NC STATE UNIVERSITY

NASA Student Launch

Aerospace Engineering Capstone Senior Design 2020 – 2021

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Course Instructor: Dr. Ewere | Section Instructor: Michael Hughes | Customer: NASA

Ejection Charges

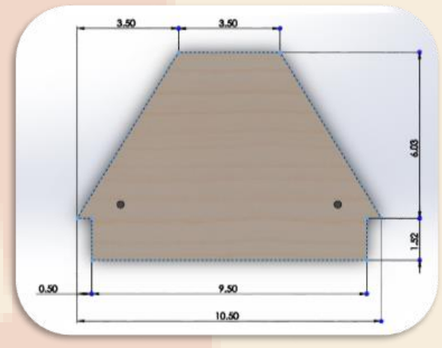

A new calculator for sizing black powder ejection charges using 4F black powder was developed to adapt to issues encountered in previous years. Online calculators used in the past by previous teams had been found to generally underestimate the charge size needed for a given chamber volume

This calculator considers a basic reaction model for black powder combustion, given below by:

$$10\ KNO_3 + 3S + 8C \rightarrow 2K_2CO_3 + 3K_2SO_4 + 6CO_2 + 5N_2$$

From this reaction model, it can be calculated that only 33.5% of the products by mass are gaseous and therefore useful for ejection.
To increase calculation accuracy further, the products of the reaction (assumed to be at adiabatic flame temperature for 4F black powder) were modeled as a mixing problem between the air inside the cavity at the ambient pressure and the hot ejection gases. From this, the mass of black powder needed to produce sufficient ejection gases for a desired pressure rise may be backed out.

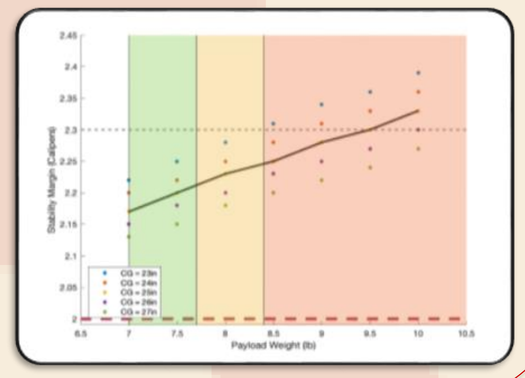
Stability



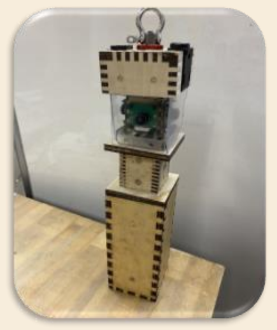
CG, CP, and Stability
Knowing the center of gravity, center of pressure, and stability throughout the first few moments of flight are critical to ensuring a successful flight. RockSim was used to calculate these predictions after being fed data about every single part of the launch vehicle. The CG is manually determined through balancing and is measured from the tip of the nose cone. The fin design can be seen on the right.

A 24" 4:1 Ogive nose cone and three-fin-configuration was chosen to achieve the desired stability margin over 2.0 calipers.

Accounting for Variance
On the right is a tolerance study on stability margin, which shows how the stability of the launch vehicle varies with both the weight and center of gravity of the payload.

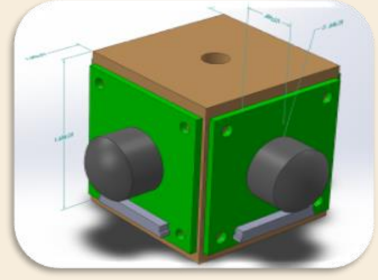
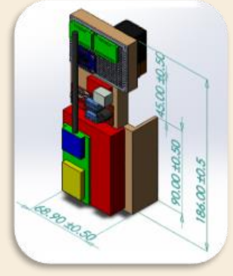
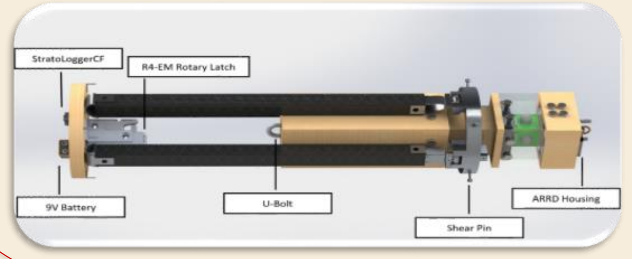


Payload Design

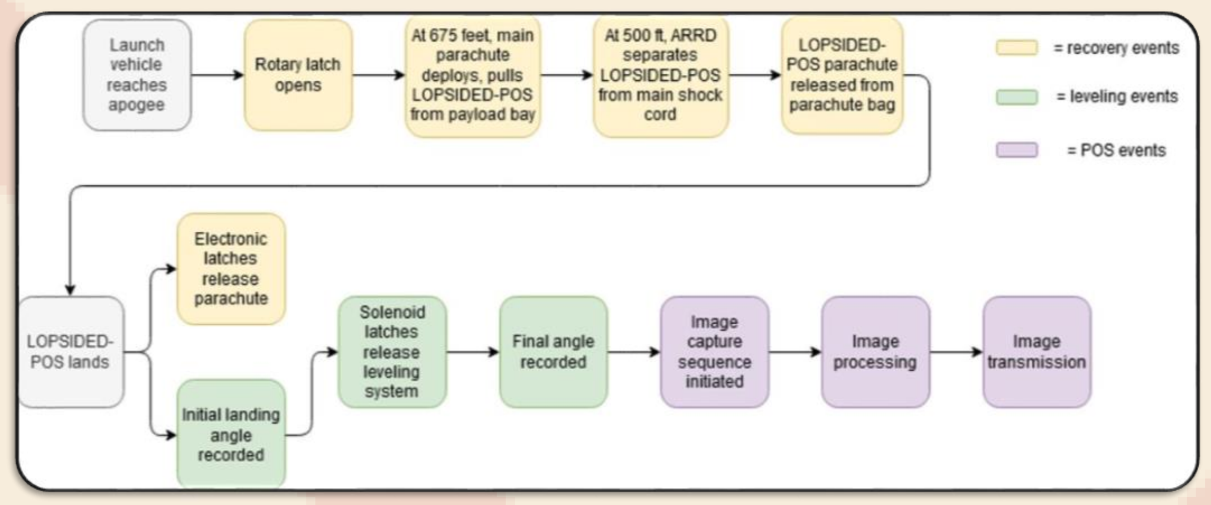
Top Section: contains the POS cameras and recovery hardware.
Middle Section: connects the leveling ring system and legs to the body.
Lower Section: contains most LOPSIDED-POS electronics.
Support Section: allows the payload to tilt using two gyroscopic metal rings. Its neutral orientation is held using two sets of locking solenoids. They release to allow for leveling up to 23 degrees.

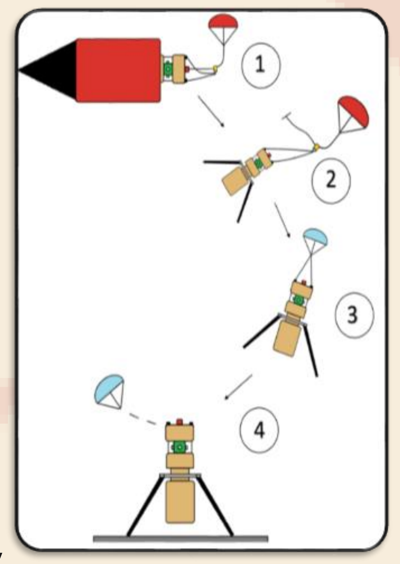
Four Fisheye Camera Modules: For post-level imaging.
FM Transmitter: For transmitting images using Slow-Scan Television (SSTV).
Orientation Sensor: For initiating leveling and image capture, and to record leveling angles
12V Battey: for powering payload electronics

StratoLogger CF: Detects apogee to release LOPSIDED-POS inside the payload bay.
ARRD Housing: Holds ARRD which detaches LOPSIDED-POS from main parachute chord.
R4-EM Rotary Latch: holds onto LOPSIDED-POS during ascent and is actuated by an Arduino Nano.

Payload CONOPS

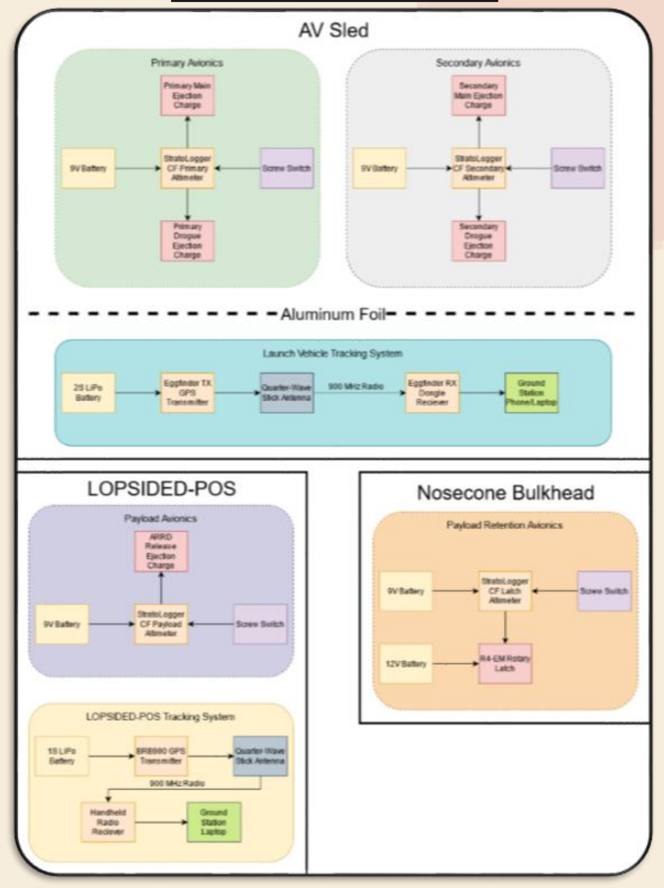




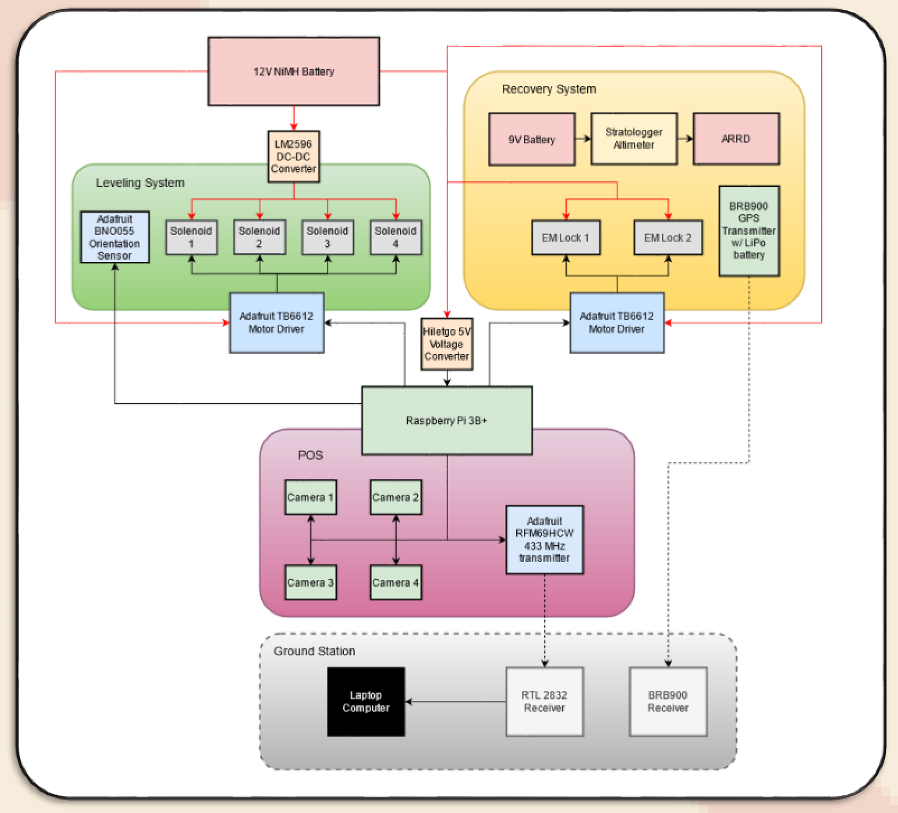
The payload consists of two main systems – the Lander for the Observation of Planetary Surface Inclination, Details, and Environment Data (LOPSIDED), and the Planetary Observation System (POS). LOPSIDED is a planetary lander that houses the POS, which is used to deliver data in the form of images captured from LOPSIDED's landing site.

Functional Block Diagrams

Launch Vehicle

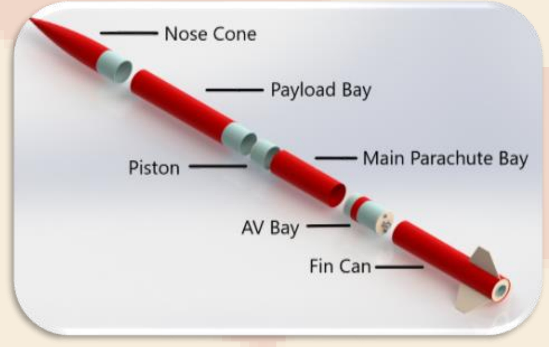


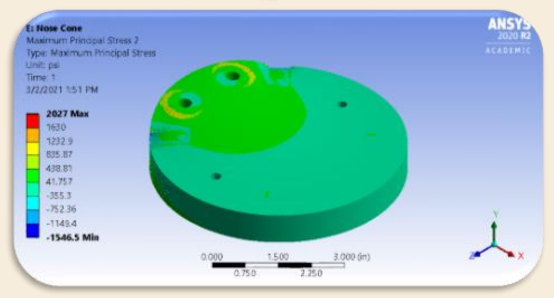
Payload



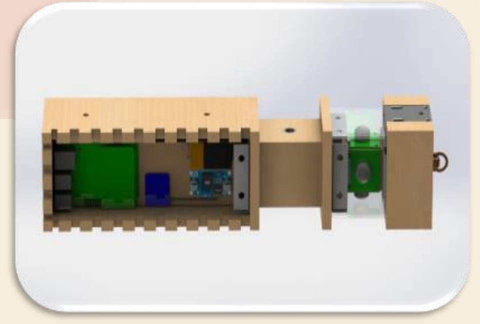
CAD Models and Final Prototypes

Launch Vehicle (*81.5*)






Payload (*LOPSIDED-POS*)


Manufacturing

Launch Vehicle

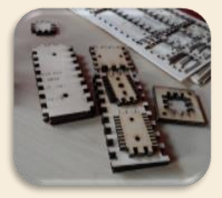
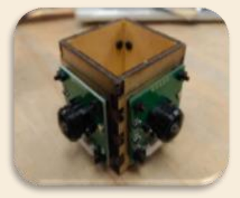
Fiberglass tubing was brought to the machine shop to cut the proper lengths for body and coupler sections as well as cut fin slots in the fin can.

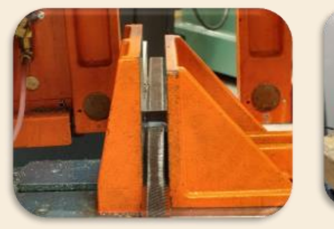
Bulkheads and fins were manufactured from laser-cut plywood layers that were then epoxied together and placed under vacuum to cure. Additional hardware such as U-bolts were added once the epoxy had cured.



Payload

- **Body** - Laser cut aircraft grade plywood
- **Gimble Rings** - CNC'ed 6061 Al stock
- **Skeletal Frame** - Waterjet, bent 6061 Al sheet metal
- **Leg Brackets** - Waterjet, bent 6061 Al sheet metal
- **Legs** - Carbon fiber square tubes
- **POS Window** - Polycarbonate
- **Electronic Brackets** - 3D printed ABS




Testing

Launch Vehicle

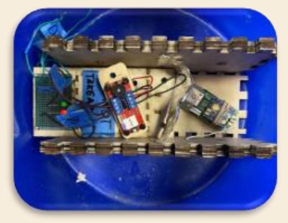
Structural testing was performed on the bulkheads and some hardware to ensure everything had a sufficient factor of safety under in-flight forces. Extra nose cone and AV bay bulkheads were manufactured to be tested in a universal testing machine. Both types of bulkheads were tested to 1000 lbf with no visible damage meaning they would easily be able to resist the highest expected loadings.


Payload

Multiple tests were conducted to verify LOPSIDED-POS mission requirements, including:

- Tilt range testing
- Battery life testing
- Transmitter range testing
- Drop testing






Flight Results






The team conducted test flights on February 20th and March 27th, 2021 and a final flight on April 10th, 2021. During the Payload Demonstration Flight, LOPSIDED was successfully jettisoned from the launch vehicle. On the final flight, LOPSIDED successfully captured images using the POS after landing. The highest altitude the Launch Vehicle reached was 3,084 ft. The Launch Vehicle's recovery system performed nominally.