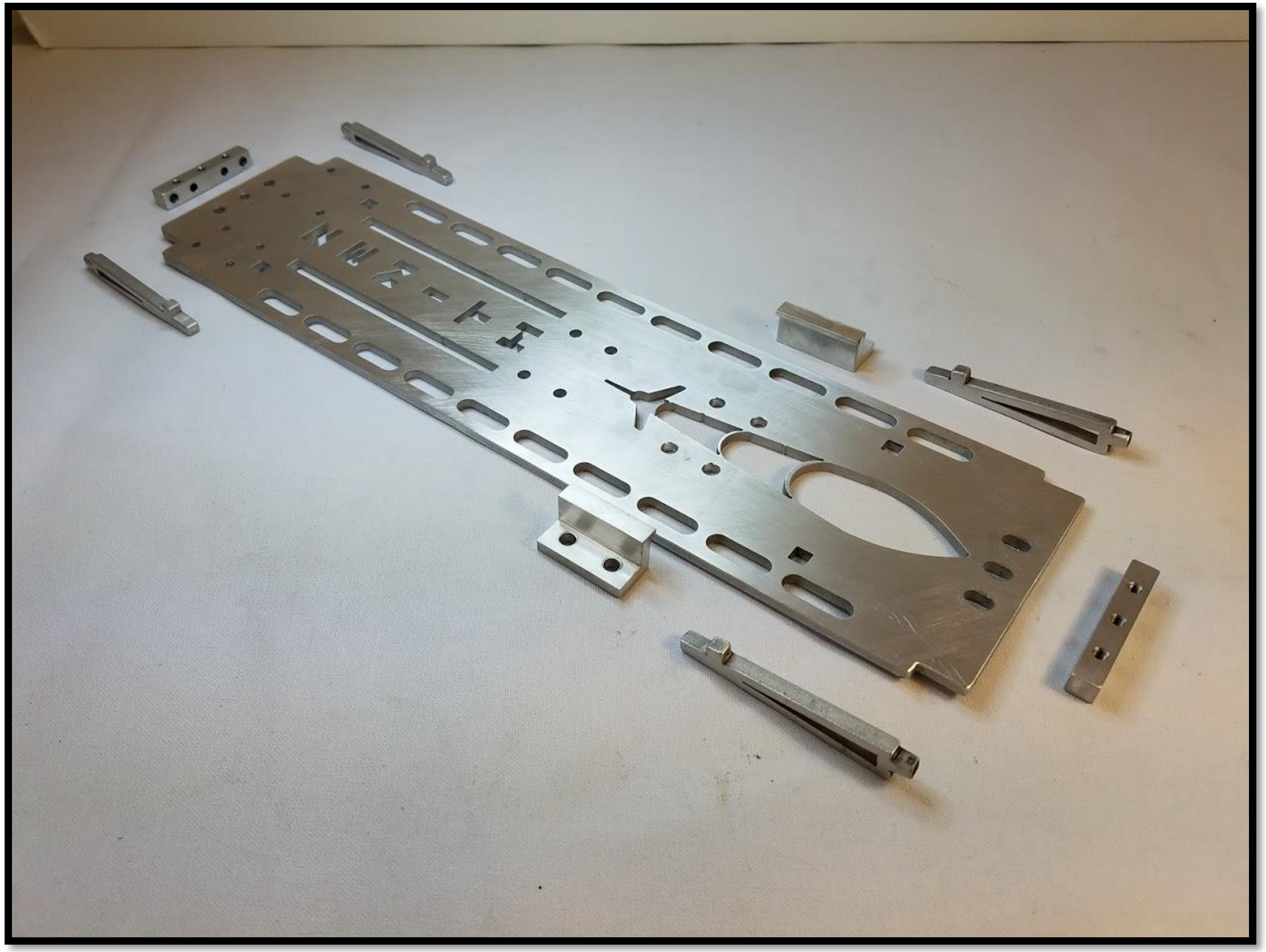
ROCS Cont….

- Similar machining process to AETB
- Ball bearings filling each raceway
- Eliminate possibility of bearing ring bottoming out



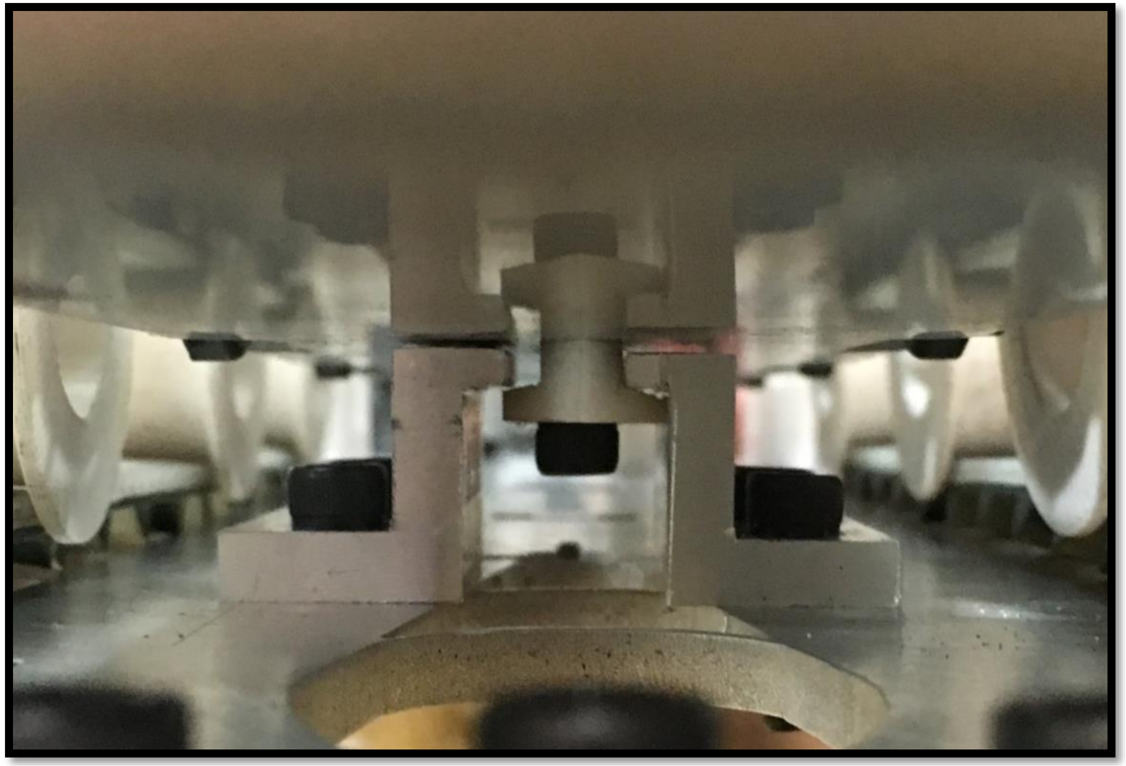
ROCS Cont....

- Bridging sled weight reduction
- T-Slot moved forward of rover CG
- Crescent mounting brackets and support ribs securely interface sled with bearings



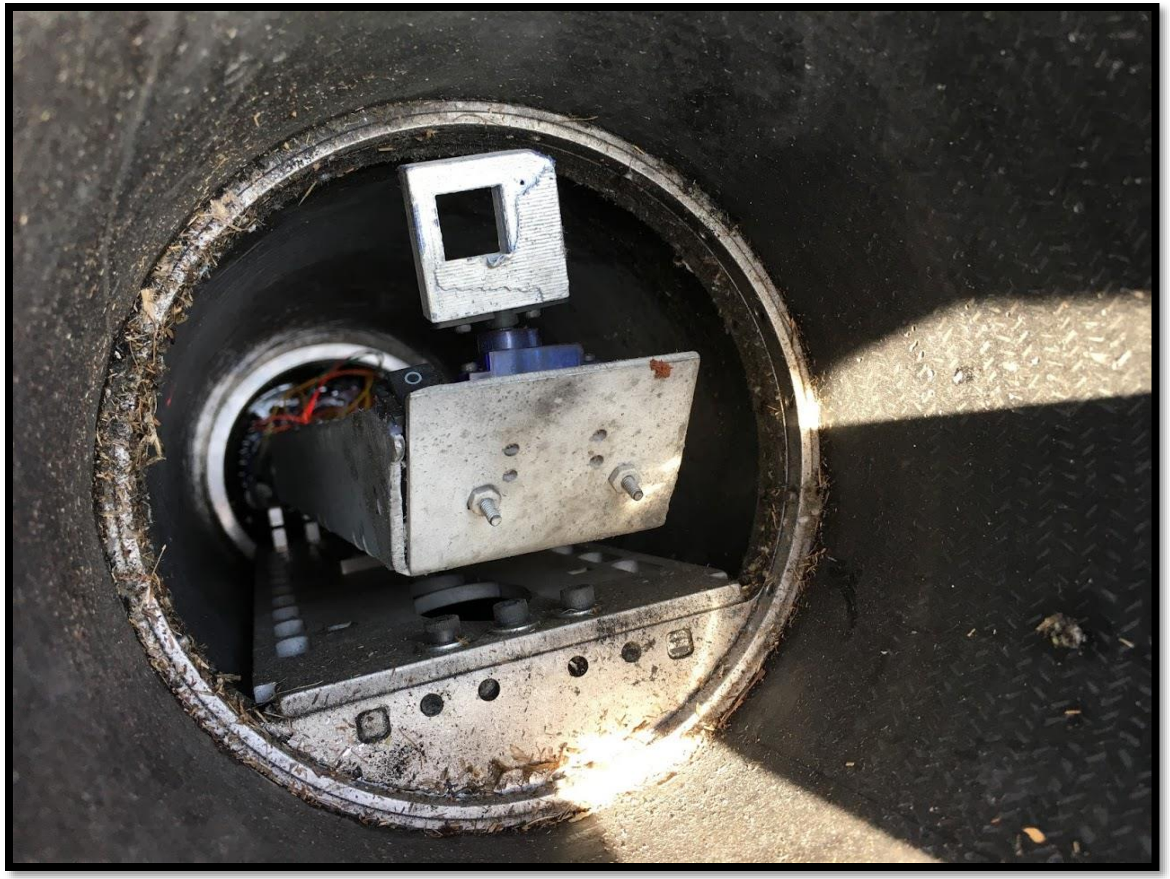
ROCS Cont....

- Securely restricts rover to bridging sled
- Adequate clearance allowing driving
- Slot successfully retained rover during first full-scale flight throughout



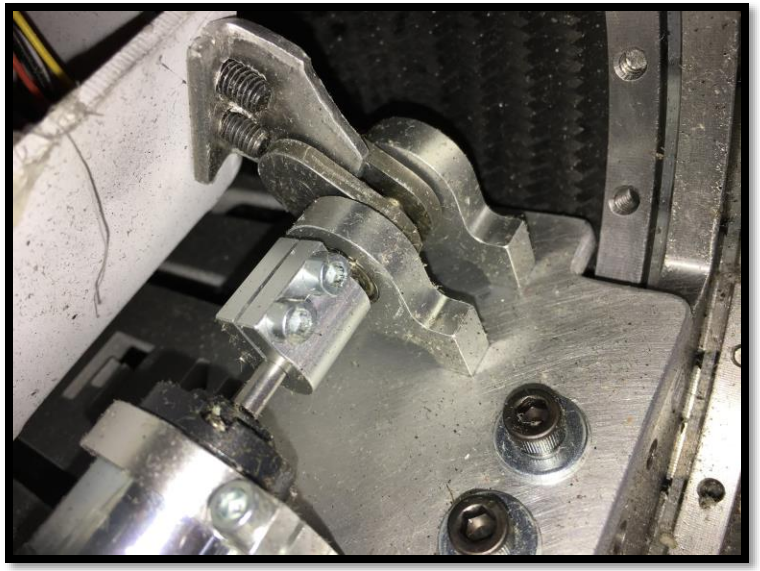
ROCS Cont....

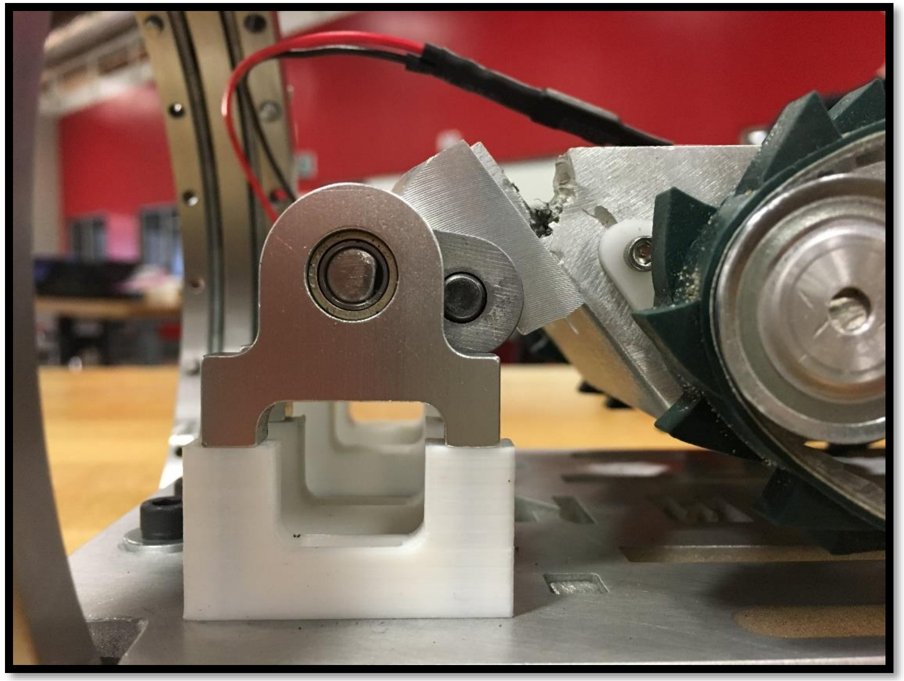
- Successfully orientated rover during full-scale flight #1



Rover Locking Mechanism (RLM)

- Tested during full-scale launch #1
- Successfully retained the payload
- Raised with spacers



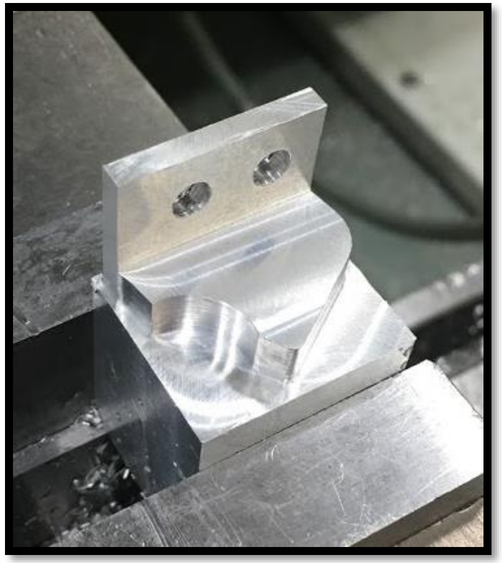


RLM Latch

- Moved up on Rover Body Structure

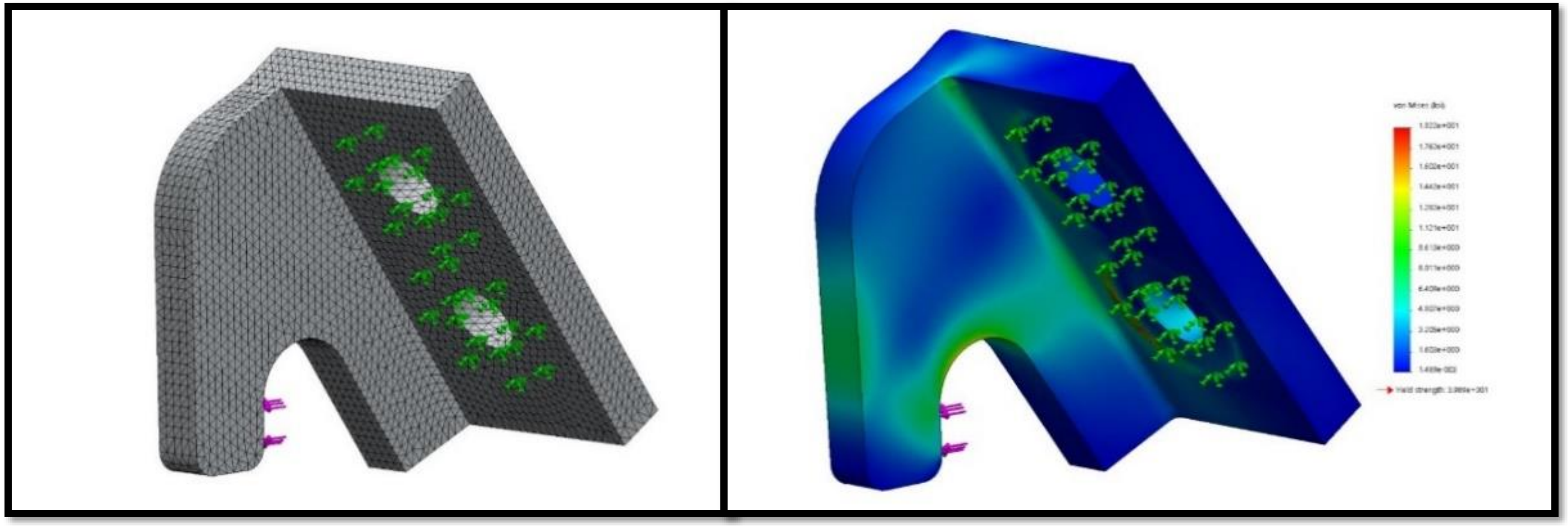
- New design using thicker aluminum

- Part was machined using CNC mill



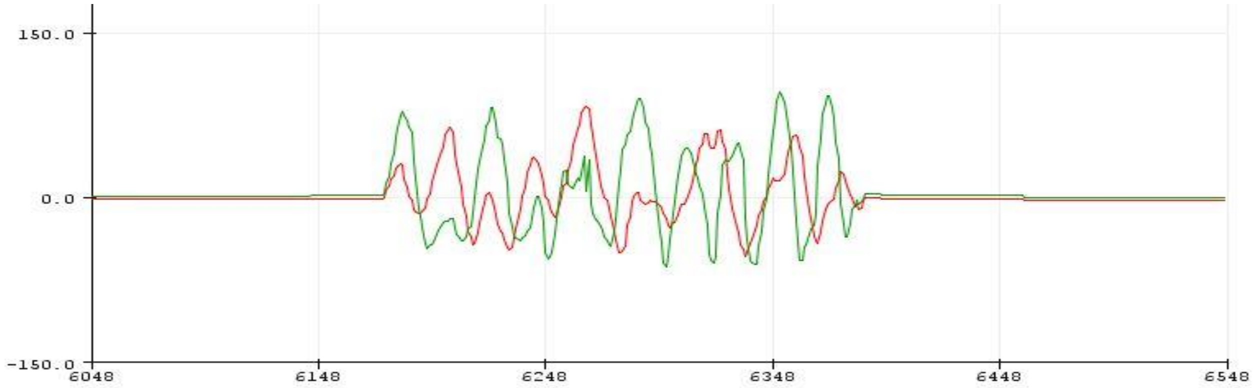
RLM Latch Cont…

- FEA confirms factor of safety of 2.1
- Part did not yield during second full-scale flight



Rover Locking Mechanism (RLM) Cont….

- Software safety check confirmed
- Accuracy of sensors confirmed



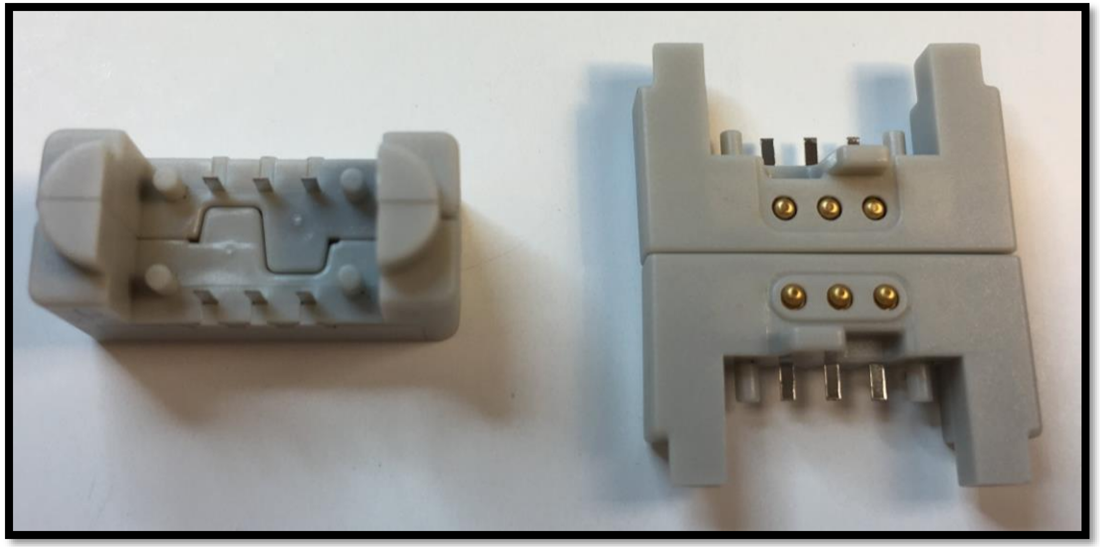
Deployment Trigger System (DTS)

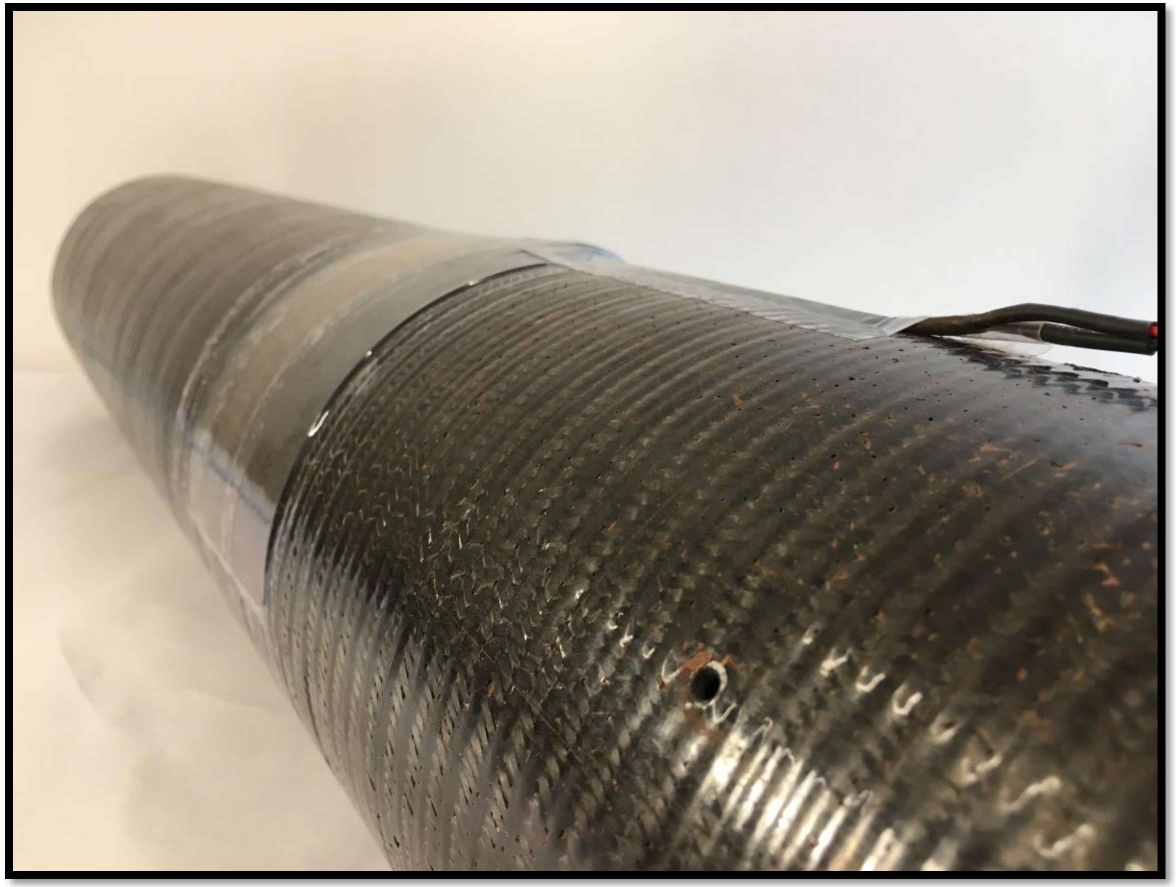
- Unique packet of data: “RCRdeploy”

- All requirements of the system have been successfully verified

DTS Receiver Side

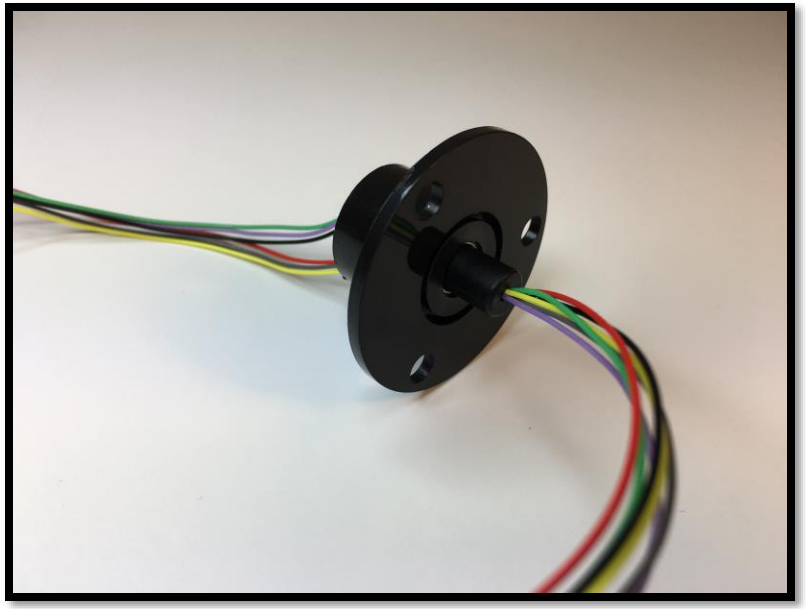
- Low profile on airframe
- Withstood 2 flights and remains functional
- Magnetic Connectors to interface with CES

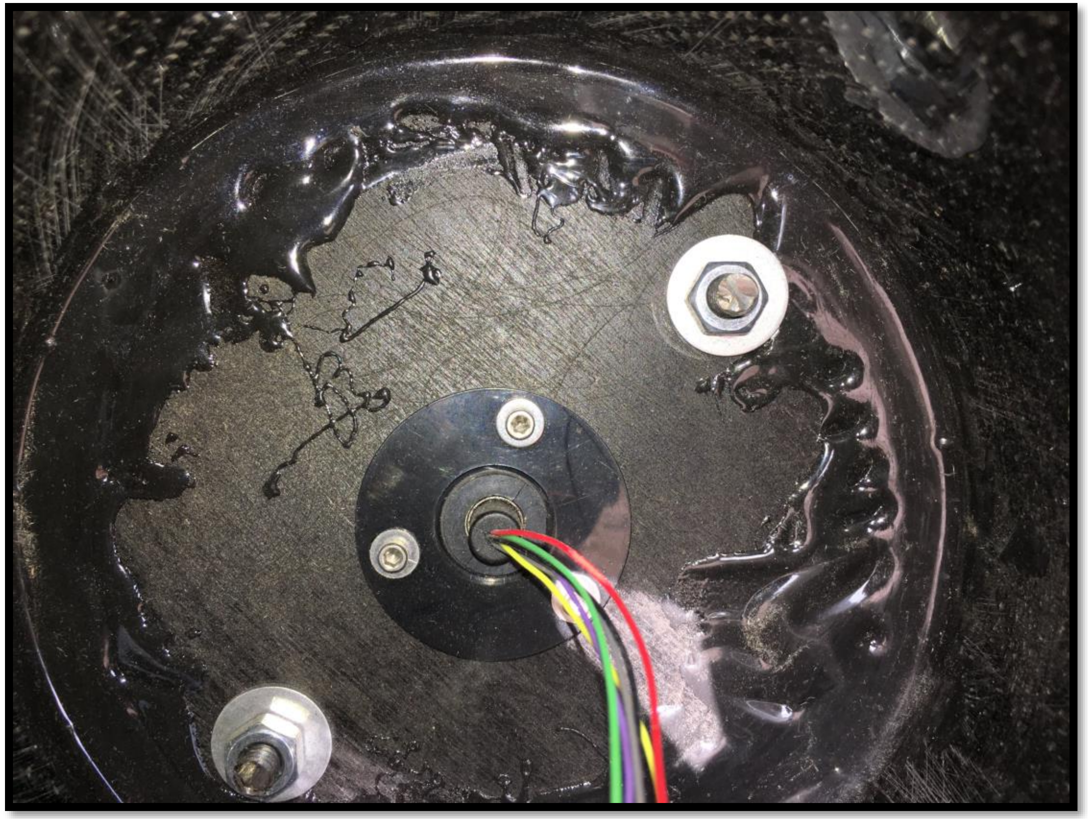




DTS Slip Ring Flange

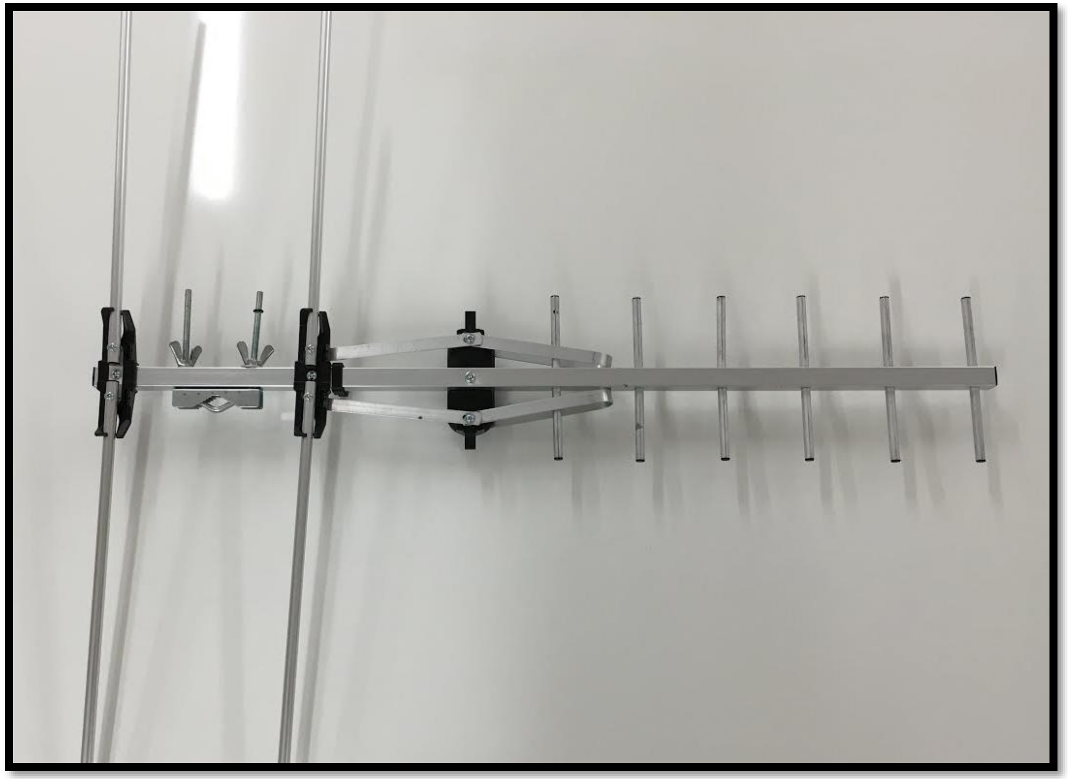
- Bolted to payload recovery bay bulk plate
- Signal fidelity through flange confirmed





DTS Transmitter Side

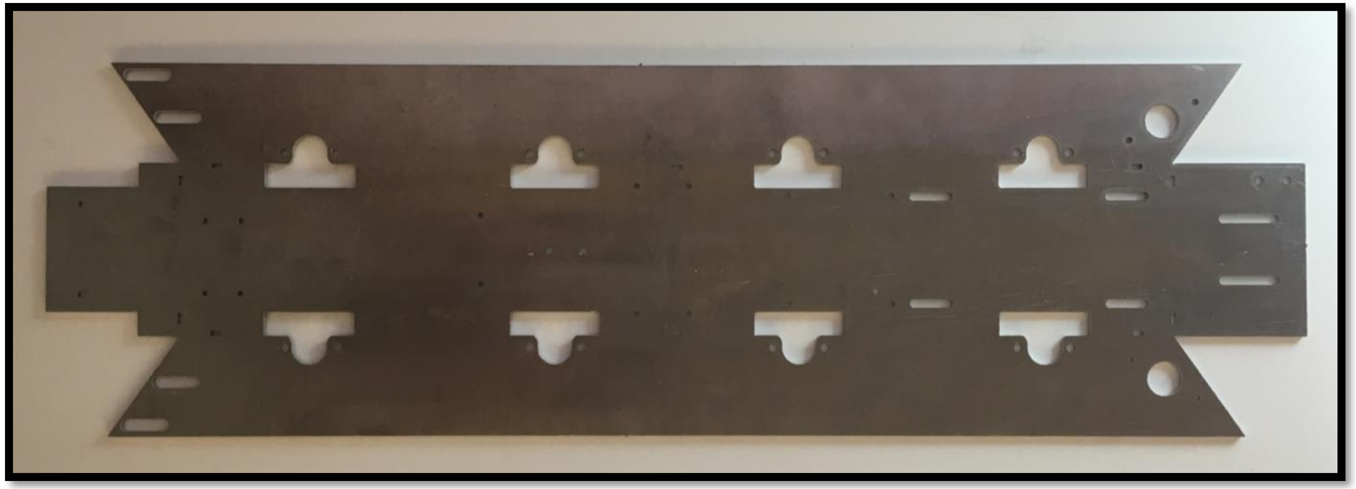
- Yagi antenna tested and functionality confirmed
- Frequency: 433.4 MHz (adjustable if need be)
- Power Level: 100 mW



Rover Body Structures (RBS)

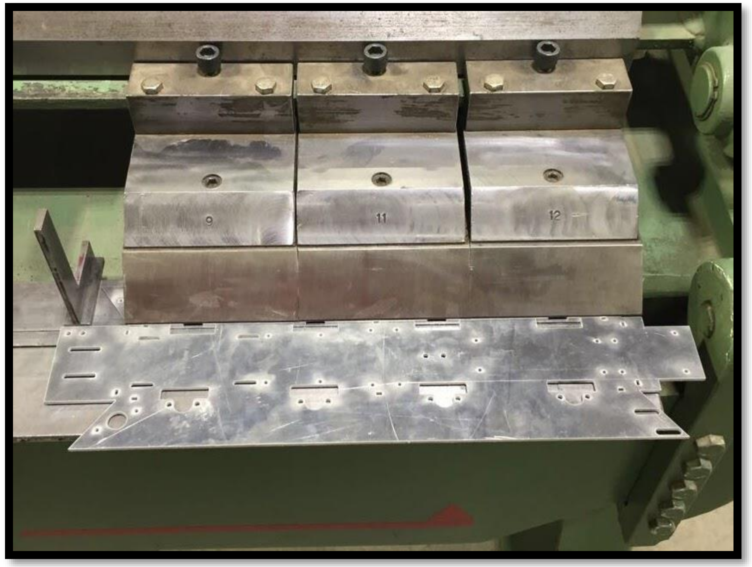
- Bending guide holes cut into RBS

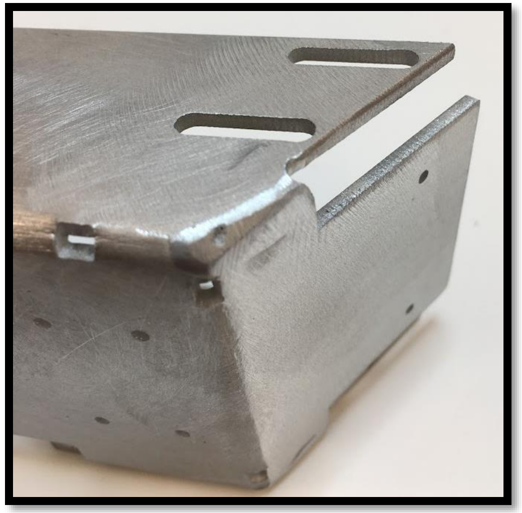
- Water jet for accuracy

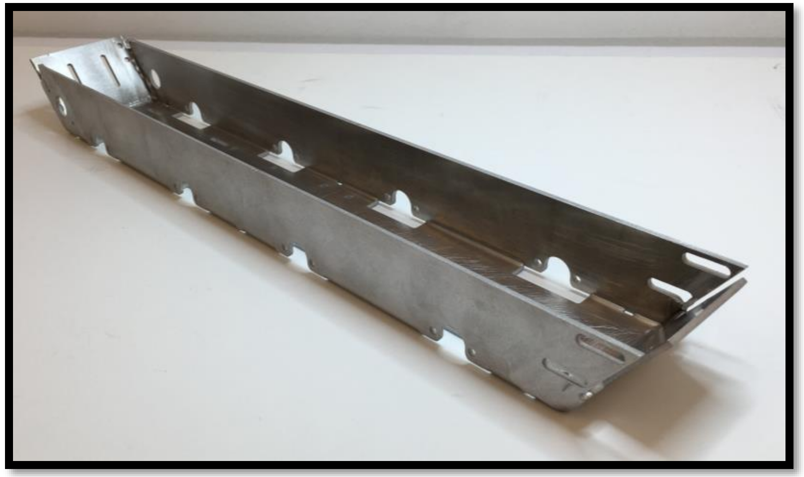


RBS Cont…

- Bent using manual finger break
- Corners welded for strength
- Seams grinded and smoothed



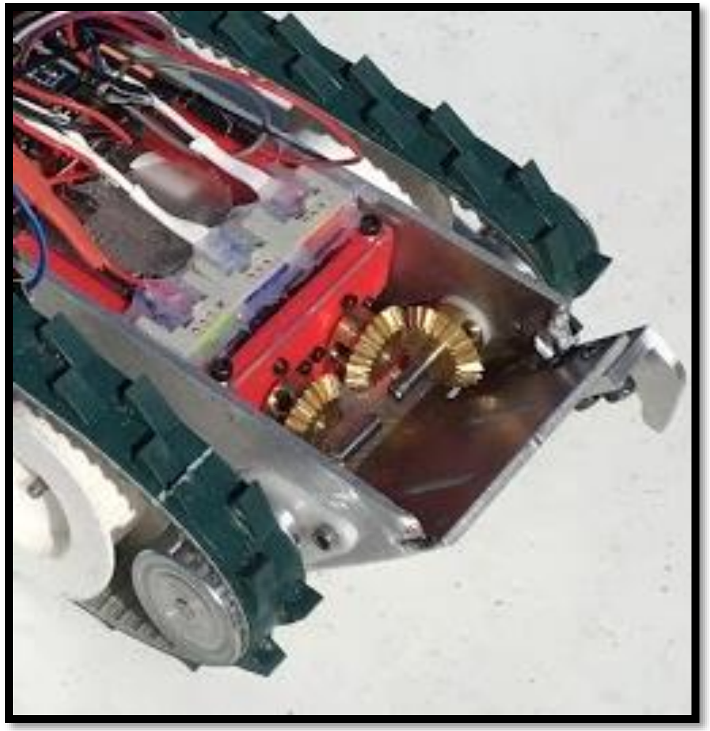


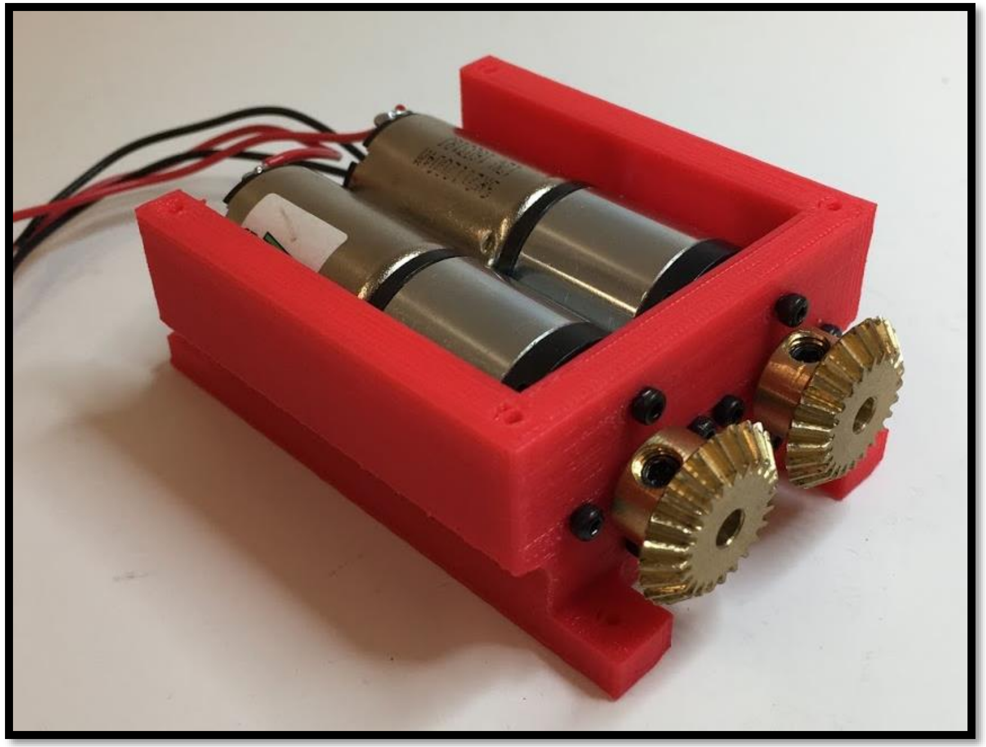


Rover Drive System (RDS)

- 2 main drive motors

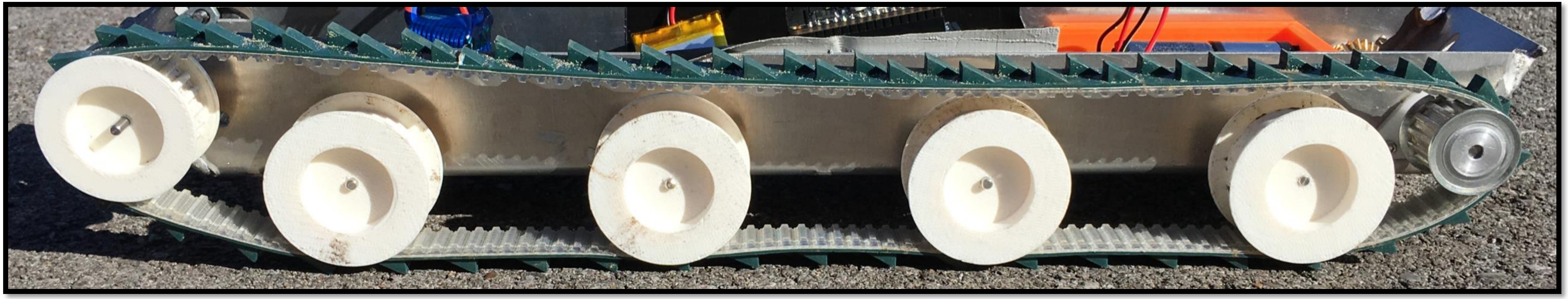
- 90 degree bevel gears





RDS Pulleys and Tread

- Front wheels contact any obstacle first
- Sawtooth treads maintain large surface contact



Rover Drive System (RDS) Cont…

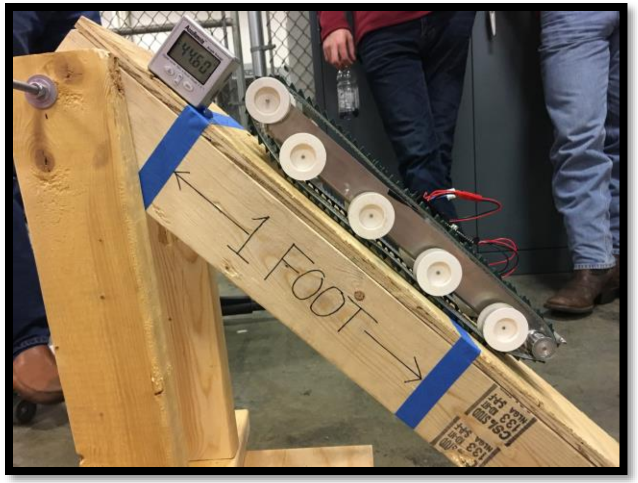
DRY

WET

Rover Drive System (RDS) Cont….

- Successfully surmounted slope of 44.60°

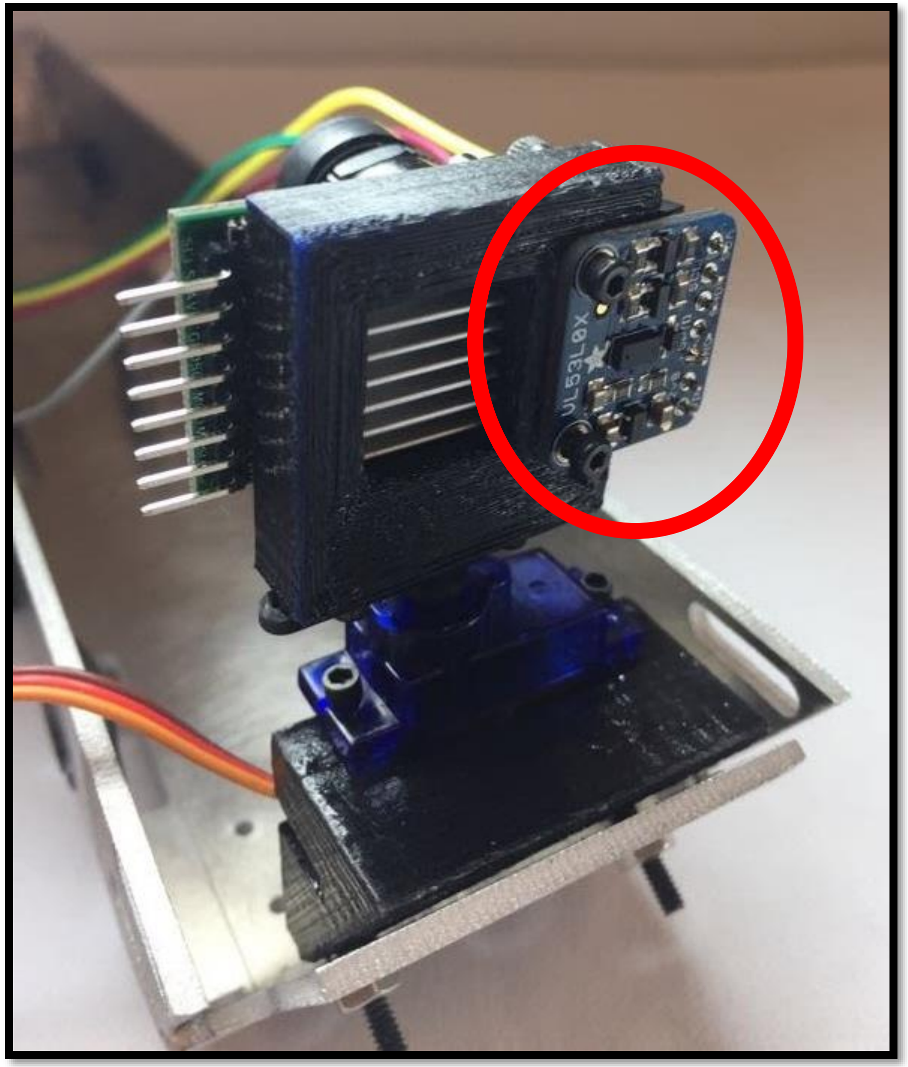
- Successfully surmounted 3.25 in. vertical step



Obstacle Avoidance System (OAS)

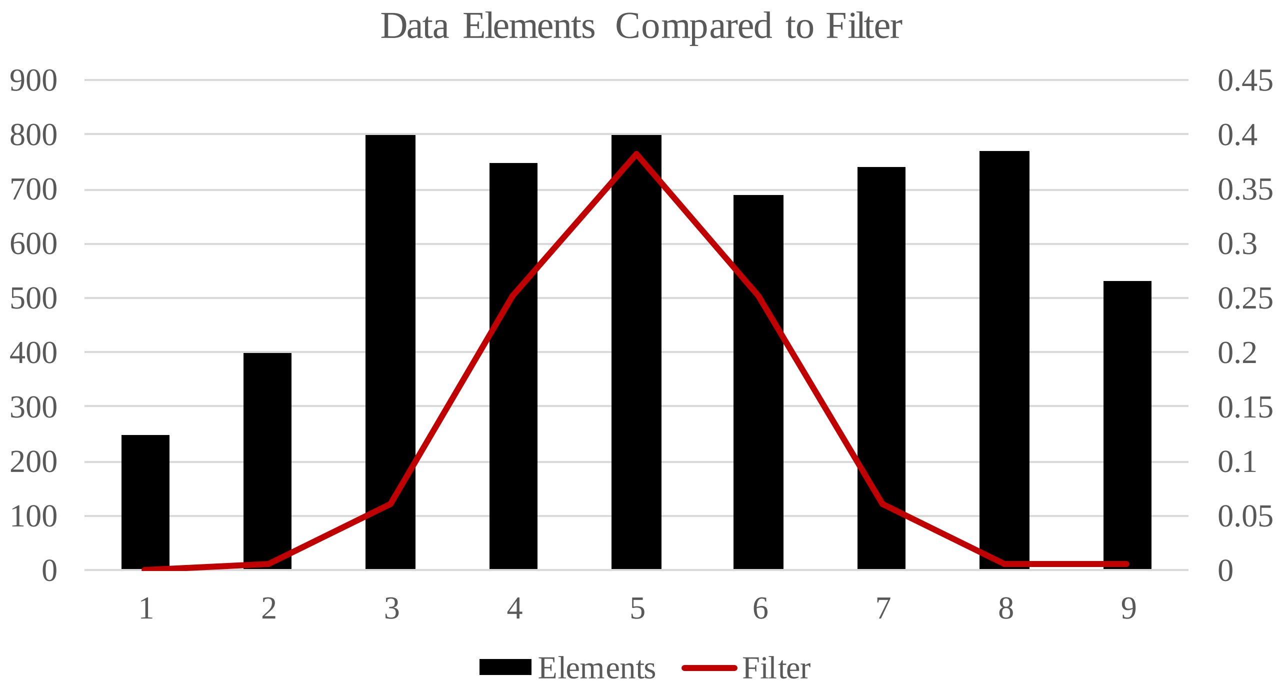
- Field of view increased to 180 degrees

- All requirements and testing has been successfully completed

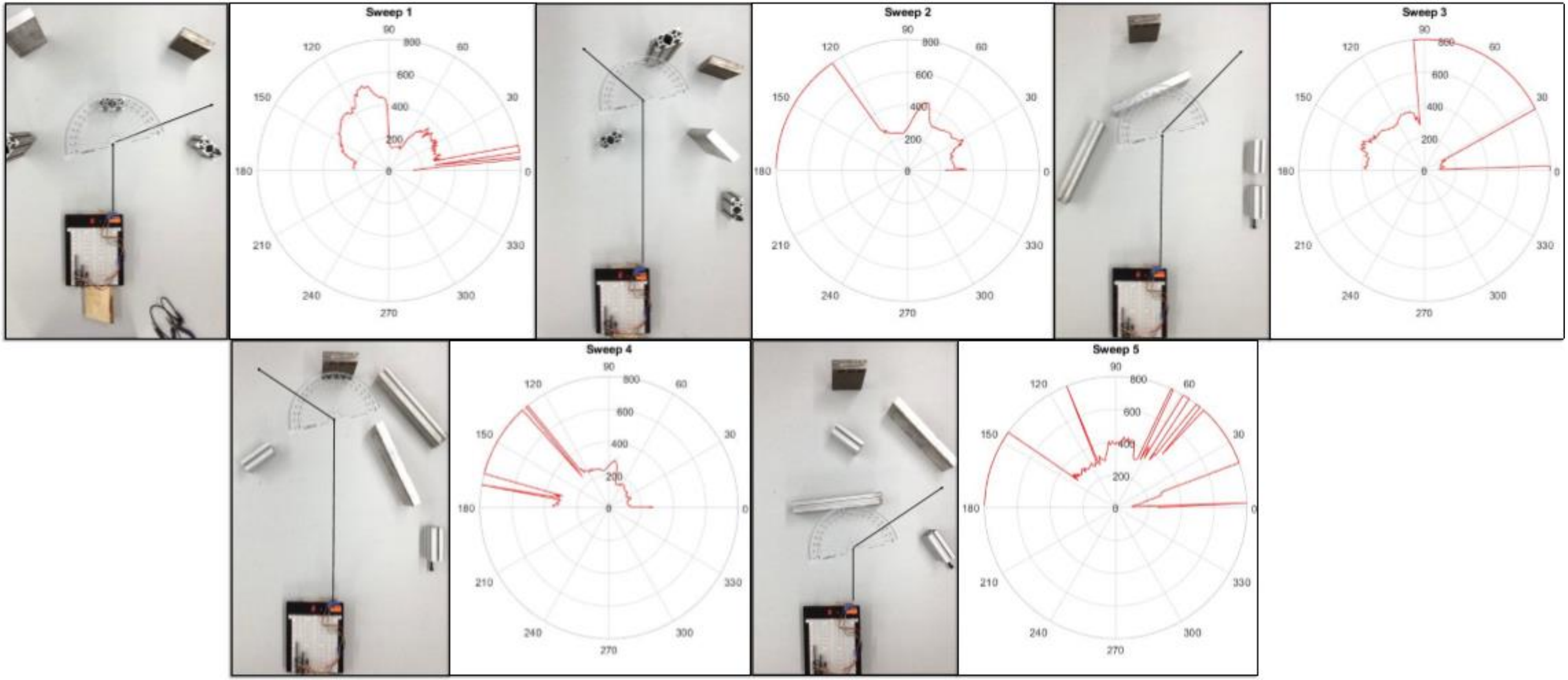


OAS Algorithm

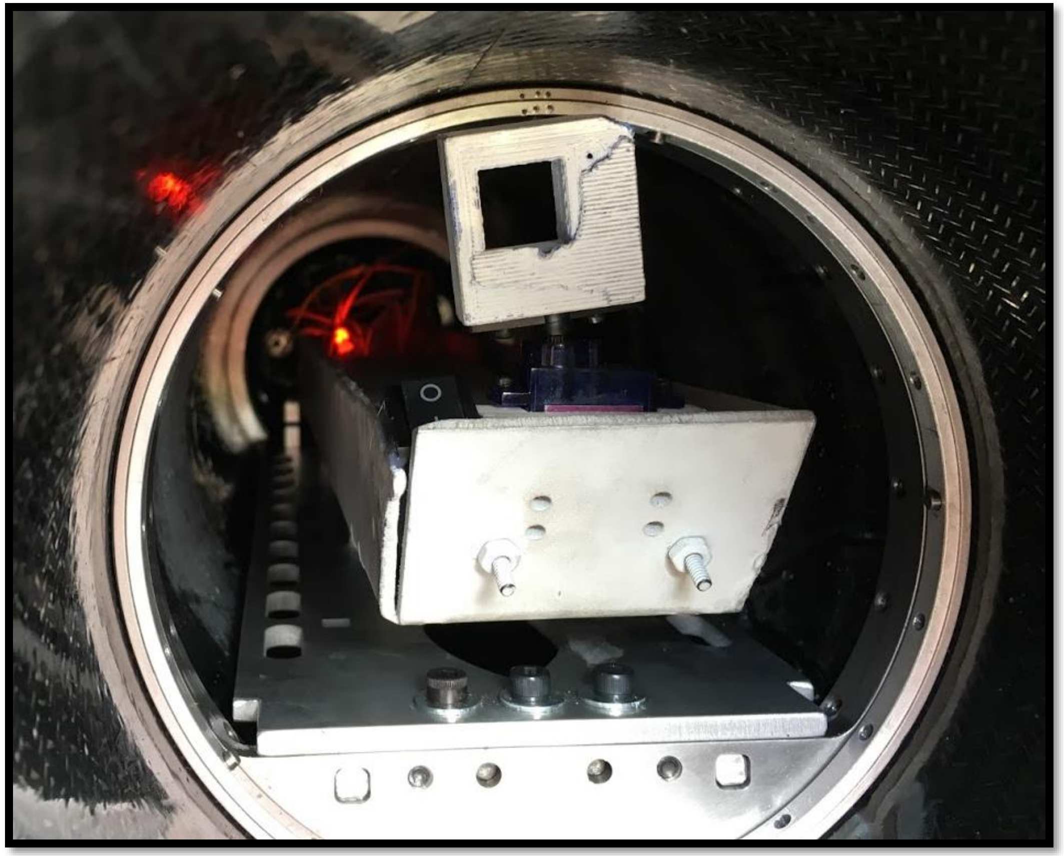
- 180 data elements taken during sweep
- Gaussian filter applied to elements
- Prioritizes middle elements

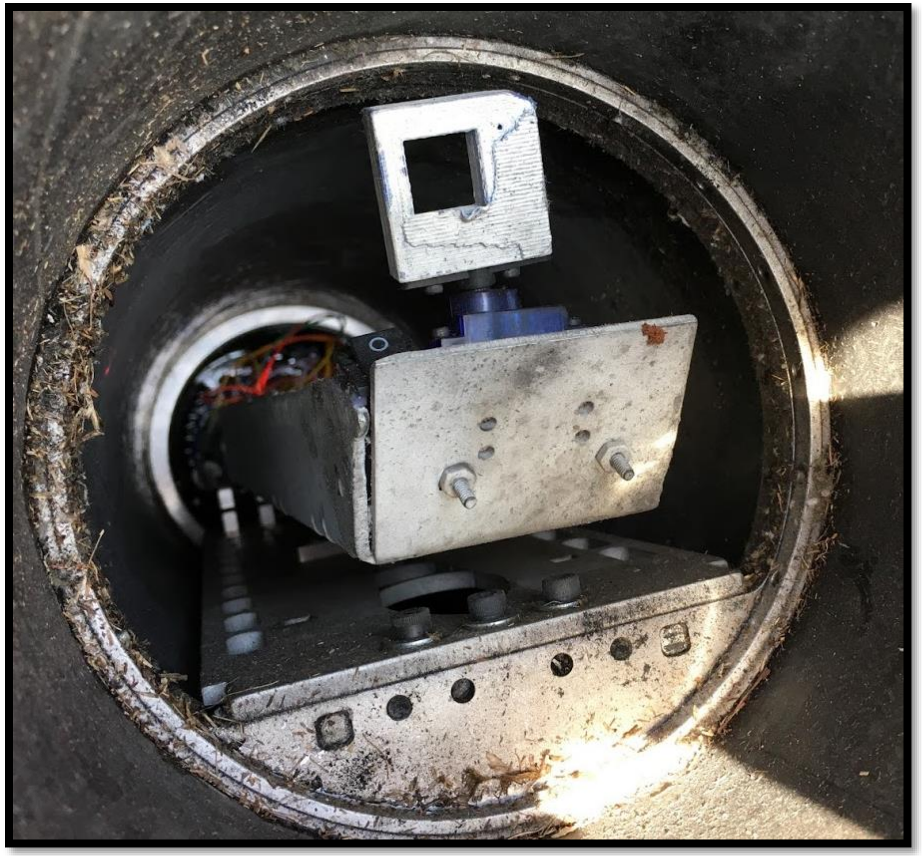


OAS Path Finding



OAS BP Coverage Test Results





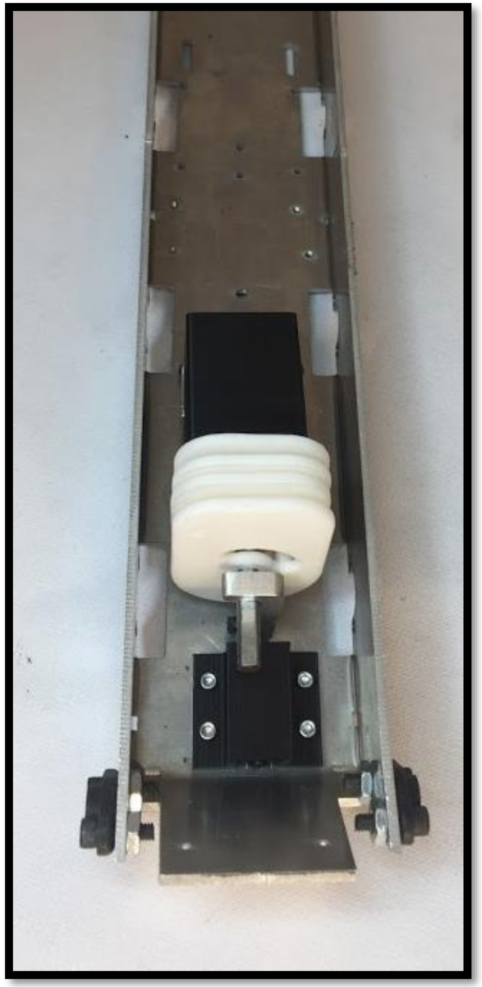
Majority of black powder coated RBS, not sensor mount

Solar Array System (SAS)

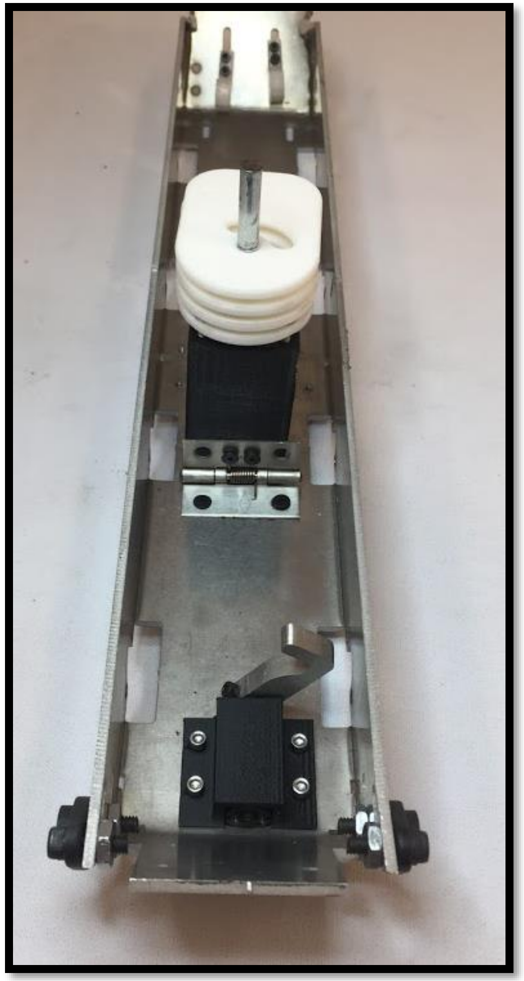
- Actuation via spring hinge confirmed

- Tower remains upright

Stowed



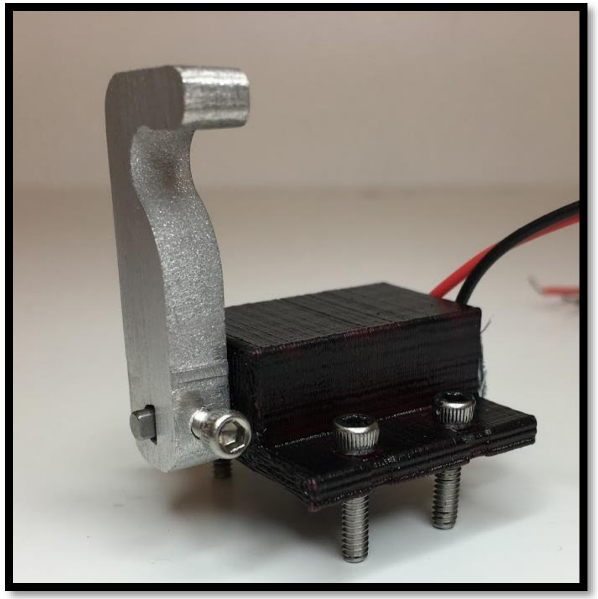
Deployed

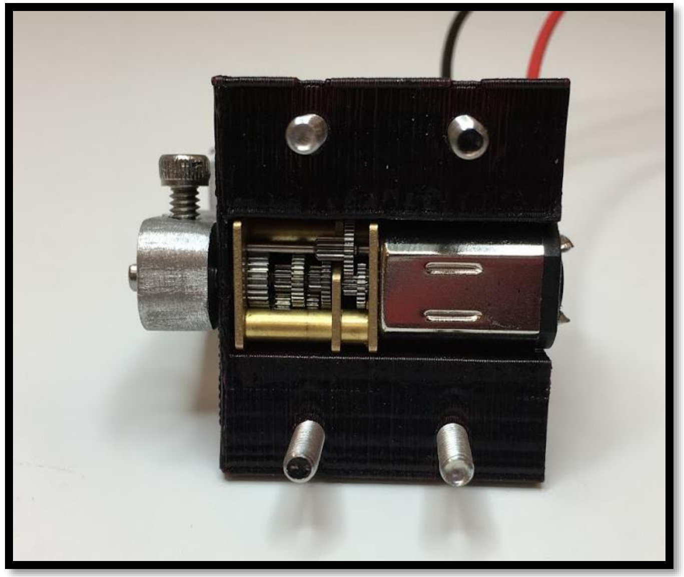


SAS Cont…

- Tower unlock motor/latch operation confirmed

- Powered by controller battery through NMOS

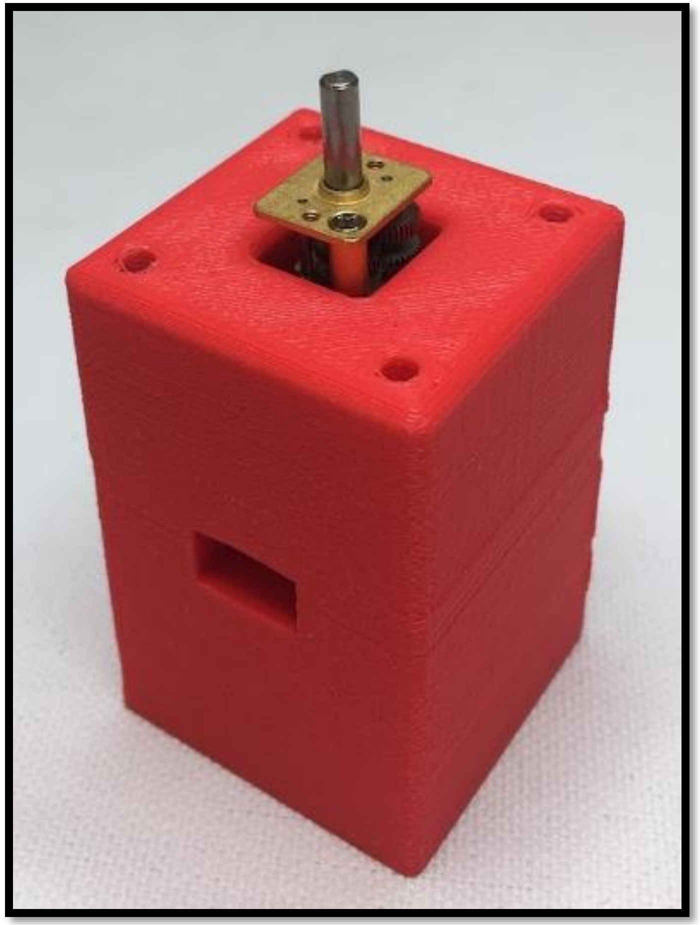




SAS Cont…

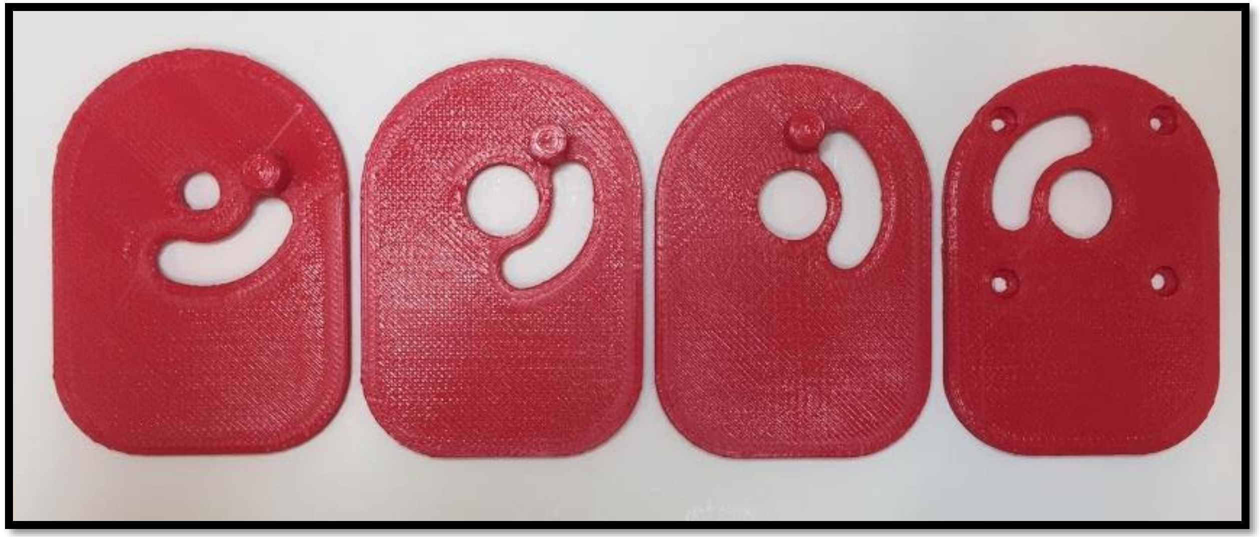
- Solar Array Deployment Motor fitted with spacers and extension

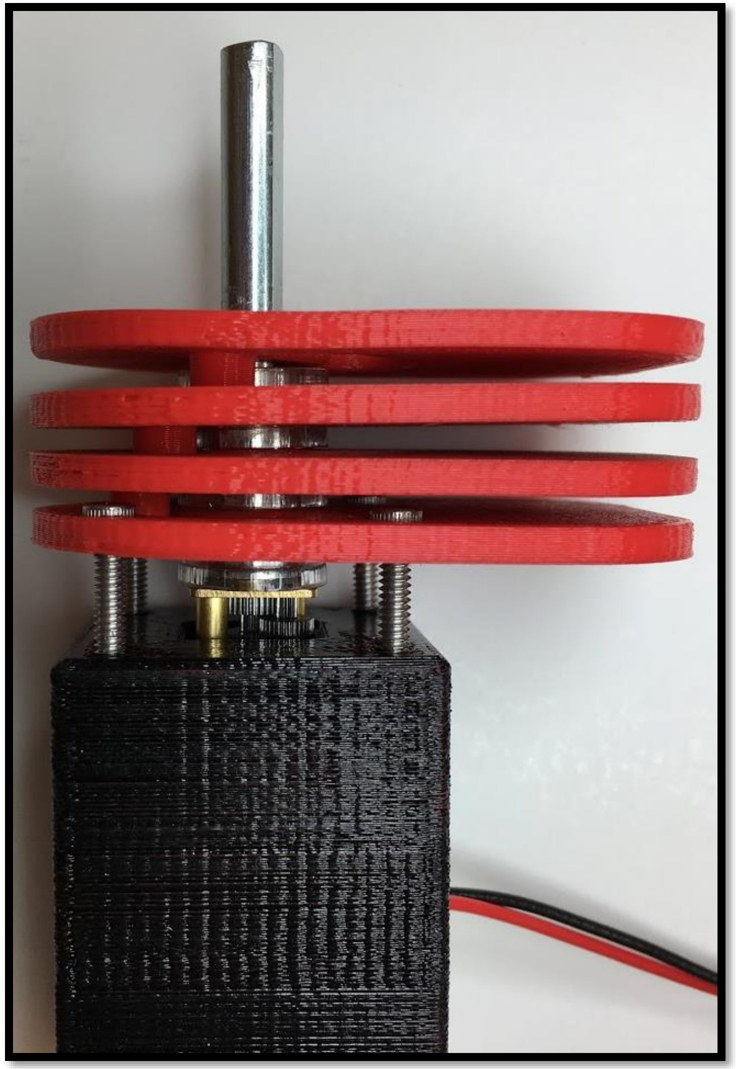
- 3D printed tower base/motor housing



SAS Cont…

- 3D printed using PLA
- Center hole for mounting to deployment motor



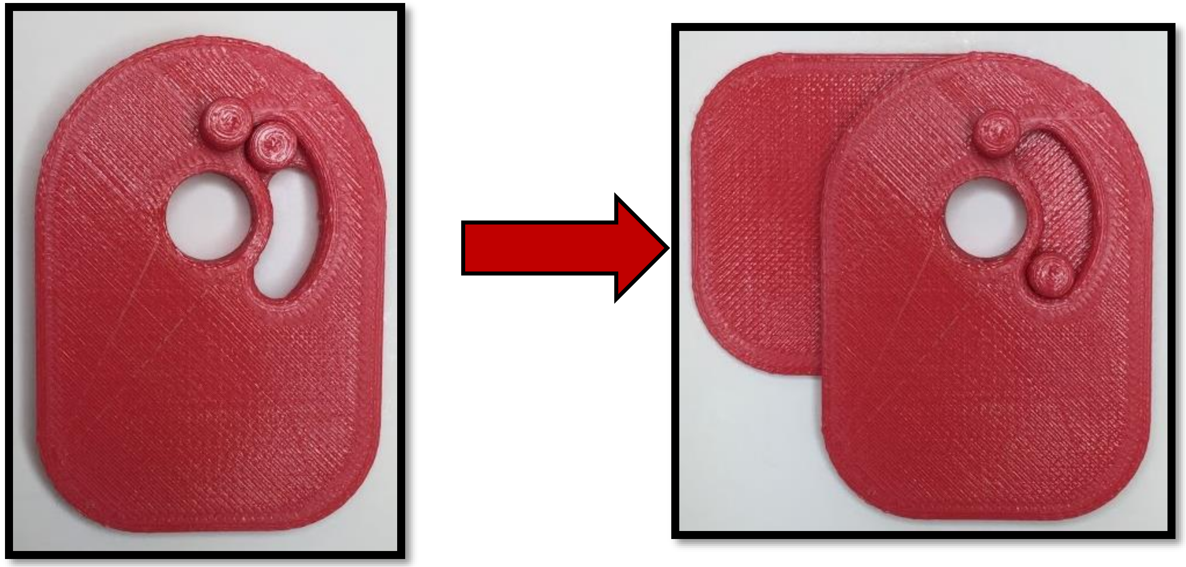


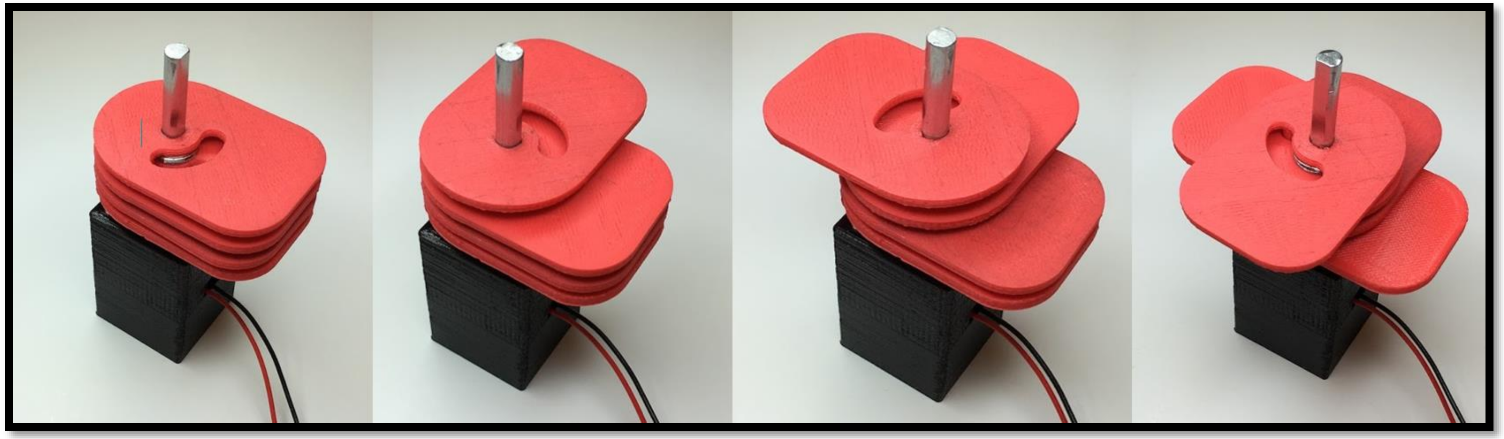
SAS Cont….

- Towing peg protrudes from bottom of support arm

- Slot for towing peg

- Each arm triggers the next arms deployment

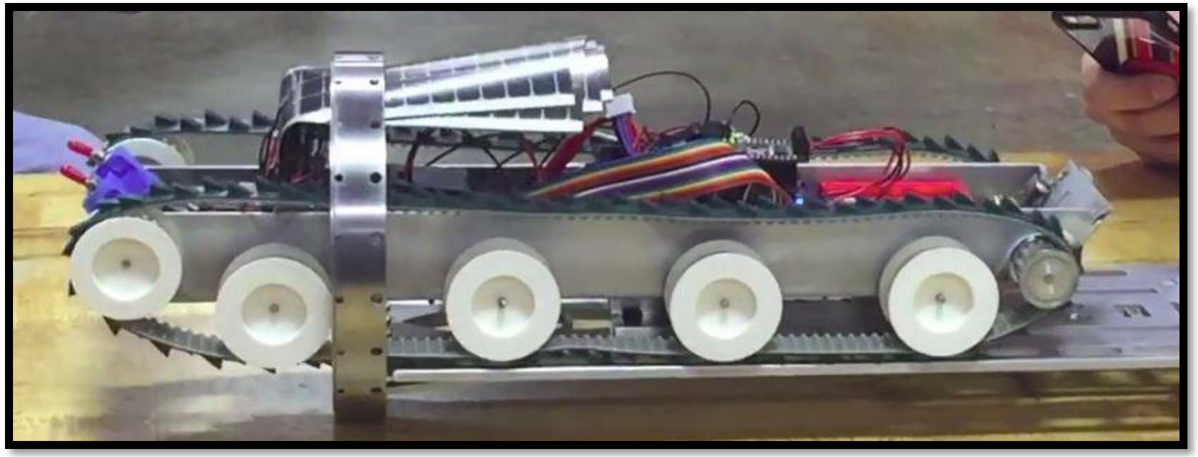


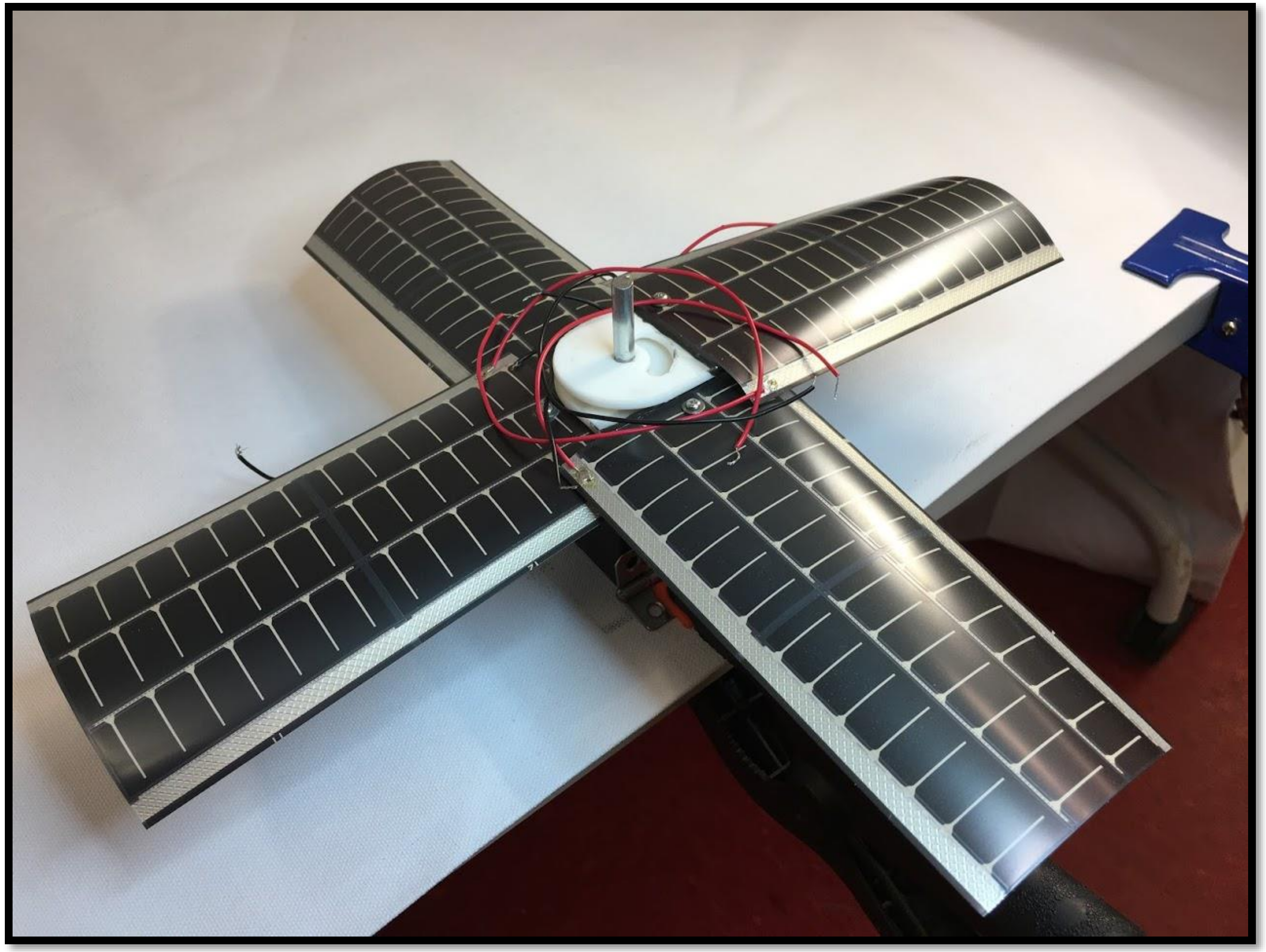


SAS Cont…

- Panels remain folded and bent backward in stowed configuration

- Panels unfold after reaching at least 5 feet

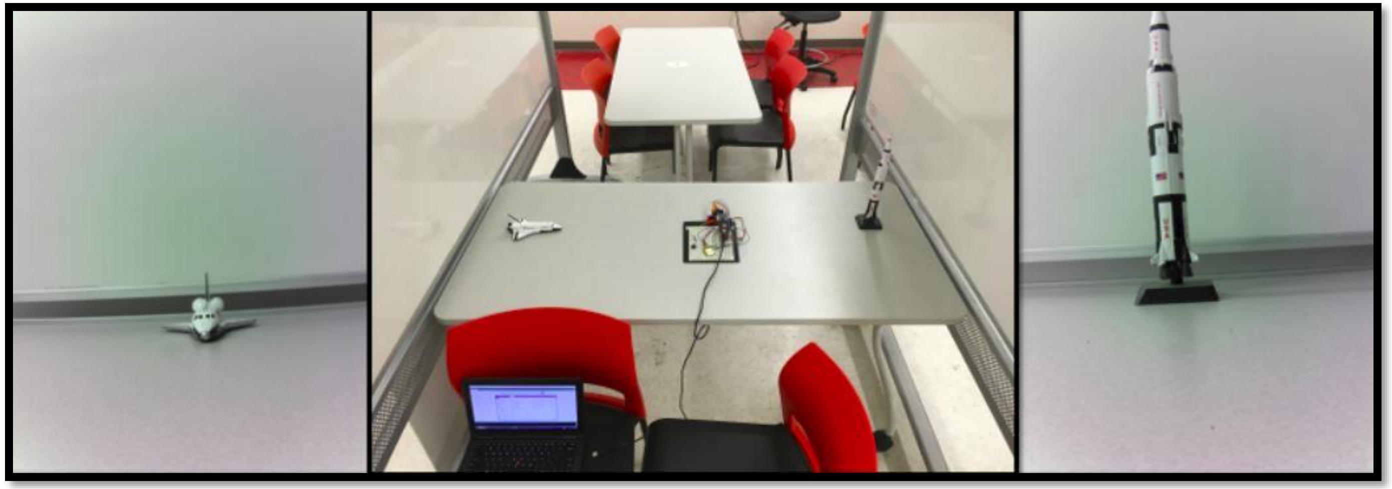


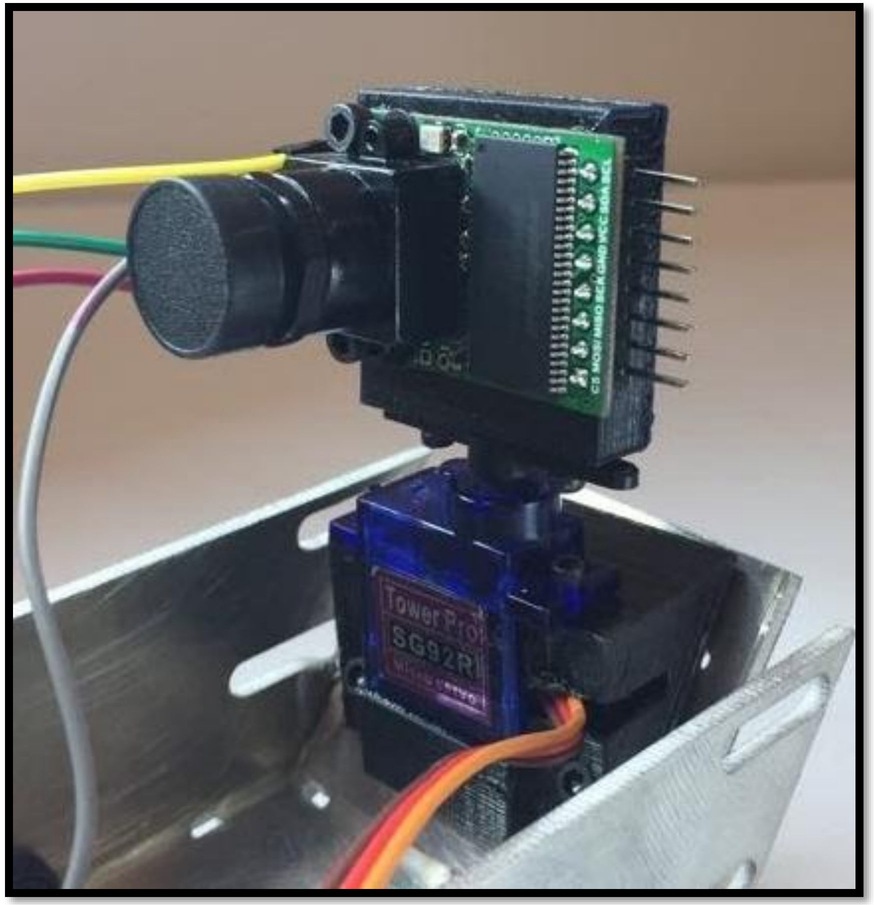


Surface Imaging System (SIS)

- Field of view increased to 180 degrees

- Solar trigger successfully tested for 3 panels





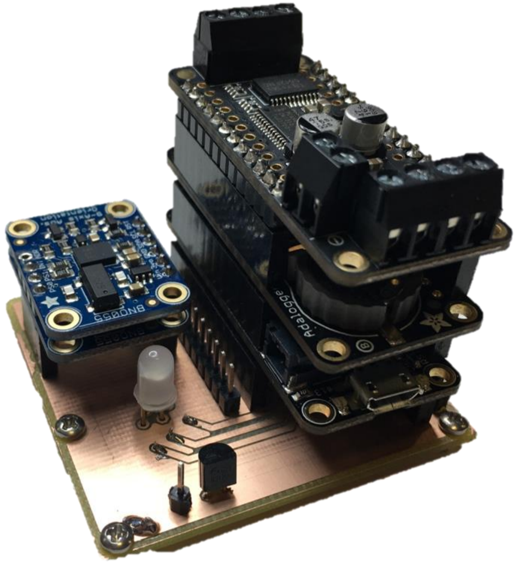
Surface Imaging System (SIS) Cont…

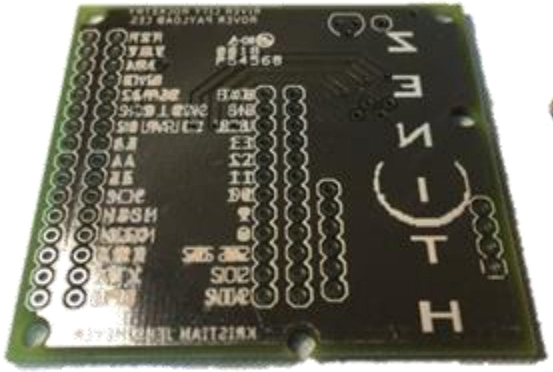
- Imaging rate of 7.4 images per minute at 1280 x 920

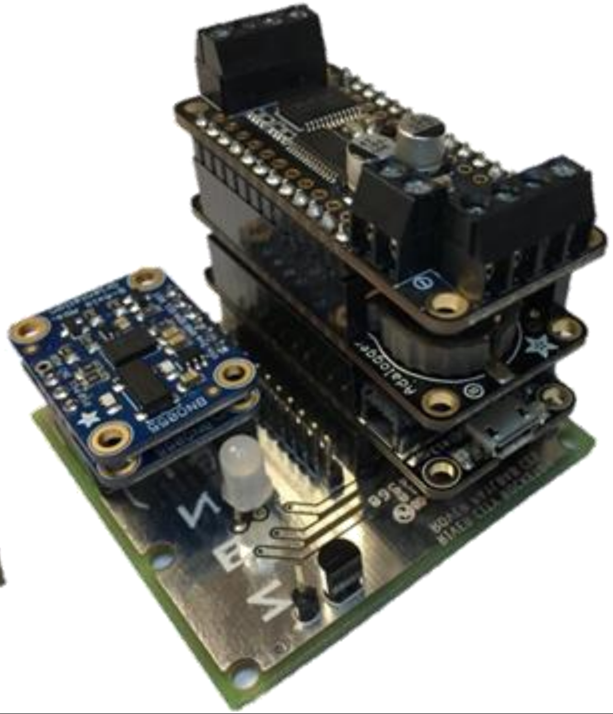
Pic #	Time Stamp (s)	Capture Time (s)	SaveTime (s)	Time Stamp Difference
1	0.00	0.174	3.095	
2	8.31	0.177	3.025	8.31
3	16.56	0.245	3.093	8.25
		●		
		●		
		●		
35	278.68	0.195	2.697	278.68
36	286.62	0.188	2.691	7.94
37	294.55	0.194	2.708	7.93
AVG.		**0.182**	**2.945**	**8.182**

Control Electronics System (CES)

- Printed Circuit Board prototype
- Electrical testing conducted
- Functional testing conducted
- Final PCB manufactured by Advanced Circuits







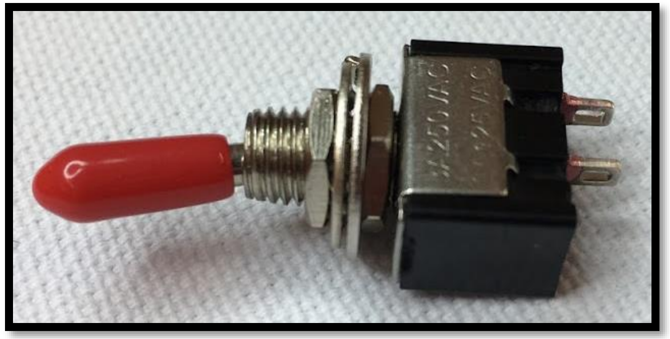
Control Electronics System (CES) Cont…

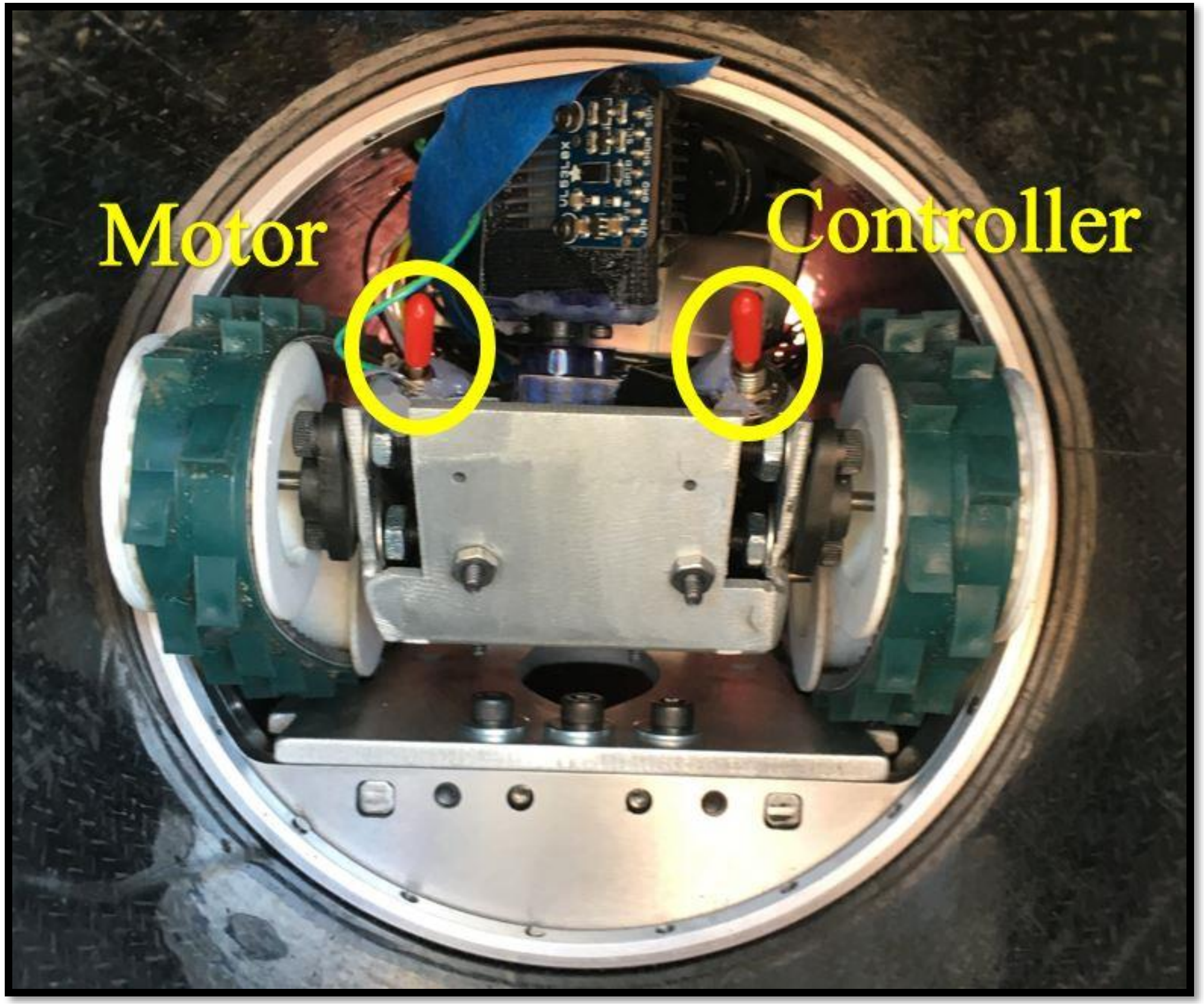
- Flight ready software has been completed
- Function based
- Robust safety measures

```
void loop(void)
{
  /************************************Begin Flight*
  DTSphase();
  bool orientation = OrientationCheck();
  if (!orientation)
    error(F("Orientation Check Failed"));
  UnlockRLM();
  ExitBay();
  DrivePhase();
  DeployArray();
  CameraPhase();
}
```

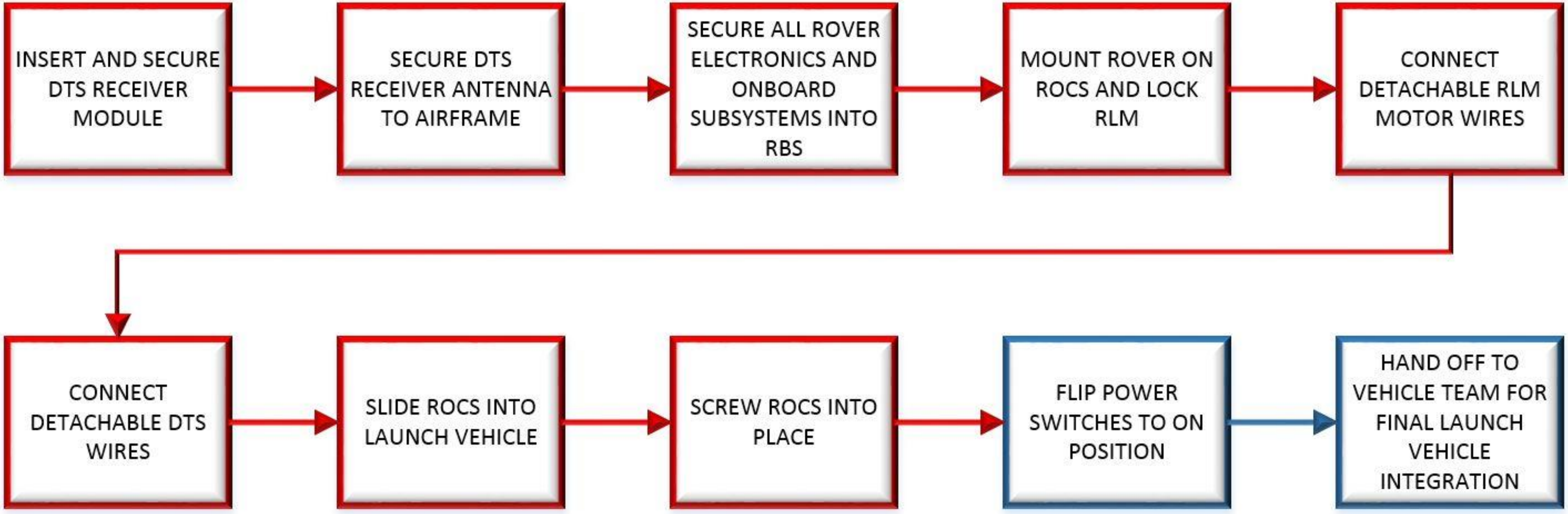
Control Electronics System (CES) Cont…

- Power switches added
- Maximize battery life





Integration

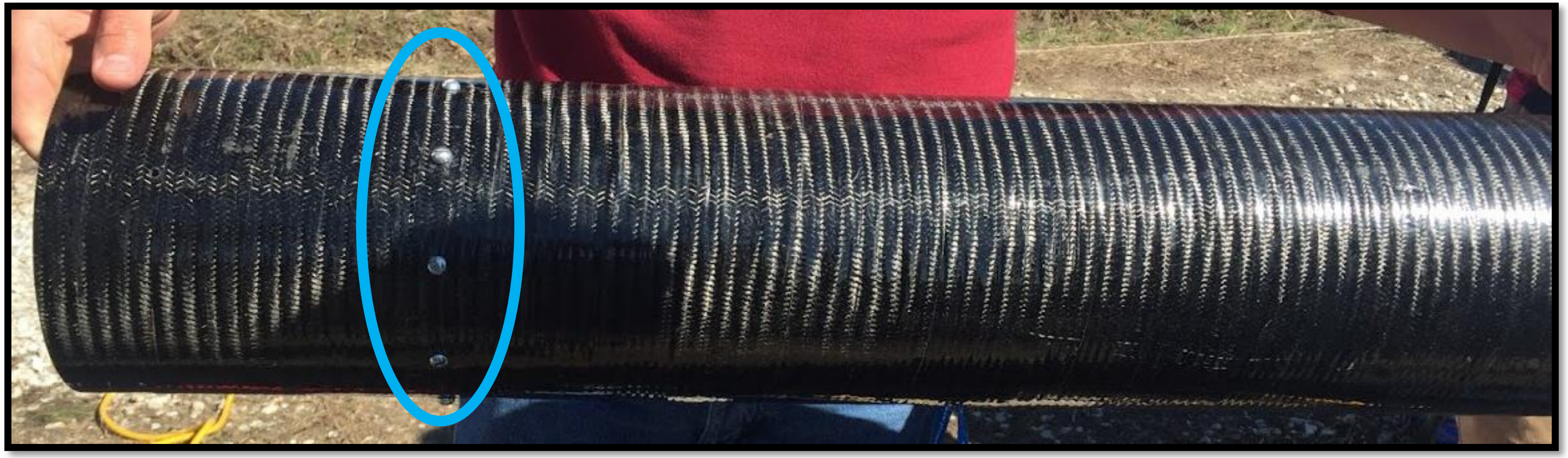


Integration

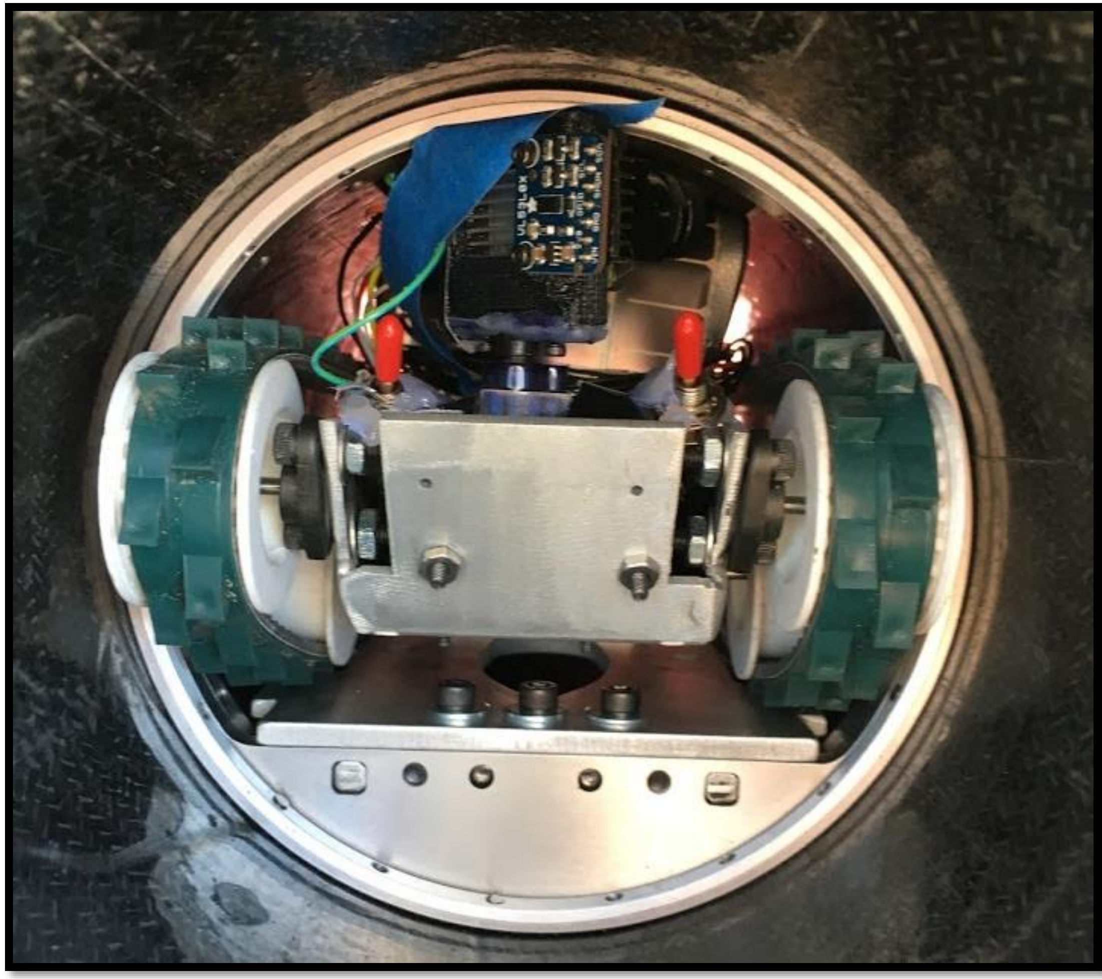
- Button head cap screws secure ROCS to internal structure of airframe

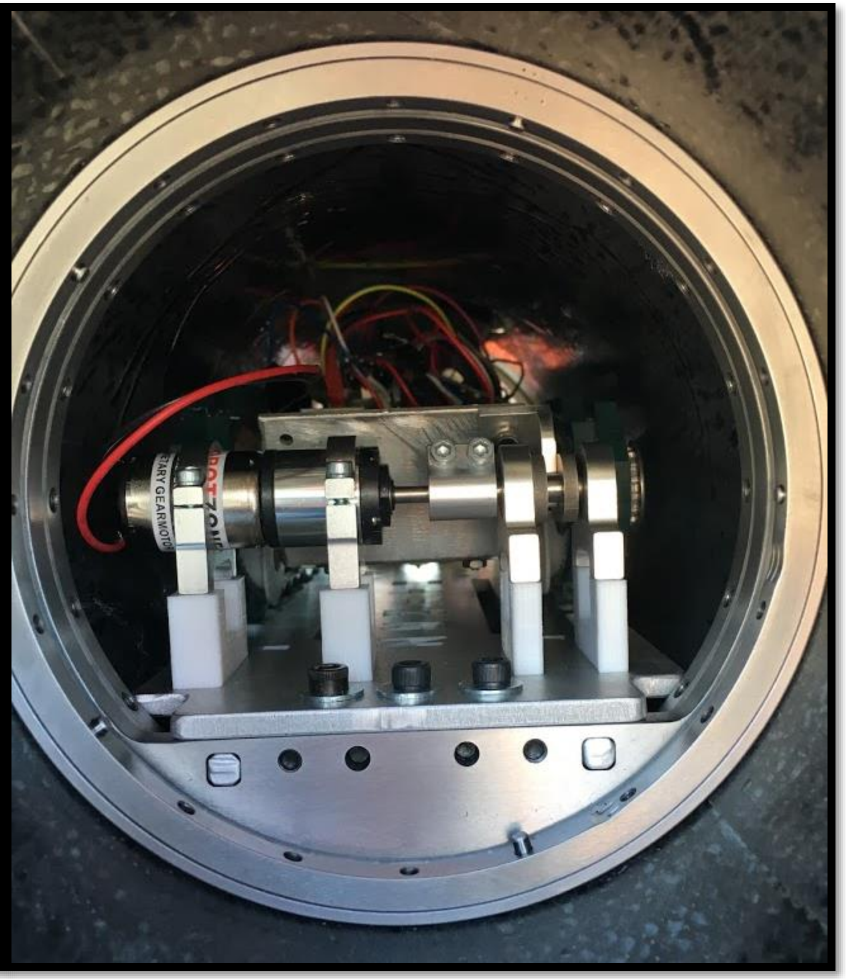
- Integration of ROCS tested at less than 5 minutes

- RLM Secures rover to the ROCS throughout the flight



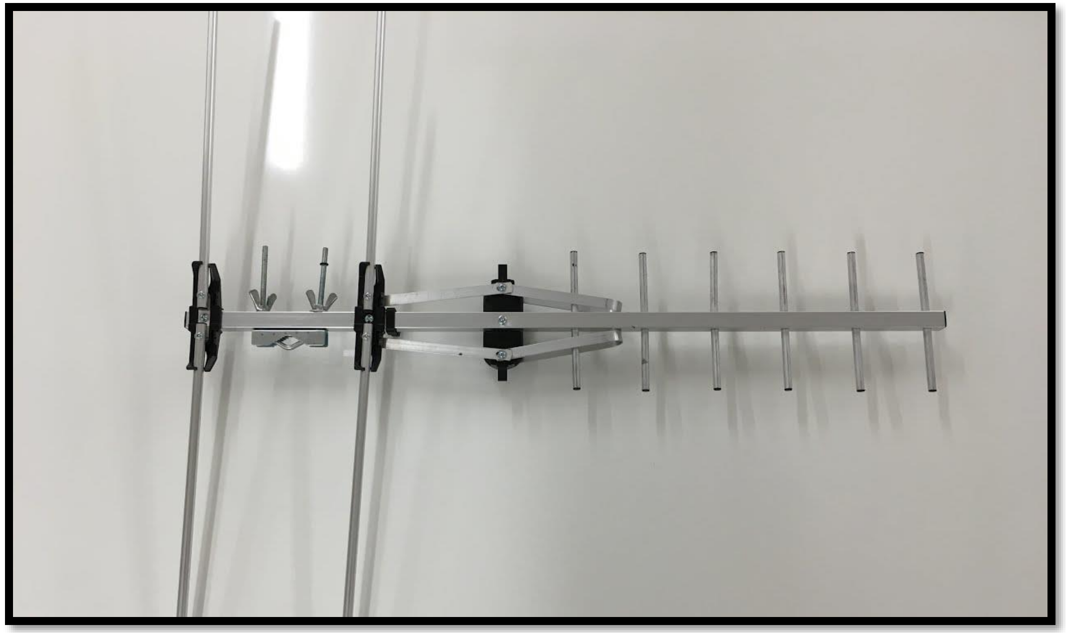
Integration





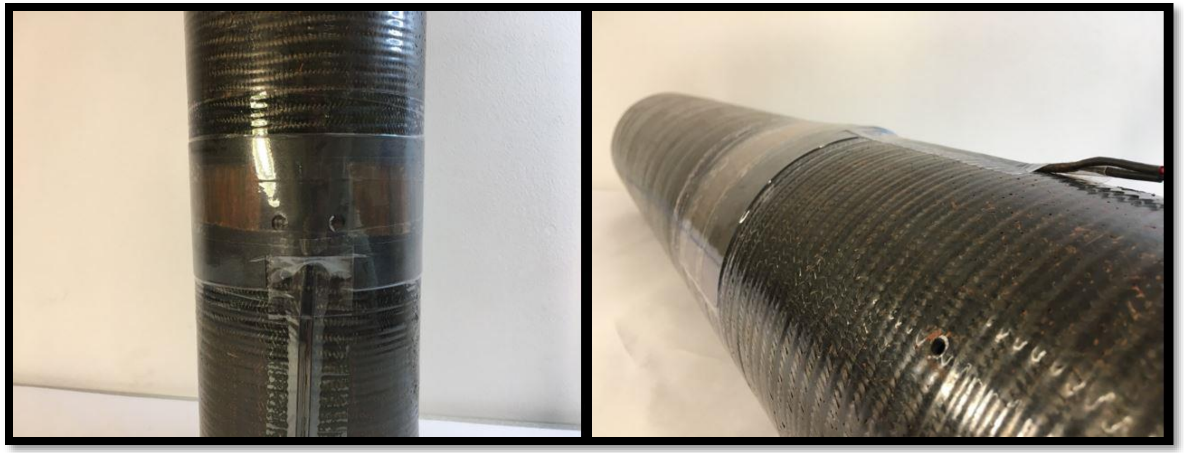
Interfaces with Ground Systems

Transmitter



433.4 MHz, 100 mW

Receiver



Requirement Verifications

- 33/41 requirements have been successfully verified
- All other requirements have been postponed and rescheduled

TEST 2					
TRIAL #	RULER DISTANCE (in.)	LIDAR DISTANCE (in.)	DEVIATION (in.)	%ERROR	ACCURACY
Short Range					+/- 0.128 in.
1	5.00	4.96	0.04	0.80%	
2	7.00	7.13	0.13	1.86%	
3	9.00	9.02	0.02	0.22%	
4	11.00	11.18	0.18	1.64%	
5	13.00	13.27	0.27	2.08%	
Long Range					+/- 1.574 in.
6	40.00	41.46	1.46	3.65%	
7	38.00	39.72	1.72	4.53%	
8	36.00	37.56	1.56	4.33%	
9	34.00	35.67	1.67	4.91%	
10	32.00	33.46	1.46	4.56%	

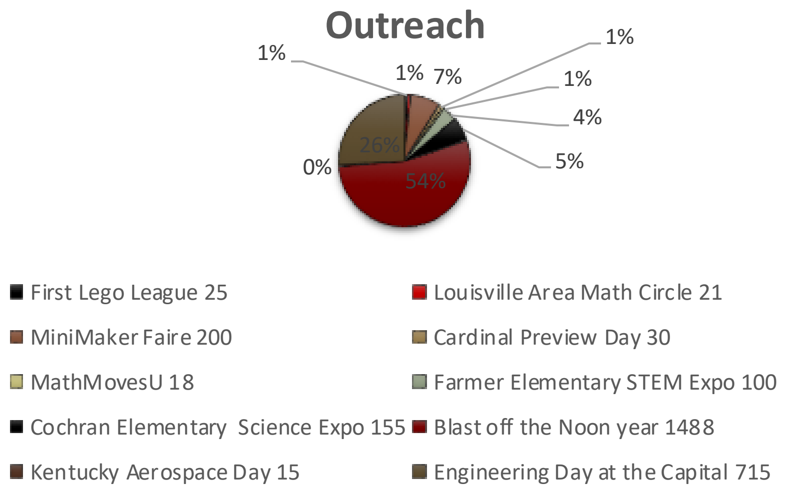
Figure: Example verification data

FRR 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
Kentucky Aerospace Day	15
Engineering Day at the Capital	715
Engineering Expo with KY Science Center	550
Engineering Expo	375
Total	3692

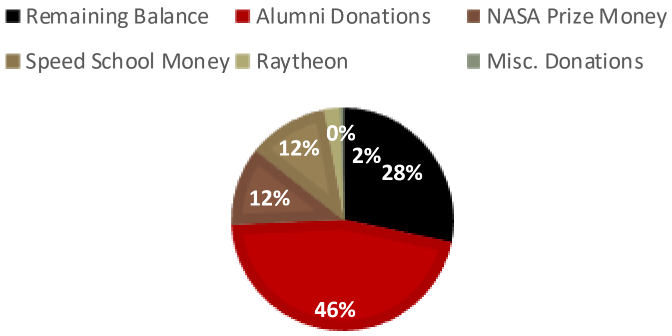


FRR Presentation Agenda

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

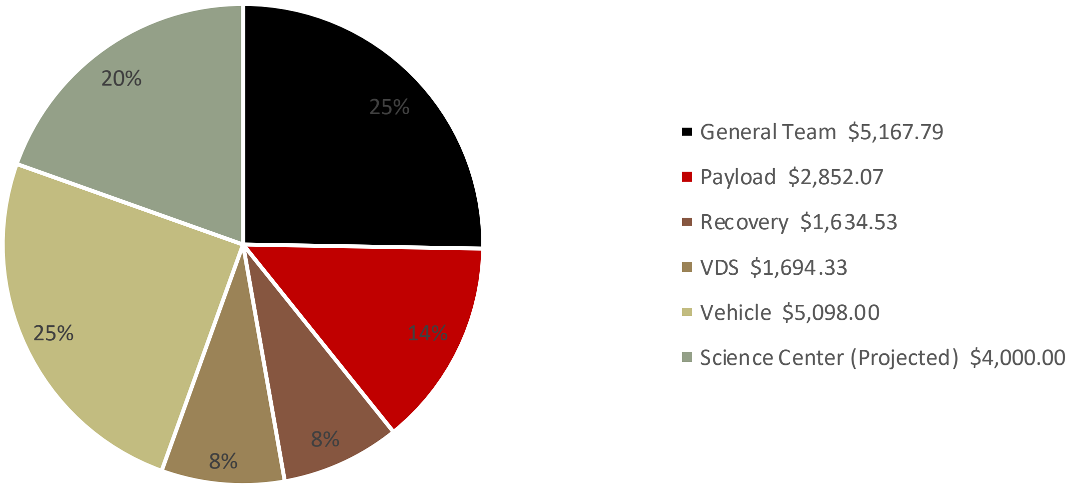
Budget

INCOME



Source	Amount
Remaining Balance	$ 12,300.00
Alumni Donations	$ 20,000.00
NASA Prize Money	$ 5,000.00
Speed School Money	$ 5,000.00
Raytheon	$ 1,000.00
Misc. Donations	$ 200.00
Fundraiser	
Total	$ 43,500.00

Expense Report



Budget Results			
Category	Budgetted Cost	Real Cost	Percent Difference
General Team	$ (17,803.41)	$ (5,167.79)	244.51%
Payload	$ (4,406.80)	$ (2,907.95)	51.54%
Recovery	$ (1,453.00)	$ (1,634.53)	-11.11%
VDS	$ (2,268.56)	$ (1,694.33)	33.89%
Vehicle	$ (6,542.18)	$ (5,310.51)	23.19%
Total	$ (32,473.95)	$ (16,715.11)	94.28%