



UC Berkeley Space Technologies and Rocketry Critical Design Review Presentation

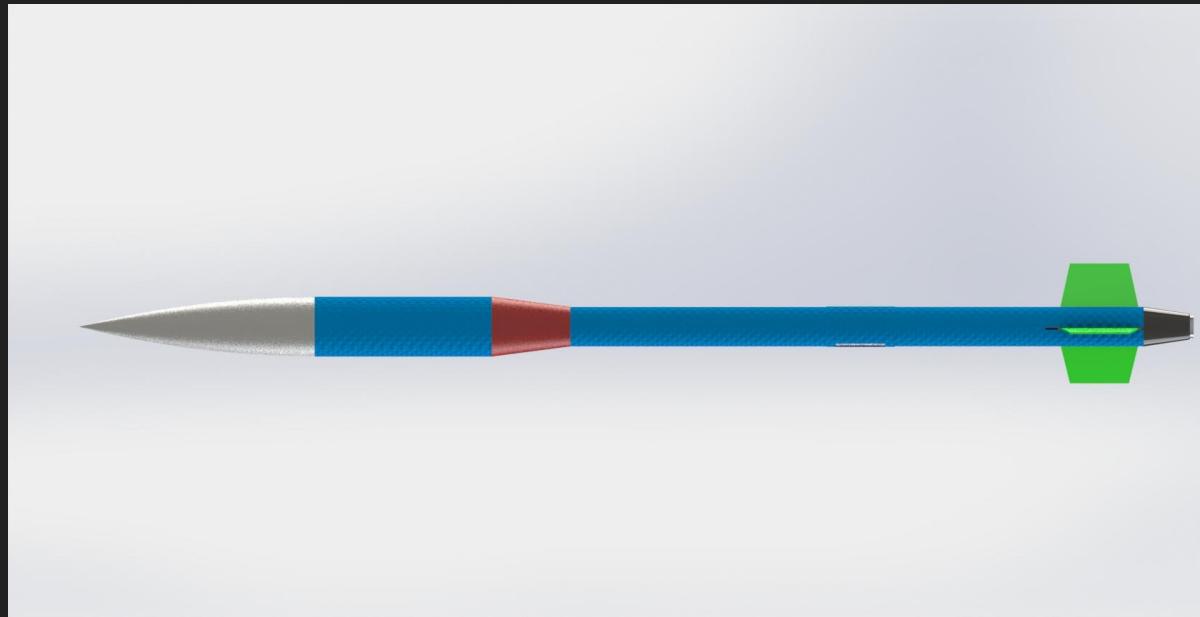
Agenda

- Airframe
- Propulsion
- Recovery
- Payload
- Safety
- Outreach
- Project Plan



Airframe

- **Length:** 9.42 ft
- **Weight:** 27.31 lbs
- **Apogee:** 5328 ft
- **Max Velocity:** Mach 0.54
- **Max Accel:** 282 ft/s²
- **Stability:** 2.37 cal
- **Launch Rail:** 12' 1515 rail



Airframe cont.

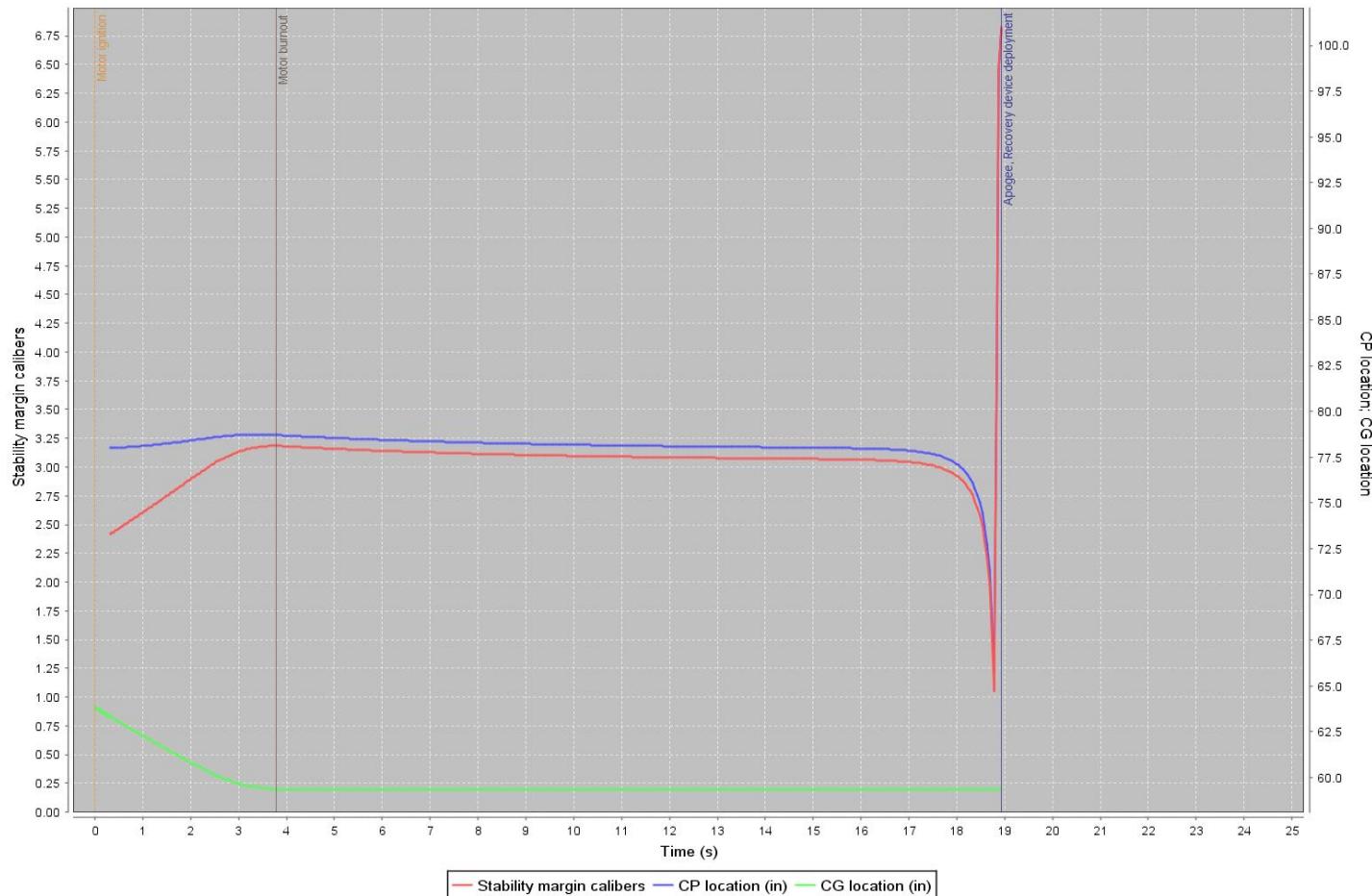
- Weights (Wet Total: 27.31 lbs. Dry Total: 22.38 lbs.)
 - Electrical - 2 lbs. (allocated) Nose Cone
 - Payload - 6 lbs. (allocated) Payload Tube
 - Recovery -
 - Recovery Tube
 - 0.811 lbs. Main Parachute
 - 0.134 lbs. Drogue Parachute
 - 0.623 lbs. Shock Cord
 - + ~ $\frac{1}{3}$ lb. misc
 - Booster +
 - 2 lbs Avionics
 - Propulsion - 4.9 lbs. (Wet only) Booster Section
 - Airframe - Rest of it Throughout the Rocket

Airframe cont.

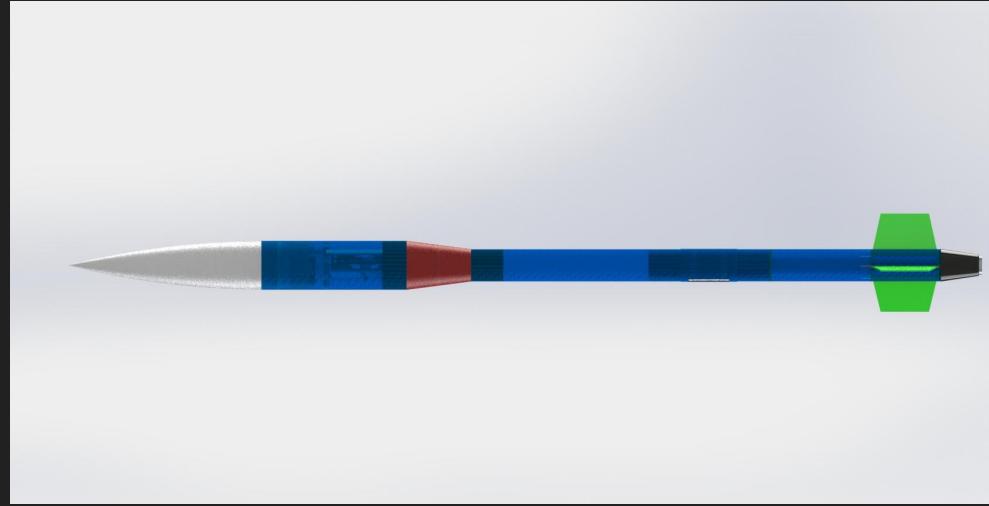
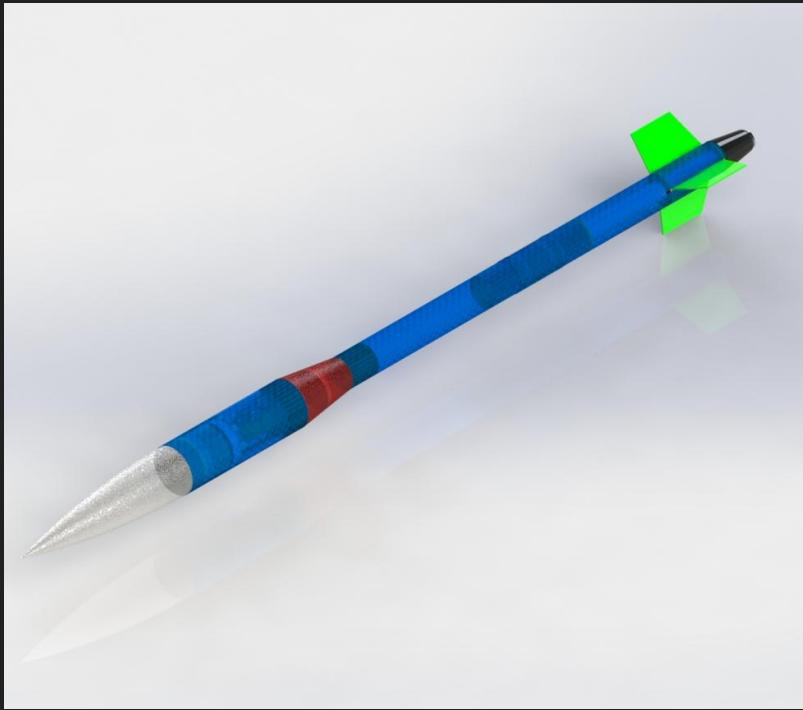
- Lengths (Total: 9.42 ft)
 - Nose Cone - 24 in. (4:1 Length:Diameter)
 - Payload/Electronics can use
 - Payload Tube - 18 in.
 - Payload - Transition Coupler - 3 in.
 - Transition - 8 in.
 - 6 - 4 in. change.
 - Transition - Recovery coupler - 4 in.
 - Recovery Tube - 26 in.
 - Recovery - Av Bay Coupler - 15 in. (Runs through the entire Av Bay tube)
 - Av Bay Tube - 7 in.
 - Booster - 26 in.
 - Boat Tail - 4.7 in.

Stability Static Margin Diagram

Stability vs. time



Airframe cont.



Airframe Tests

- Transition/Boattail Impact Test
 - To ensure that pieces are sufficiently strong in the event of landing on the specific piece
 - Will be done by dropping the pieces individually from a height that will allow it to experience the impulse that the rocket would undergo under various conditions
 - Will be determined successful or unsuccessful through visual inspection
 - This test is useful to ensure reusability



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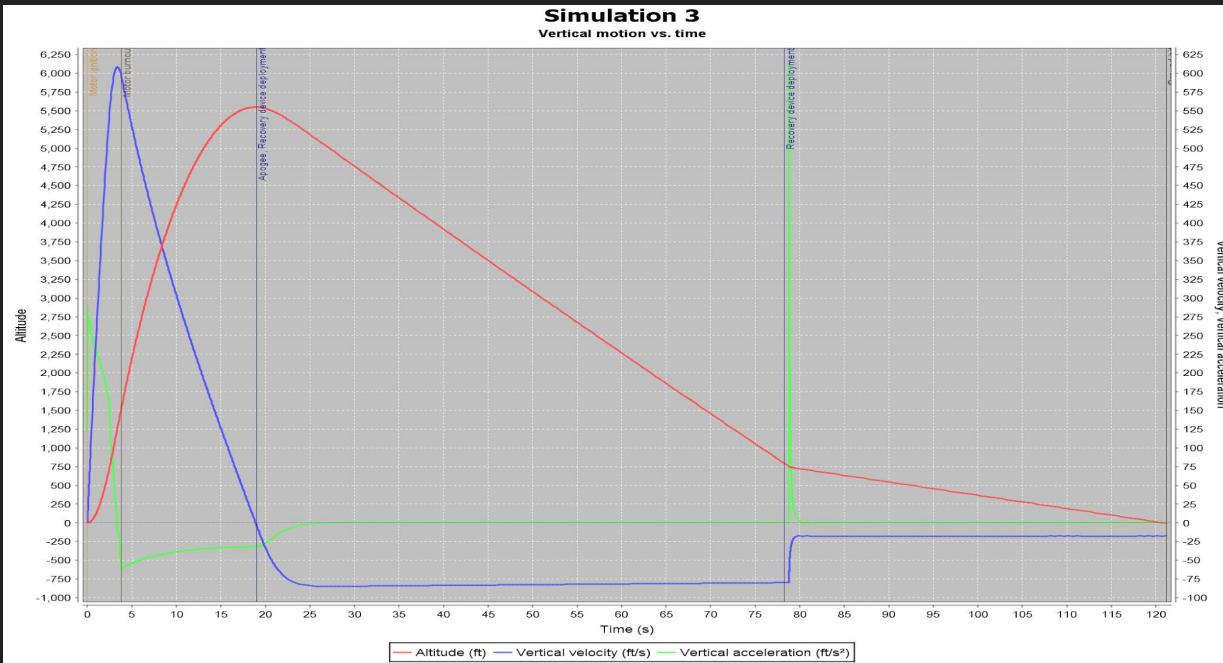
Propulsion

- Projected apogee: ~5328 ft
- Max velocity: Mach 0.54
- Max acceleration: 8.83 Gs
- Rail exit velocity: 82.8 ft/s
- Average thrust-to-weight ratio: 6.03

Optimum delay	Max. velocity	Max. acceleration	Time to apogee	Flight time	Ground hit velocity
15.2 s	609 ft/s	288 ft/s ²	18.9 s	121 s	17.7 ft/s

Propulsion

- Final motor choice - Cesaroni L730
- Flight curves

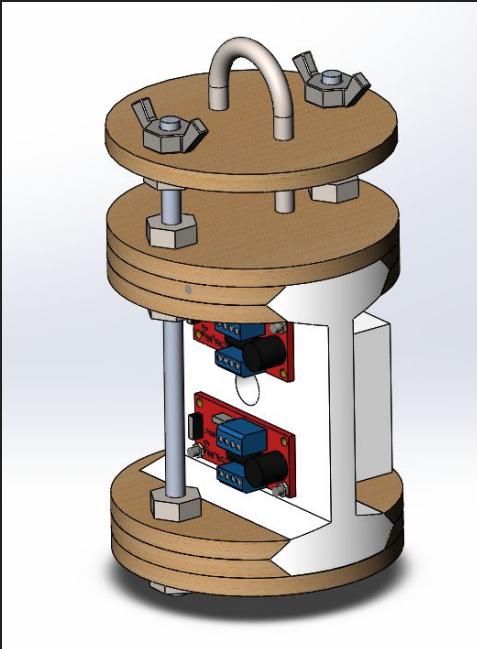


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Recovery

AVIONICS BAY



DEPLOYMENT SYSTEM



Recovery - General Specs

Parachute Sizes

- Drogue Chute: 24" Elliptical parachute from Fruity Chutes; the red and white one
- Main Chute: 72" Toroidal parachute from Fruity Chutes; the orange and black one

Deployment System

- Same side Dual Deployment
- L2 Tender Descenders
- Black Powder

Kinetic Energy Estimates

- After Drogue:
 - Nosecone - 733ft-lbs
 - Booster - 700ft-lbs
- After Main:
 - Nosecone - 51.63ft-lbs
 - Booster - 49.27ft-lbs

Velocity Estimates

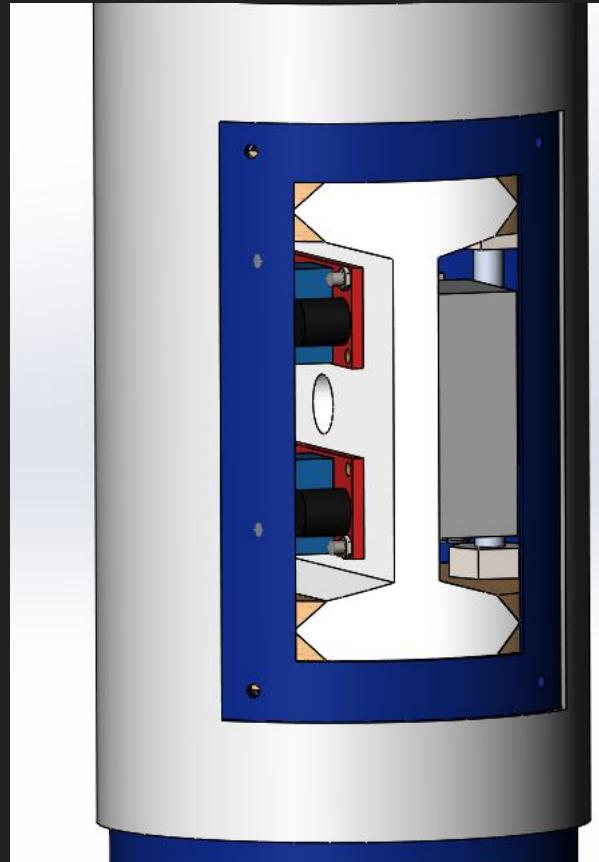
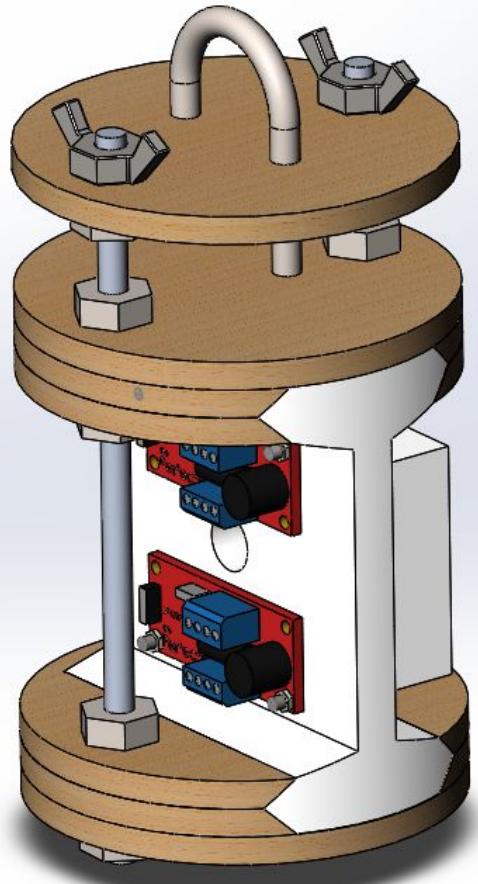
- At drogue deployment: 0ft/s
- At main deployment: 67.04ft/s
- Terminal after main: 17.29ft/s



Recovery - SLED DESIGN

- Design focus on accessibility and compactness
- Went through several iterations
- Altimeters and batteries mounted on either side
- Houses 2 PerfectFlite Stratologger CFs & 2 9V batteries
- Sled slot fits into pre-cut rails in bulkhead
- Made of 3D printed plastic

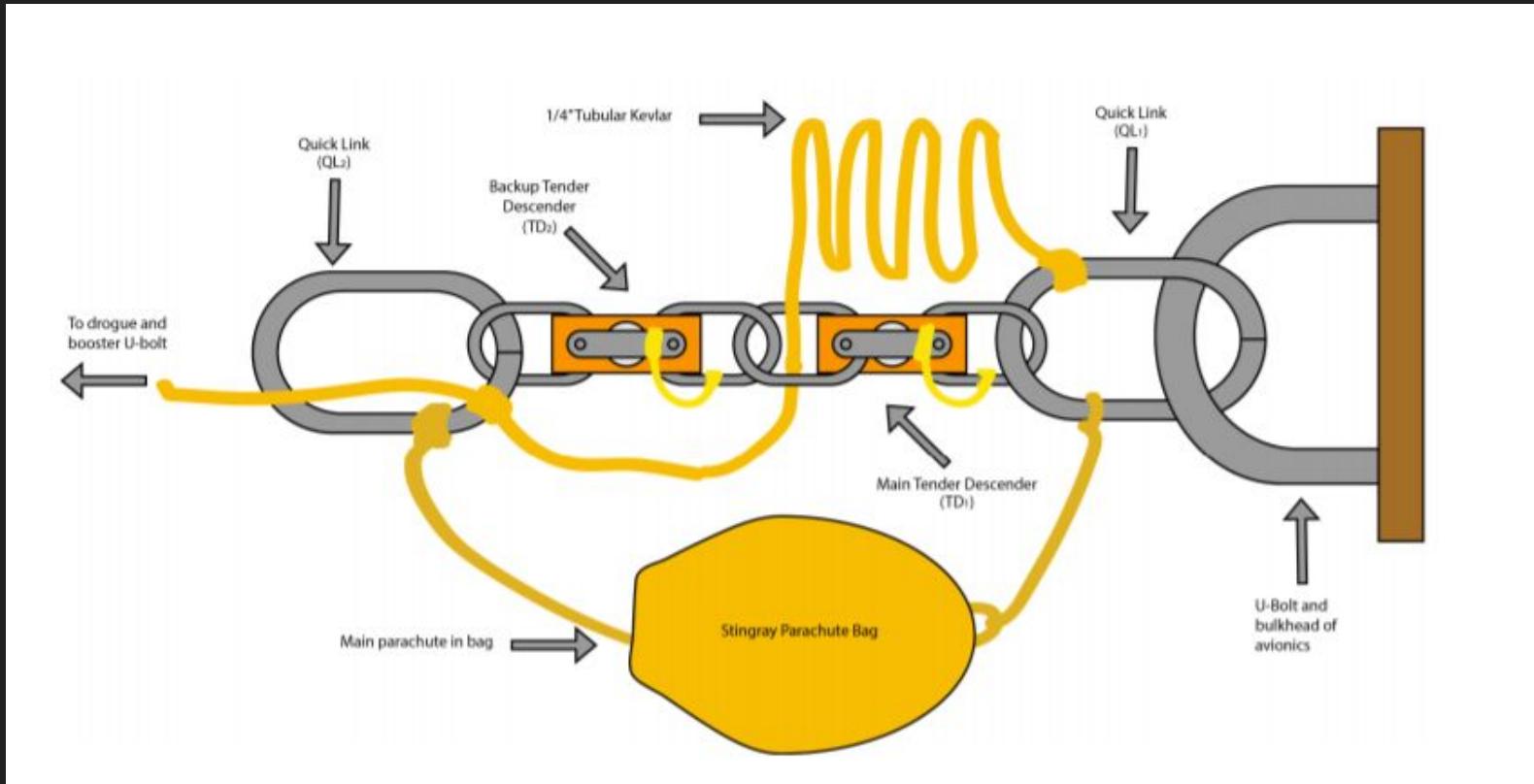




Recovery - DEPLOYMENT SYSTEM

- Using same deployment system as URSA Major
 - Parachutes will be in the front of the Av-bay
- Black Powder Ejection Charges w/ e-matches
- Redundancy

Recovery - DEPLOYMENT SYSTEM



Recovery - DRIFT CALCULATIONS

Current descent time: 117s

Wind Speed (mph)	Drift (ft)
5	858
10	1716
15	2574
20	3432

Recovery Tests

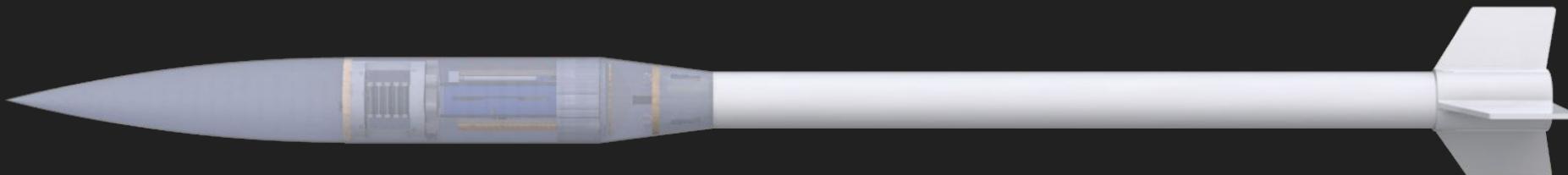
- Static Load Test
- Ground Deployment Test
- Electronics Test
 - To verify Handbook Req. 2.10

Agenda

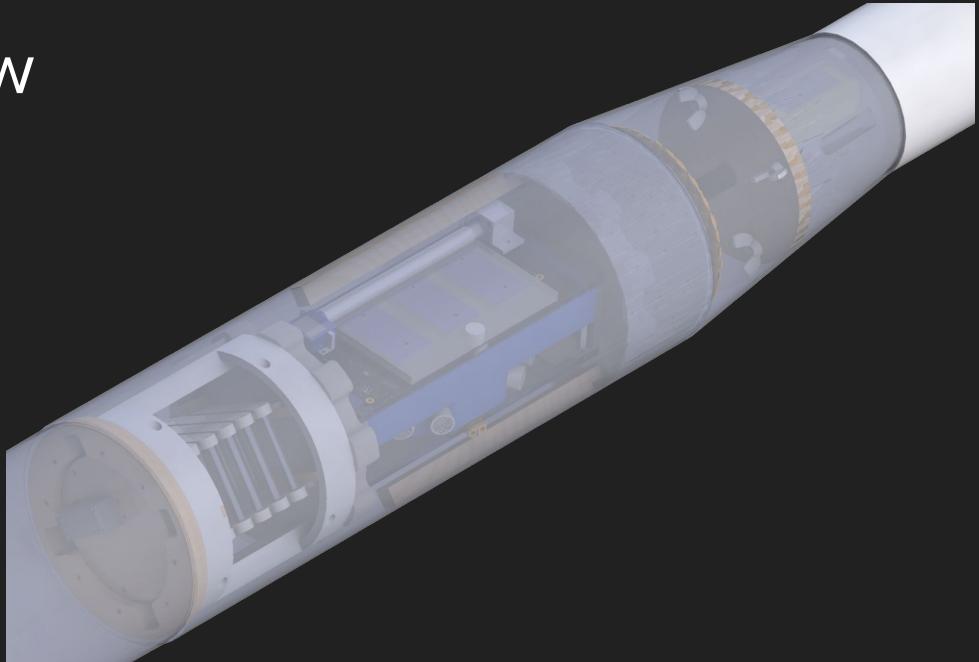
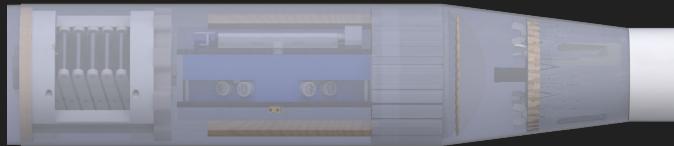
- Airframe
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- Recovery
- **Payload**
- Safety
- Outreach
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Payload - Brief Overview

- After vehicle lands, airframe is separated by a radio-triggered gas expansion deployment system (black powder)
- Rover pushed out of airframe by a scissor-lift ejection system
- Rover detects ejection and drives away from airframe
 - Distance verification using encoders + inertial measurement unit (accelerometer + gyroscope) data

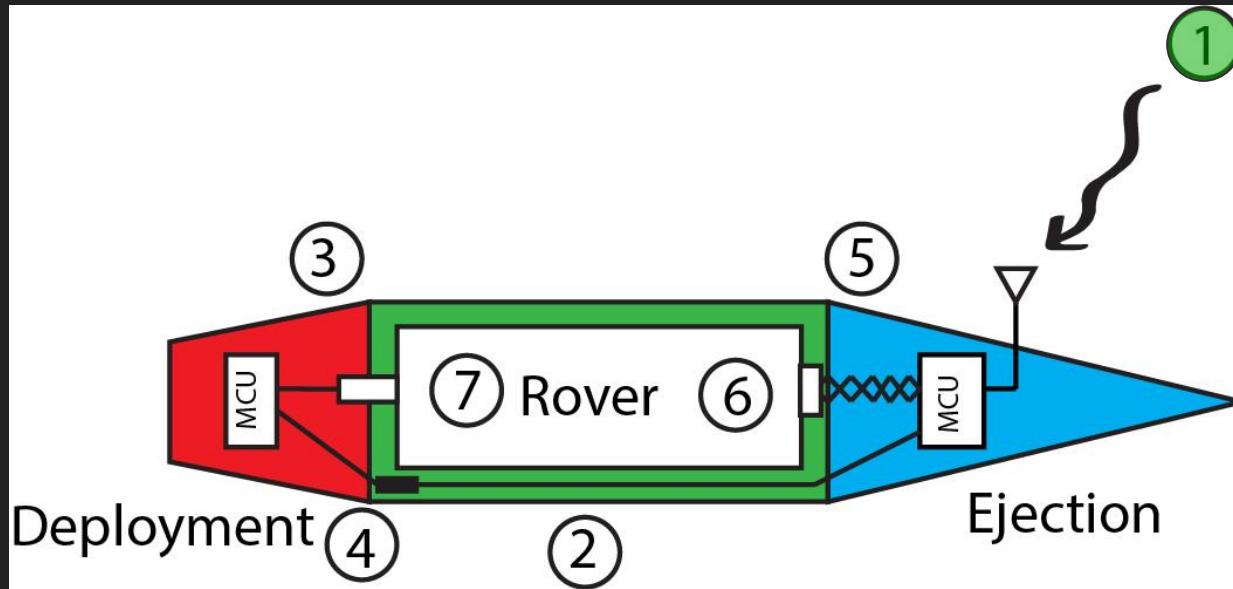


Payload - Brief Overview



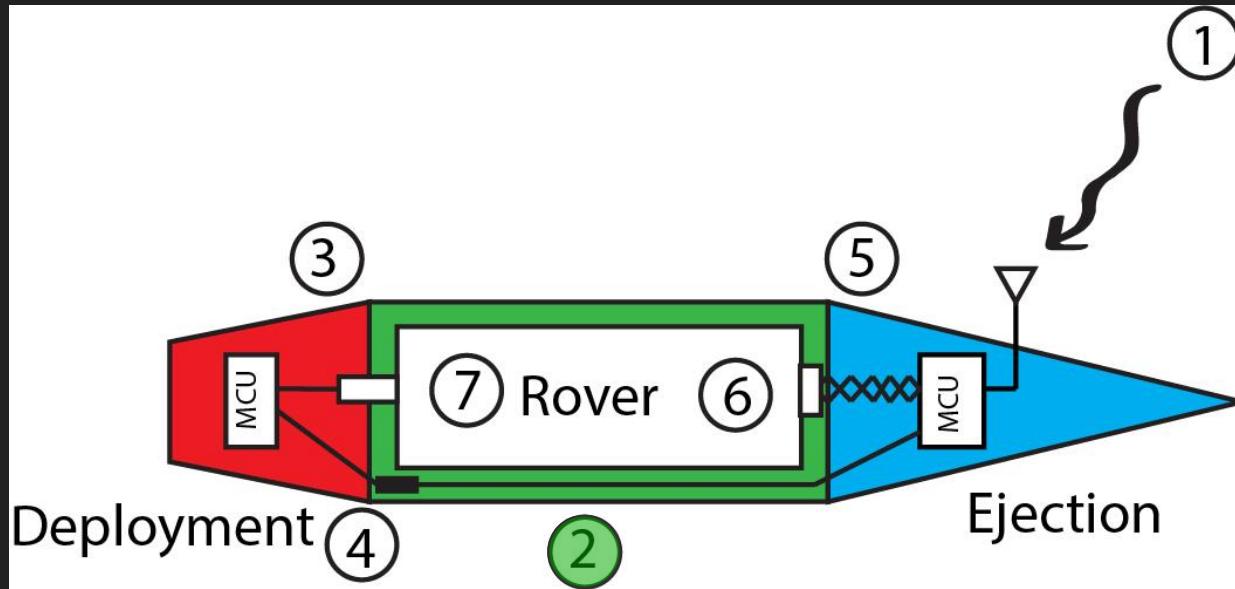
- Deployment
 - Black powder separation system
- Ejection
 - Scissor lift shove-out
- Movement
 - Rectangular two-wheeled rover capable of obstacle avoidance and traversing rough terrain
- Solar
 - Deployment system and panel functionality verification

Payload - Deployment/Ejection Overview



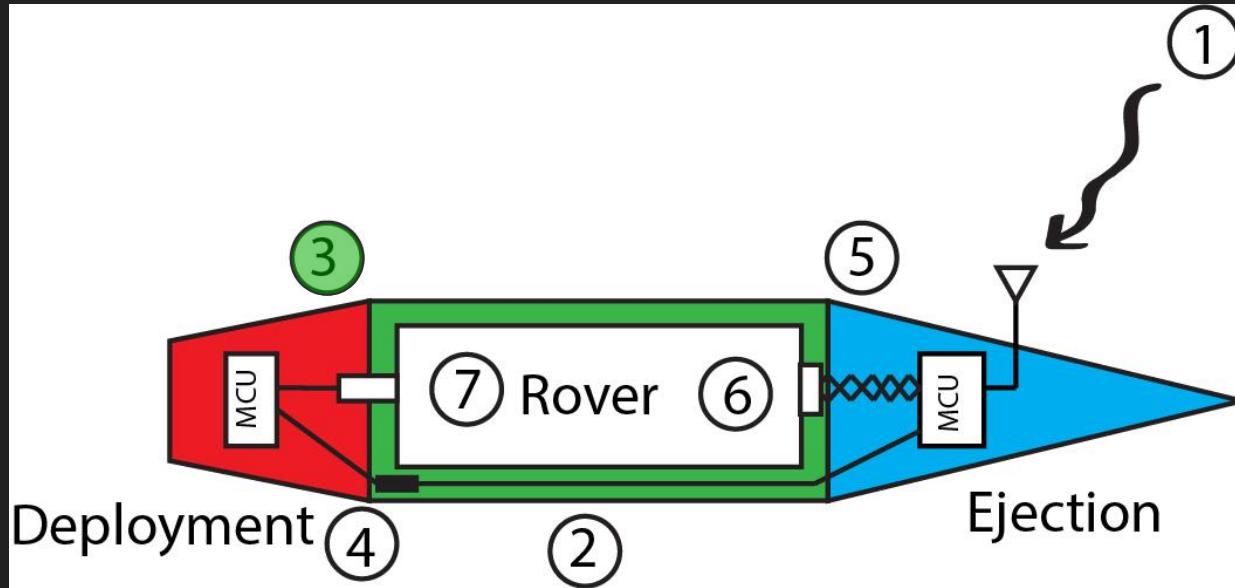
1. Ejection computer receives remote signal to begin payload process.

Payload - Deployment/Ejection Overview



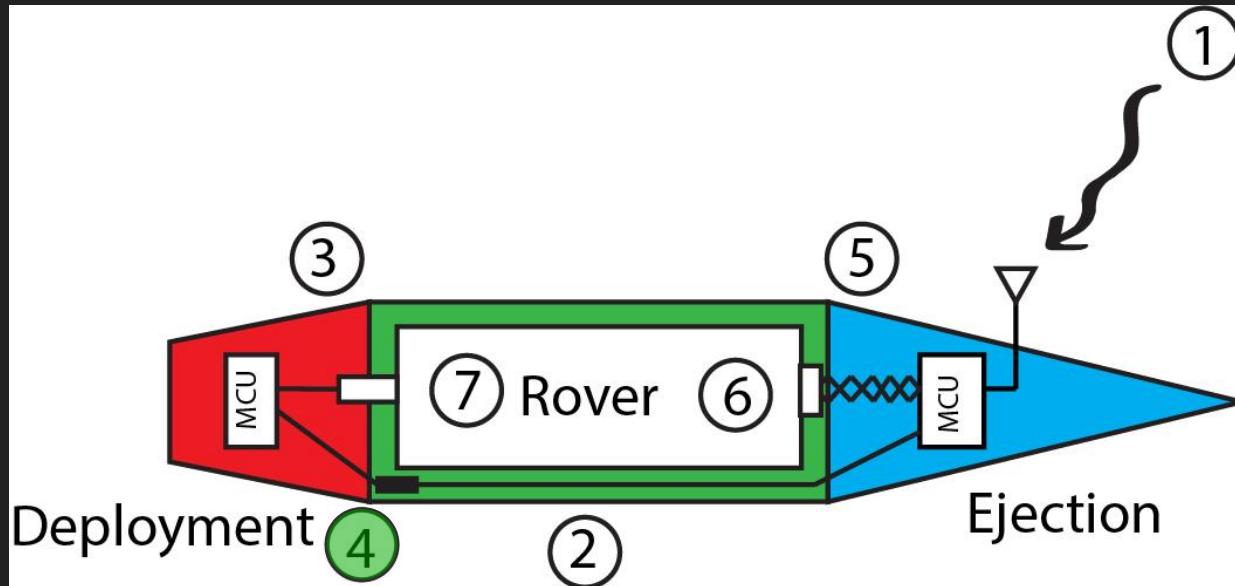
2. Ejection computer sends a signal via breakaway wires to deployment computer.

Payload - Deployment/Ejection Overview



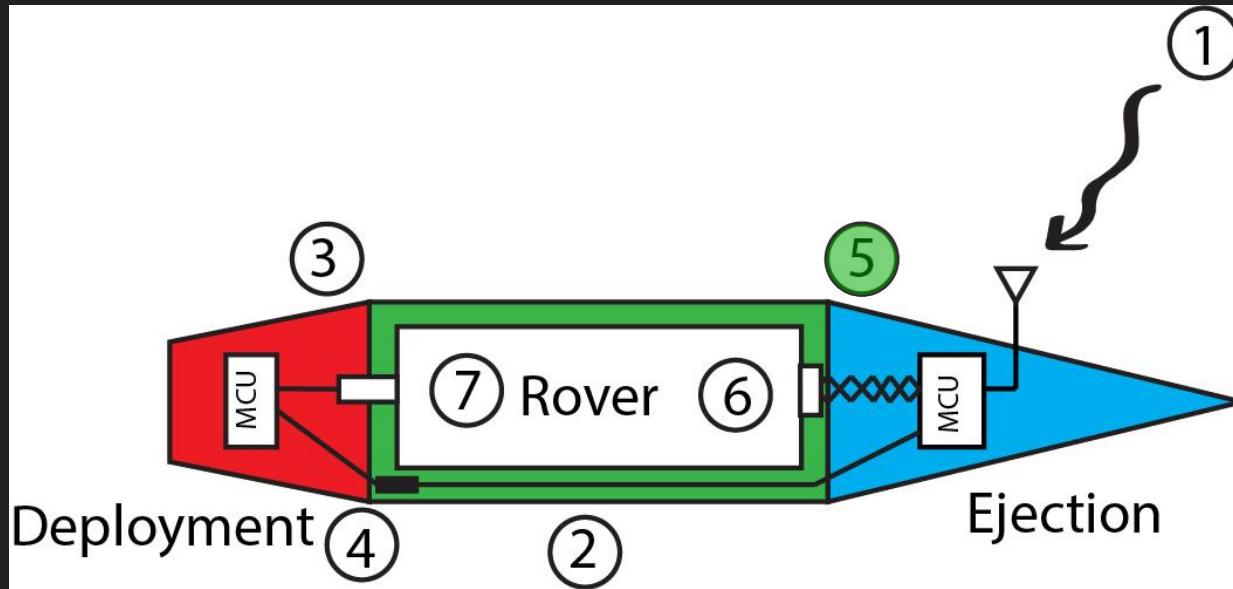
3. Deployment computer initiates black powder deployment.

Payload - Deployment/Ejection Overview



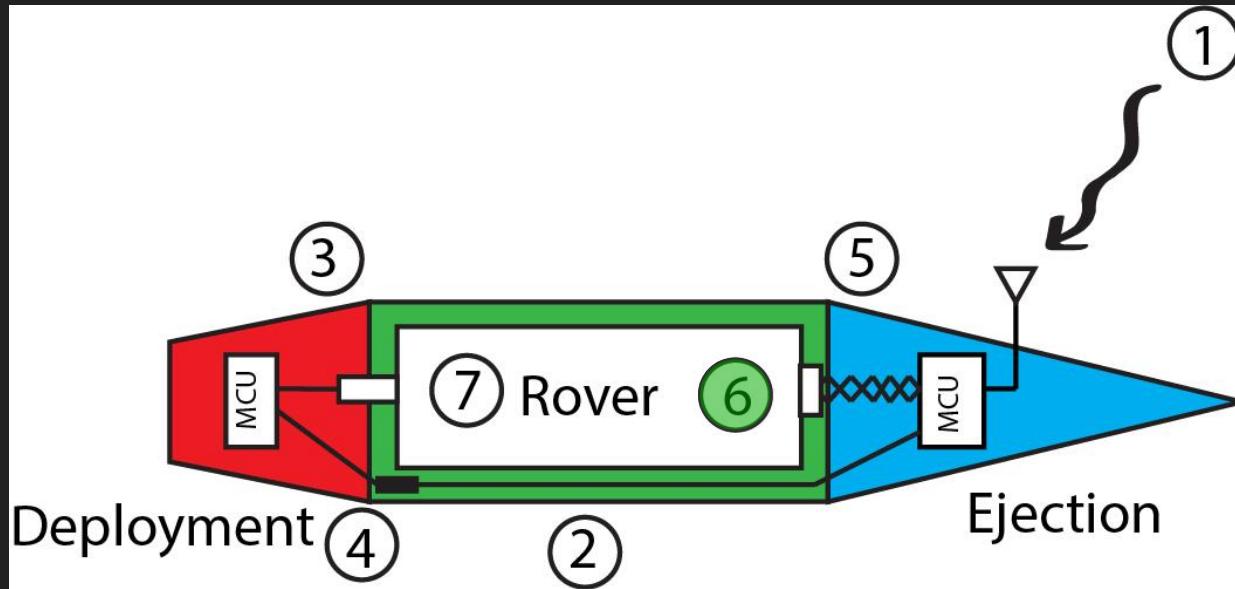
4. Deployment process disconnects breakaway wires.

Payload - Deployment/Ejection Overview



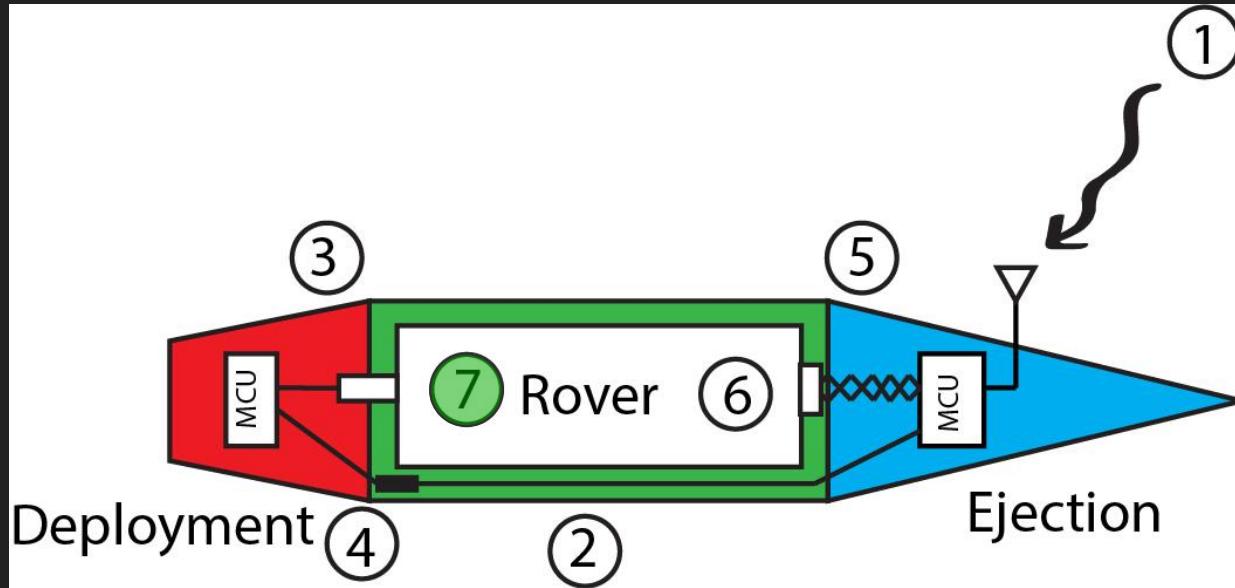
5. Ejection computer detects disconnection of breakaway wires and initiates rover ejection.

Payload - Deployment/Ejection Overview



6. Rover detects successful ejection by monitoring a switch, accelerometer, and gyroscope.

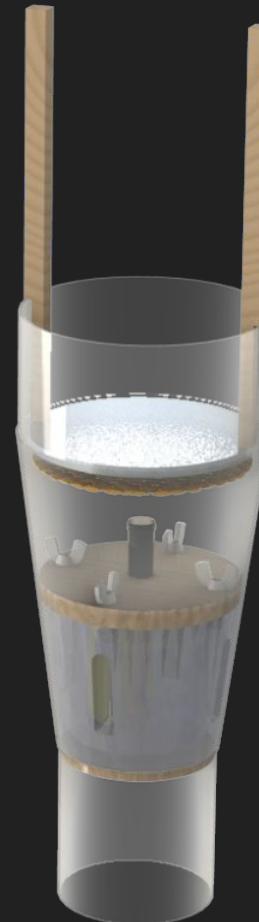
Payload - Deployment/Ejection Overview



7. Rover begins moving.

Payload - Deployment

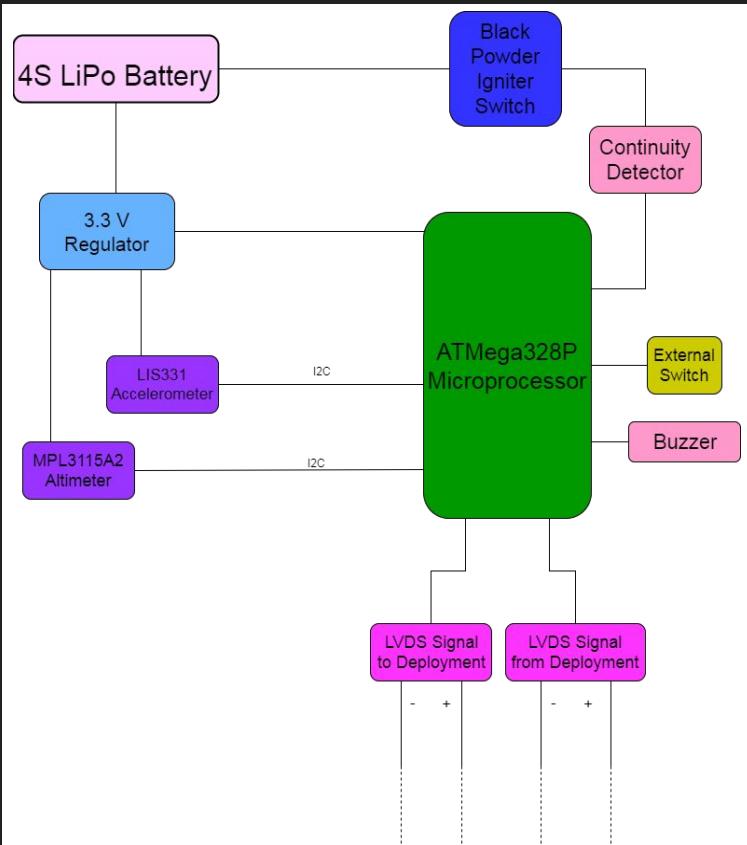
- Black powder ejection system
 - 1.5g Powder Charges
- Nomex Shielding for heat protection
- Elect. Bay separate from Ignition Chamber with electronics mounted to sled
- Breakaway wire connector from ejection electronics
- Weight estimate:
 - Currently ~1.4 lb



Payload - Deployment: Separation

- Verification of successful landing using altimeter and accelerometer data
 - Waits for confirmation from main flight computer prior to deployment
 - Data is transferred through breakaway wire connection
- Deployment frame section is self contained
 - Section of airframe contains logic board, battery, and all hardware necessary for deployment
 - Deployment section receives command from main flight computer to deploy. Electrical charge sent to E-Match to ignite contained Black Powder charge to shear airframe pins
- Separation confirmed with main flight computer
 - The rover and the main flight computer will be made aware of a successful separation through the disconnection of the breakaway wire connection.
- Ejection handoff

Deployment Electronics Board



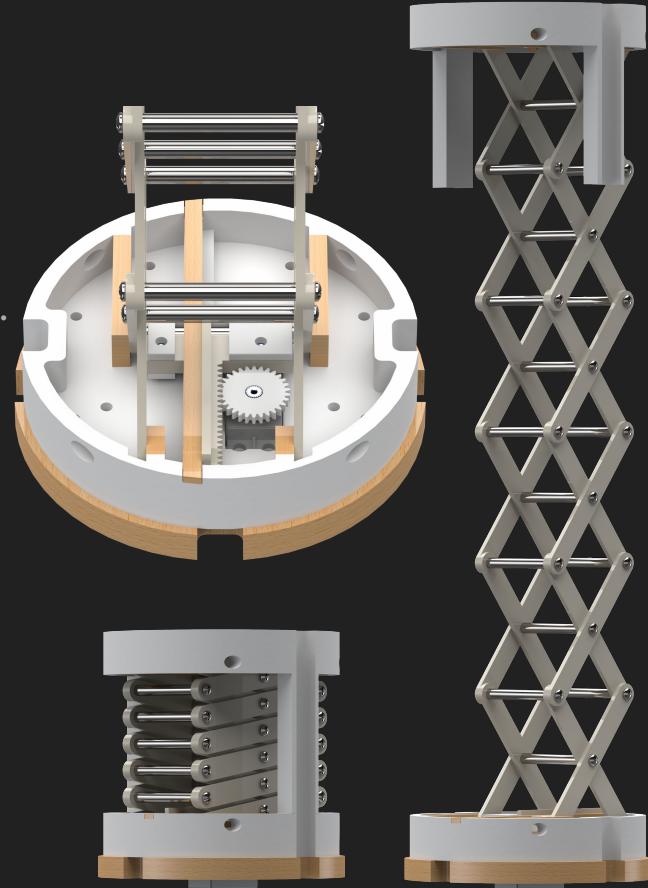
- 4S LiPo Battery in series with external switch
- Microprocessor for custom code
- Continuity detector and buzzer for verification of black powder igniter connection
- Accelerometer and altimeter for verification that the rocket is on the ground
- Pneumatic solenoid valve for deployment, powered directly from battery
- Low-Voltage Differential Signal (LVDS) from the ejection computer to receive the start command and to the ejection computer for breakaway wire disconnection

Payload Deployment Tests

- Black Powder Ground Test
- Remote Radio Trigger
- Separation Distance

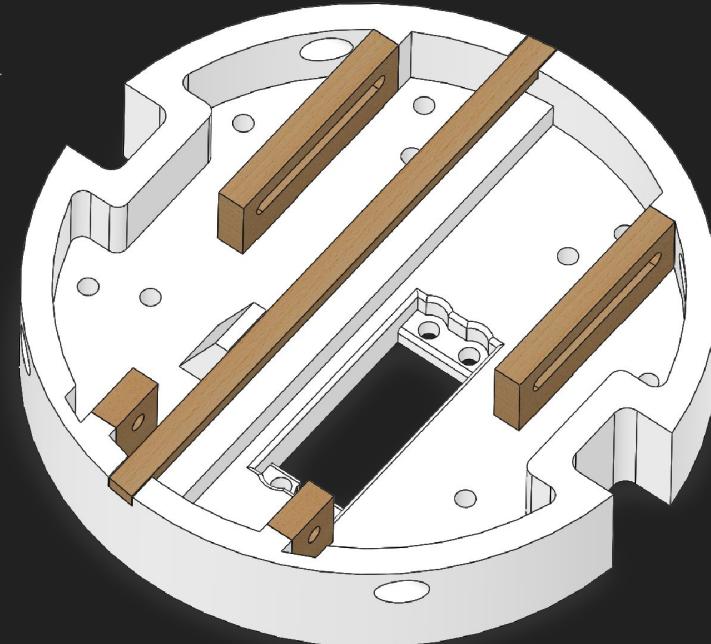
Payload - Ejection

- Horizontal scissor lift used to eject rover out of the payload section and onto the ground.
- Electrical components are mounted on a sled attached to nosecone side of scissor lift.
- Compressed length: 6 inches
- Extended length: 19.5 inches
 - Scissor lift extends the length of the rover plus a 1.5 in. margin of safety.
- Weight estimate:
 - Currently ~1.6 lb



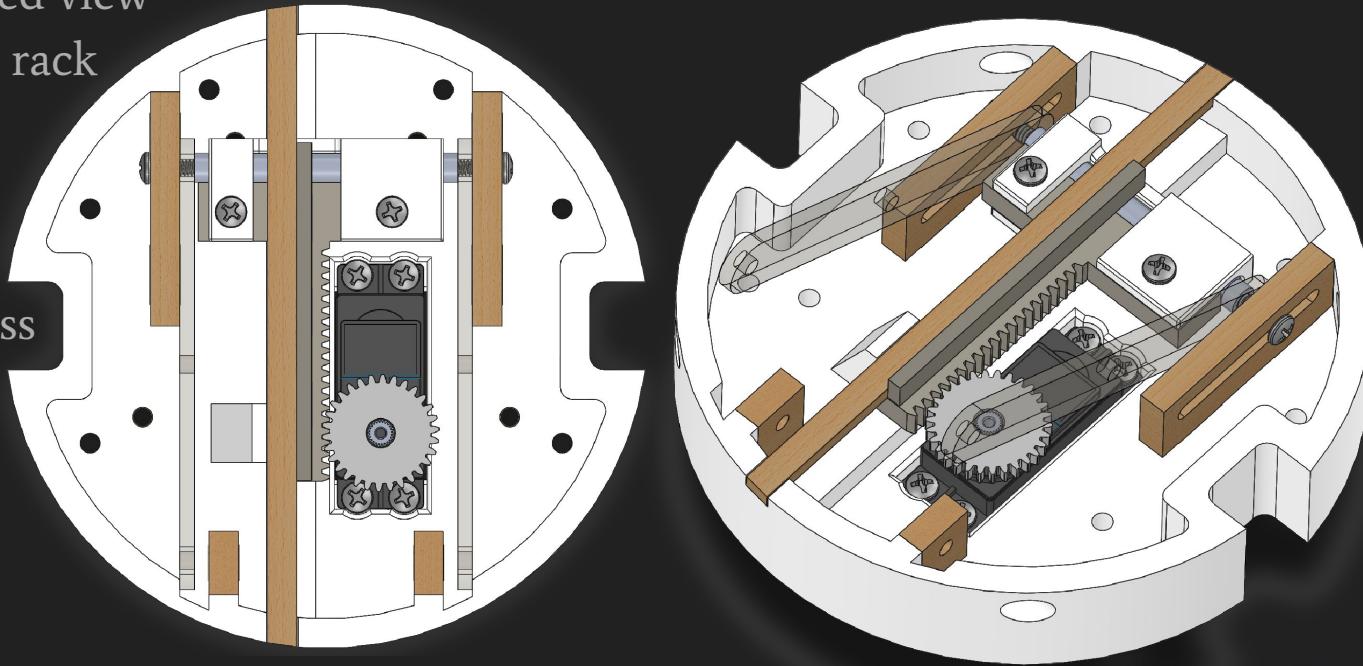
Ejection - Baseplate Frame

- Base frame made from 3D-printed PLA
- Slots and hinge tabs, along with guide rail made from laser-cut wood
- Mounting holes for #6-32 screws
- 1 inch thick



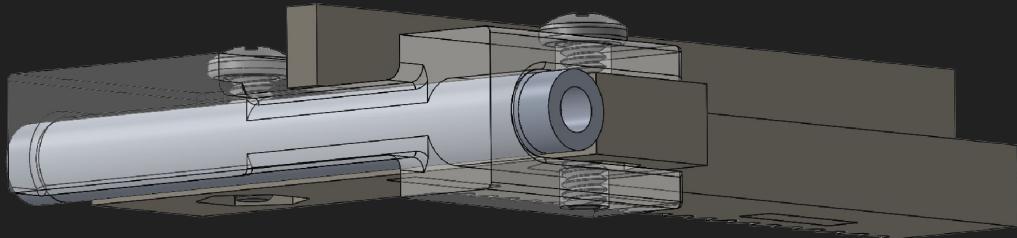
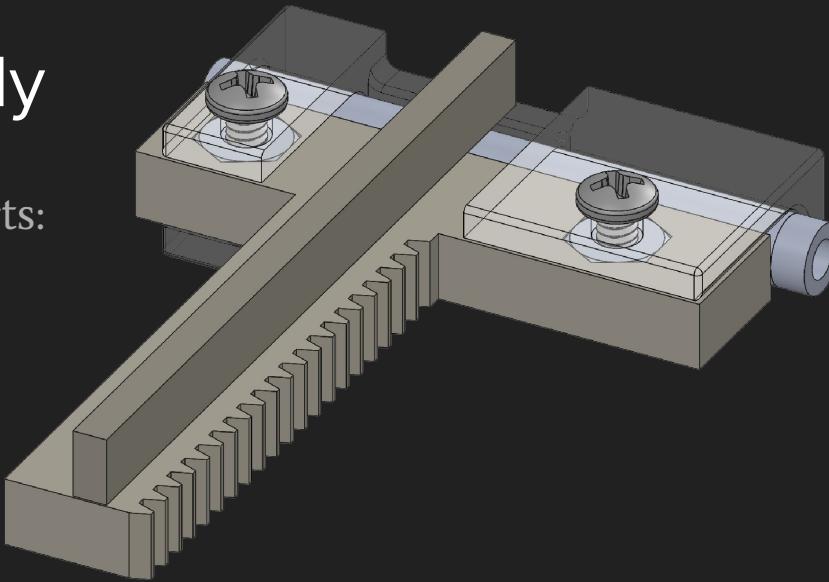
Ejection - Baseplate Assembled

- Partially assembled view of baseplate with rack and pinion drive mechanism
- Side cutouts accommodate pass through wires



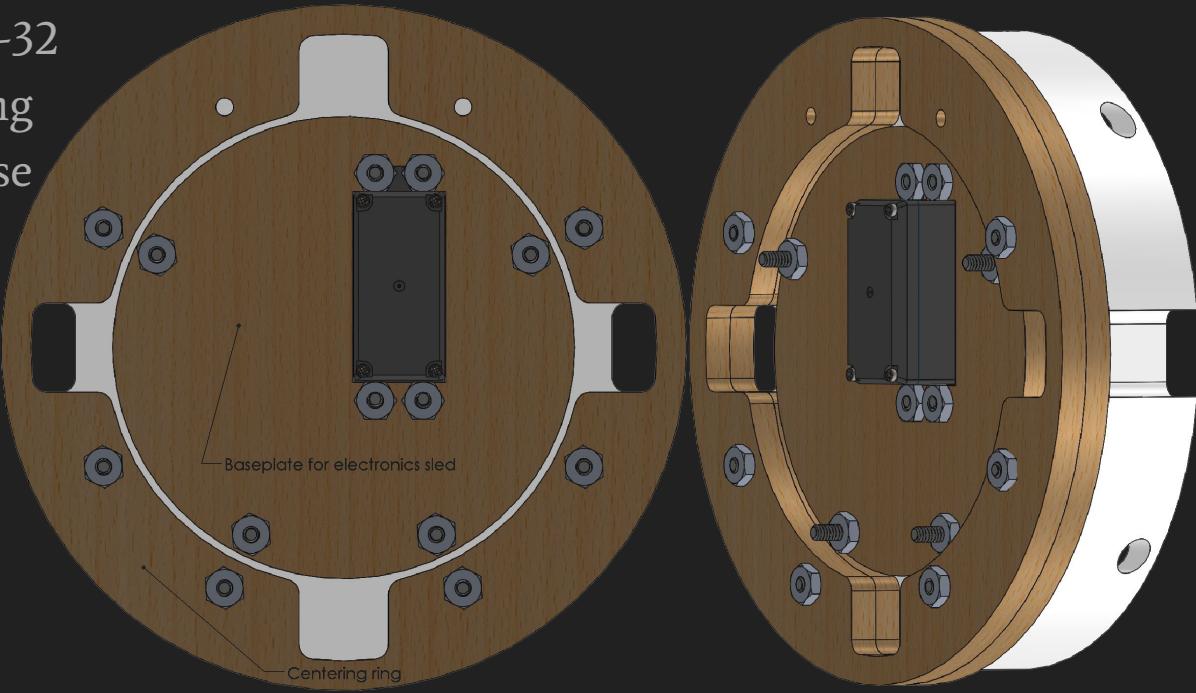
Ejection - Rack Assembly

- Rack assembly composed of 3 parts:
 - Laser-cut acetal rack
 - 3D-printed PLA clamp
 - Aluminium standoff
- Joined using screws & hex nuts

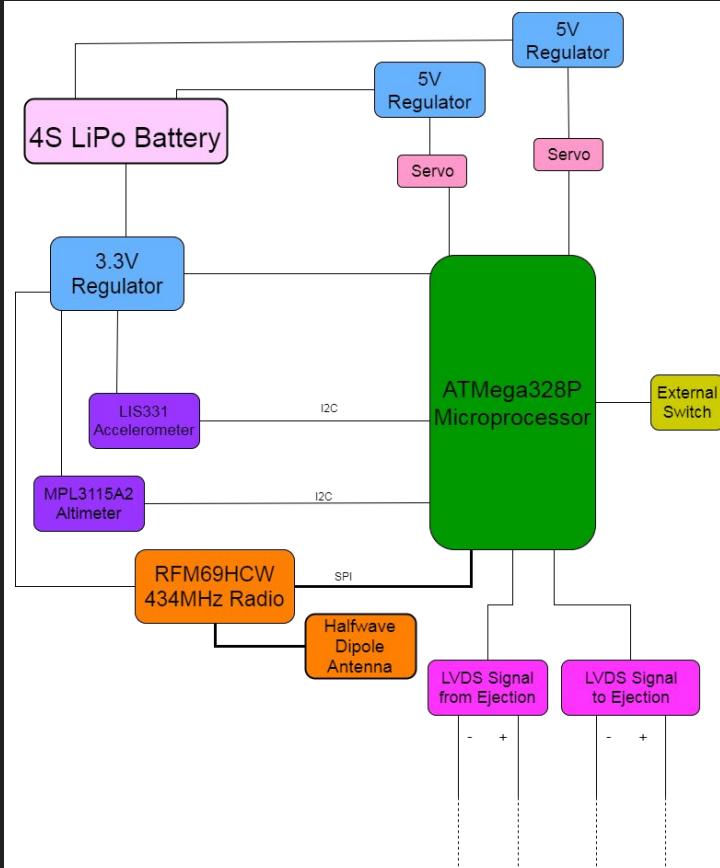


Ejection - Mounting Details

- All screws and nuts are #6-32
- 6 screws mount base to ring
- 4 screws mount sled to base
- 4 screws mount servo
- Cutouts in ring for pass-through wires



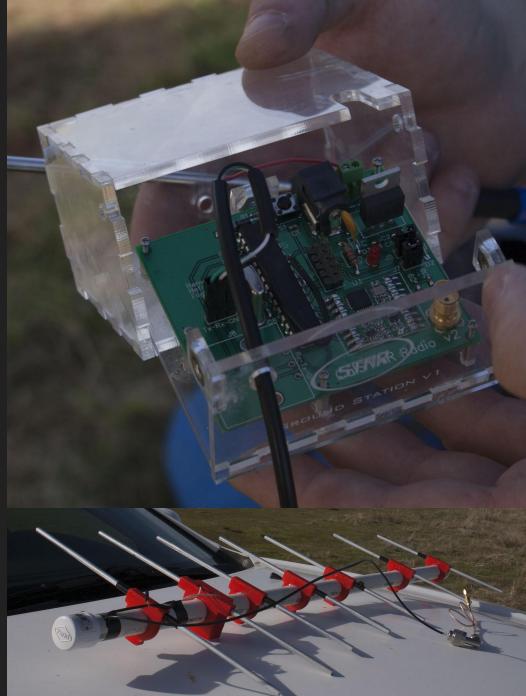
Ejection Electronics Board



- 4S LiPo Battery in series with external switch
- Microprocessor for custom code
- 434MHz Radio with half-wave dipole antenna for remote signal reception
- Accelerometer and altimeter for verification that the rocket is on the ground
- Two servos for scissor lift activation
- LVDS to the deployment computer to signal deployment start and from the deployment signal to detect breakaway wire disconnection

Ground Station

- 434MHz Radio, 500mW
- Antenna
 - 434MHz Yagi
 - 7 element
 - Handheld



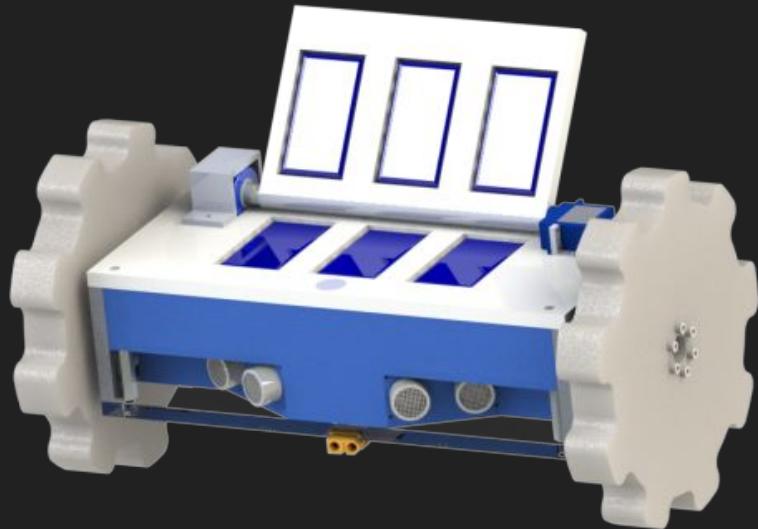
Payload - Ejection Tests

- Frame Load-bearing Capacity
- Life Actuation Force
- Linkage Lateral Flex
- Linkage Vertical Flex
- Lift Range of Motion

Rover Overview

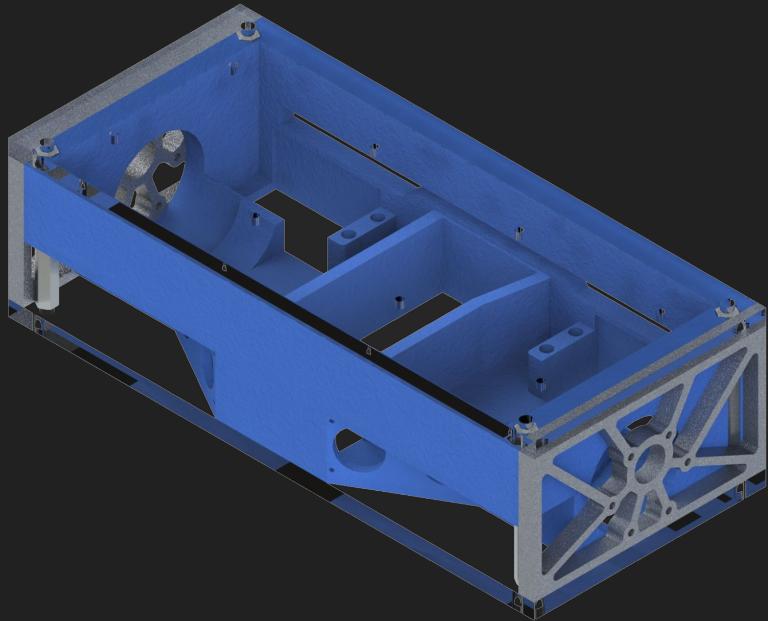
Chassis Dimensions: 8.5" x 3.75" x 2.0"

- Rectangular frame with polycarbonate surfaces, PLA sidewall, and aluminum supports.
- Solid toothed cross-linked polyethylene wheels
 - Lightweight, deformable
 - Uniform material, Solid hub / soft treads
- Twin polycarb skids
 - Stabilizing skids hold rover body in place
 - Simple design that takes mechanical load off of servos



Rover Chassis Design

- Fully enclosed chassis offers improved environmental protection over triangulated PDR design
- Panels designed to facilitate waterjet cutting and 3D printing for ease of manufacture



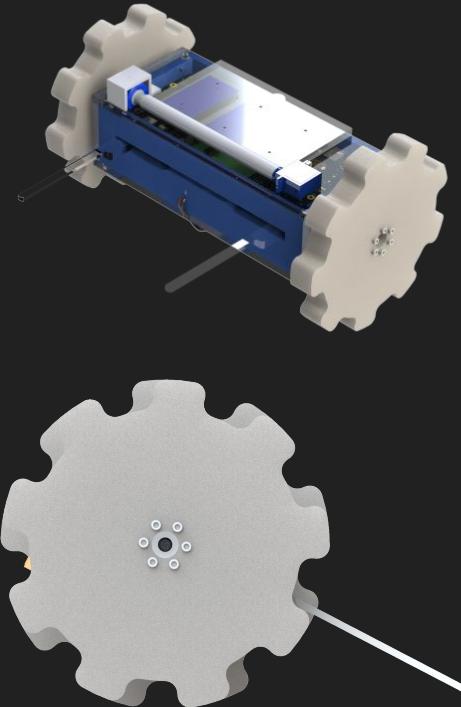
Rover Wheel Design

- Solid polyethylene design extremely lightweight.
- Deformability of material improves terrain negotiation, facilitates tight packing into airframe, and dampens in-flight vibrations.
- Off-the-shelf Pololu wheel hubs are a simple and lightweight mounting solution.



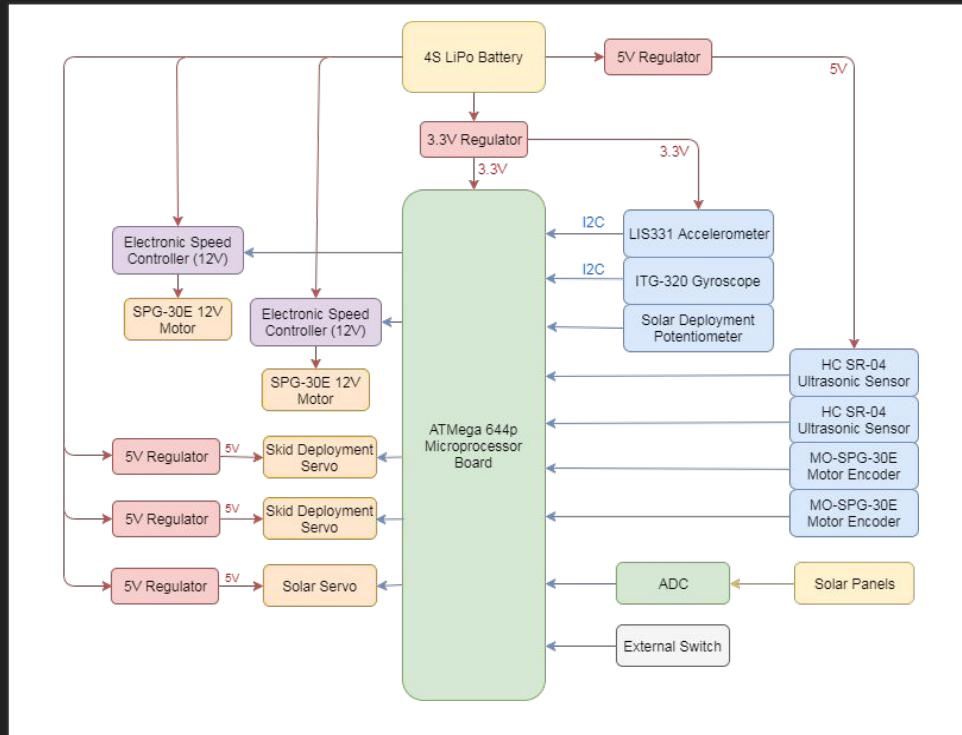
Rover Skid Design

- Polycarbonate skids hold the body stable as the motors turn the wheels, preventing free rotation.
- Skids deploy from a port on the rear of the rover, allowing the servos to remain shielded.
- Lateral skid deployment takes motor torque off of the servos.
- Servos allow automatic deployment and retraction.



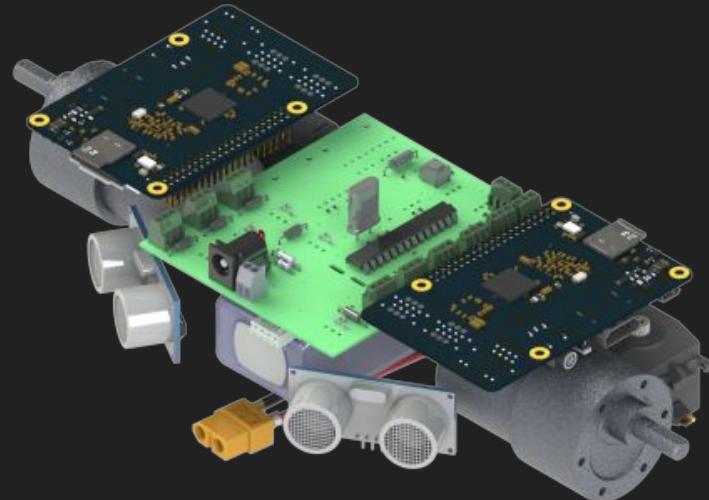
Rover Electronics Overview

- 4S LiPo Battery
- Microprocessor for custom code
- Tactile touch switch on wheel
- Accelerometer, gyroscope, ultrasonic sensors, and motor encoders
- Two motors with ESCs
- Two servos for skid deployment
- One servo for solar deployment
- Potentiometer and ADC for verification of solar deployment



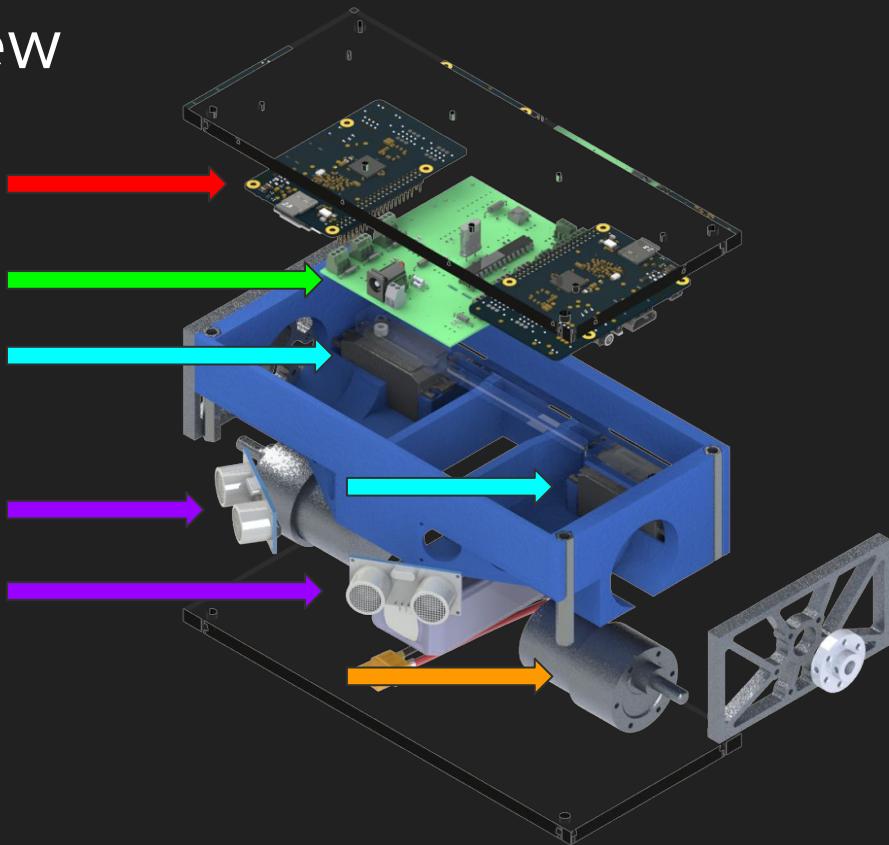
Rover Electronics Overview

- Motor Controller (x2)
- Rover Computer
- Servos (x2)
- Ultrasonic Sensors (x2)
- Motor (x2)



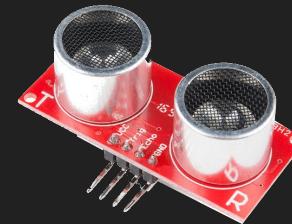
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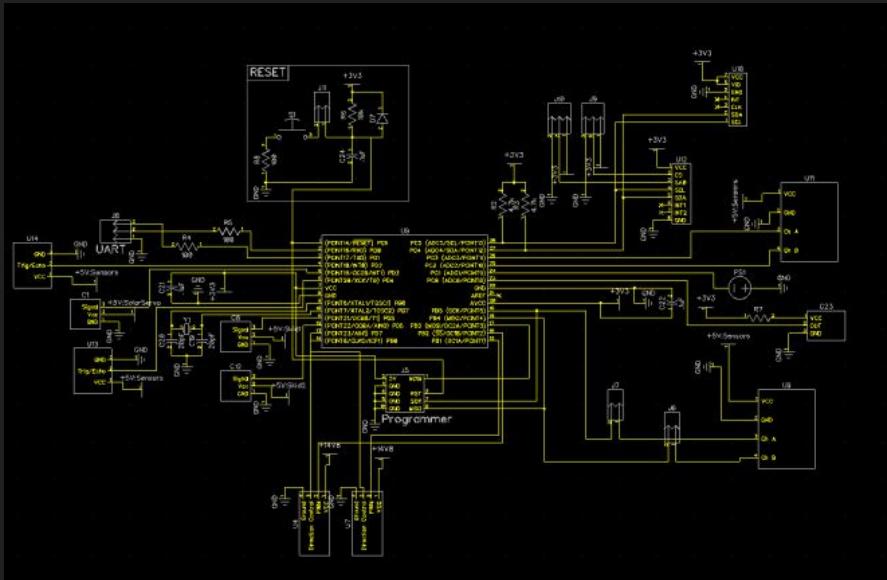
Rover Electronics - Components

- Motors: 12V Brushed DC Spur Gear motor with encoders
 - 38 RPM, 83.26 oz-in rated torque, 316 oz-in stall torque at 1.8A
 - Electronic Speed controllers
- Battery: 1300mAh 4S 45C LiPo battery
 - Small form factor: 2.8 x 1.4 x 1.4”
 - Sufficient discharge rate and capacity
- Collision sensors: 2x forward mounted HC SR-04
 - Light, cheap and reliable outdoors
- Distance measurement / navigation
 - Encoders for primary navigation
 - Accelerometer and gyroscope to check movement
- Servos for skid deployment



Rover Computer

- Upgraded to ATMega 644p to accommodate larger and more complex rover program.
- Custom designed board offers superior customizability.
- Board manages all rover components.

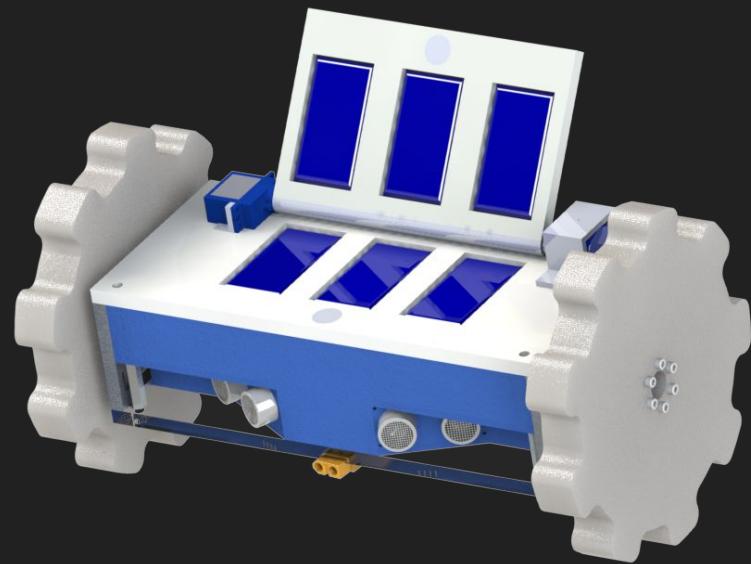


Rover Tests

- Manufacturing Testing [COMPLETE]
- Terrain Test
- Electronics Resilience Test
- Hill Climb Test
- Rover Actuation Test
- Distance Measurement Test
- Obstacle Avoidance Test

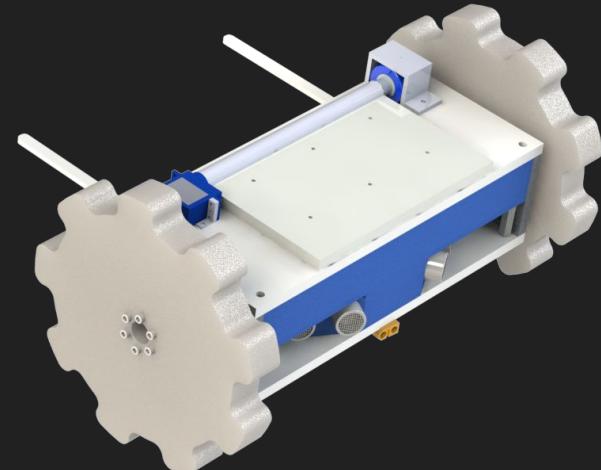
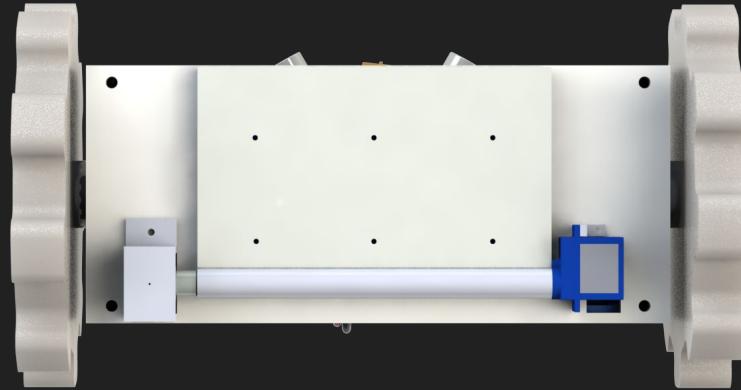
Rover Solar Overview

- 2" x 1" solar cells chained together on two panels
- One panel mounted above rover electronics
- Second panel mounted on hood of rover body



Rover Solar Mechanism

- Hood attached to body with hinge
- Hinge actuated with servo whose fins are attached to rod to rotate hood
- Potentiometer shaft attached to hinge to verify deployment position
- Voltage output of solar panels passed to rover computer
- Magnets on hood and body to prevent unintended deployment



Payload - Solar Tests

- Solar Cell Integration
- Servo Integration
- Panel Deployment

Payload Electronics Tests

- Communication between
 - Ground Station and Deployment Board via radio
 - Ejection Board and Deployment board via breakaway wire
- E-match activation via deployment board

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Safety

Safety Officer: Grant Posner; Team mentor: David Raimondi

Personnel safety is maintained throughout all construction and launch over multiple sites:

- Jacobs Hall: university training required
- Etcheverry Hall: university training required
- Richmond Field Station: MSDS and safety procedure information is available, and PPE is provided (and required) for any build days
- Launch days: PPE is provided and required, and team procedures mitigate risk

Launch commit criteria, derived from Environmental Hazards Analysis, are in the team's launch procedures



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Outreach

- Completed Events:
 - Ohlone College Night of Science (Oct 7, 2017)
 - Parent Education Program (Oct 14, 2017)
 - High School Engineering Program (Oct 21, 2017)
 - Discovery Days, CSU East Bay (Oct 28, 2017)
 - Discovery Days, AT&T Park (November 11, 2017)
- Current Outreach Numbers:
 - 1716 direct interactions with students
 - 1289 indirect interactions with community members (not including students above)
- Planned Events:
 - Expanding Your Horizons (March 17, 2018)
 - First Friday at Chabot Space & Science Center (November 5, 2018)
 - Space Day (TBD)



Subscale Launch Analysis

- Apogee: 4366ft AGL
- Max Velocity: 640ft/s
- Avg. Velocity: 62.43ft/s
- Duration of Flight: 115s
- Recovery:
 - Drogue deployment: apogee & apogee + 1 sec
 - Velocity after drogue: 60ft/s
 - Main deployment: 800ft AGL & 850ft AGL
 - Velocity after main: 20ft/s



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Project Plan - Requirements Verification - General

Complete:

- Engage a minimum of 200 participants in educational outreach
- Each team must identify a mentor

Ongoing:

- Develop and host website

Project Plan - Requirements Verification - Vehicle (Complete)

- The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner.
- Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.
- Each altimeter will have a dedicated power supply.
- Each arming switch will be capable of being locked in the ON position for launch
- The launch vehicle will have a maximum of four (4) independent sections.
- The launch vehicle will be limited to a single stage.
- The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system.
- The launch vehicle will require no external circuitry or special ground support equipment to initiate launch.

Project Plan - Requirements Verification - Vehicle (Complete)

- The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the various safety organizations
- Final motor choices must be made by the Critical Design Review
- Any motor changes after CDR must be approved by the NASA Range Safety Officer
- The total impulse provided by a College and/or University launch vehicle will not exceed 5,120 Newton-seconds
- The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.
- The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit
- All teams will successfully launch and recover a subscale model of their rocket prior to CDR.
- The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model.
- The subscale model will carry an altimeter capable of reporting the model's apogee altitude.



Project Plan - Requirements Verification - Vehicle (Complete)

- All Vehicle Prohibitions are met

Project Plan - Requirements Verification - Vehicle (Ongoing)

- The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.
- The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.

Project Plan - Requirements Verification - Vehicle (Incomplete)

- The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components.
- The vehicle and recovery system will have functioned as designed.
- If the payload is not flown, mass simulators will be used to simulate the payload mass
- The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.
- The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.
- All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day.
- After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer
- Full scale flights must be completed by the start of FRRs (March 6th, 2018)
- The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL).

Project Plan - Requirements Verification - Recovery (Complete)

- The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a lower altitude.
- The recovery system electrical circuits will be completely independent of any payload electrical circuits.
- All recovery electronics will be powered by commercially available batteries.
- The recovery system will contain redundant, commercially available altimeters
- Motor ejection is not a permissible form of primary or secondary deployment.
- Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.
- An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver
- Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device
- The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight

Project Plan - Requirements Verification - Recovery (Complete)

- The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.
- The recovery system electronics will be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.

Project Plan - Requirements Verification - Recovery (Ongoing)

- Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.
- At landing, each independent sections of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.
- The electronic tracking device will be fully functional during the official flight on launch day
- The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

Project Plan - Requirements Verification - Recovery (Incomplete)

- Recovery area will be limited to a 2500 ft. radius from the launch pads.

Project Plan - Requirements Verification - Payload

Complete:

- Each team will choose one design experiment from the list in section 4.3 of the handbook

Ongoing:

- Teams will construct a custom rover that will deploy from the internal structure of the launch vehicle

Incomplete:

- At landing, the team will remotely activate a trigger to deploy the rover from the rocket
- After deployment, the rover will autonomously move at least 5ft from the launch vehicle
- Once the rover has reached its final destination, it will deploy a set of foldable solar cell panels



Project Plan - Requirements Verification - Safety

Complete:

- Each team must identify a student safety officer who will be responsible for all respective responsibilities listed in section 5.3 of the handbook

Ongoing:

- During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO (NAR)
- Teams will abide by all rules set forth by the FAA
- Each team will use a launch safety checklist. The final checklists will be included in the FRR reports and used during the Launch Readiness Review (LRR) and any launch day operations

Project Plan - Funding and Materials Acquisition

Funding:

- Current pre-expense budget is \$ 27,389.39, \$2,000 of which is still pending disbursement
- We have spent about \$3,000 as a team. Subteam breakdown is listed in detail in the CDR.
- About 44% of our budget comes from individual donations through 3 crowdfunding campaigns
- About 35% of our budget comes from school grants
- The remaining 21% comes from corporate sponsors

Materials Acquisition:

- A majority of our purchases go through university student discount programs (Apogee, Public Missiles, X-Winder)
- 3d Printed Parts are free through the Jacobs Maker Pass program
- Bay Area Circuits and Solidworks provide free products
- Raw materials from McMaster-Carr, Electronics components from Adafruit and DigiKey, and Motors from HobbyKing
- Rocket materials from Always Ready Rocketry (Blue Tube), Fruity Chutes (parachutes), Apogee Rockets (assorted rocket parts), and Public Missiles (fiberglass fins and assorted rocket parts).

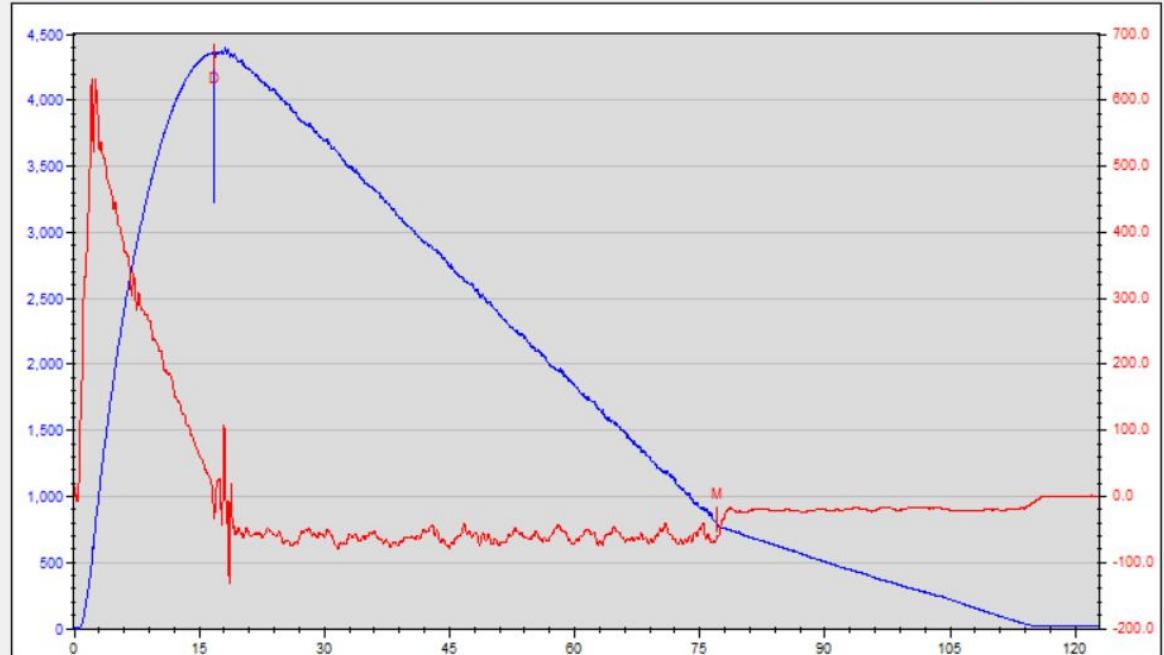


Questions?

Backup Slides

Altitude (Feet)

Velocity (Feet/Second)

Statistics:

Apogee Alt: 4361' AGL

Displayed Raw Altitude

Ground Elev: -165' MSL

 Smoothed Alt

NumSamps: 2456

 Velocity

Main Deploy: 800' AGL

 Temperature

Apogee Delay: 0 SEC

 Voltage

FlightNum: 4

PID: 3A PIM: 3A

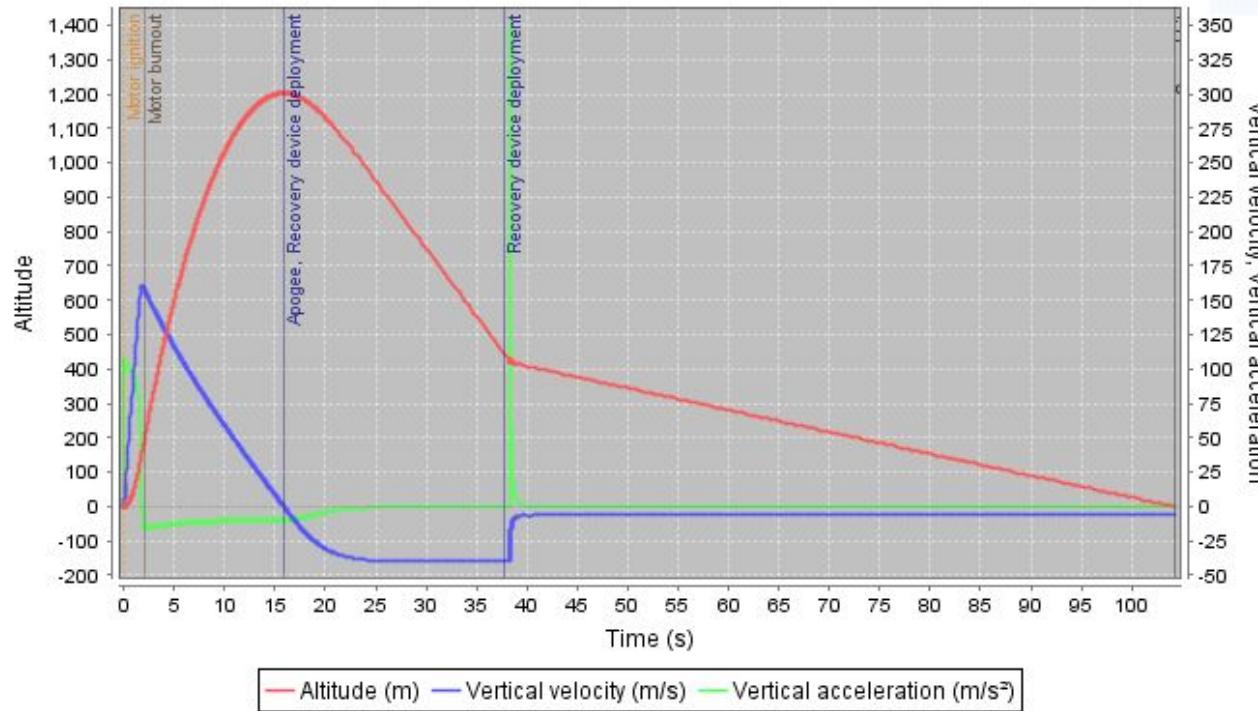
Comments

Help

Model: SLCF Serial #: 4051

Simulation 1

Vertical motion vs. time



left click drag to zoom area, mouse wheel to zoom, ctrl-mouse wheel to zoom x axis only, ctrl-left click drag to pan, right click drag to zoom dynamically.

Show data points



Close

