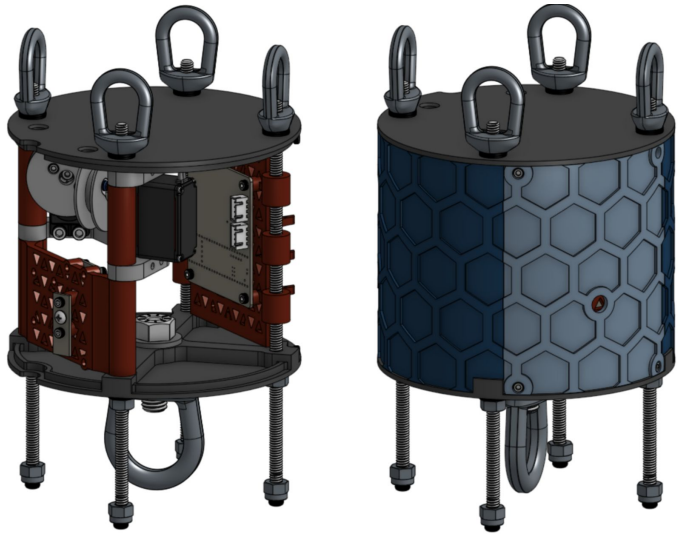
Modular, Controlled SRAD Recovery

Prepared for the 2026 IREC

DUKE AERO



Why SRAD Recovery?

- Full control of performance characteristics
- Consistent separation
- Modular design and integration
- Increased team recovery expertise

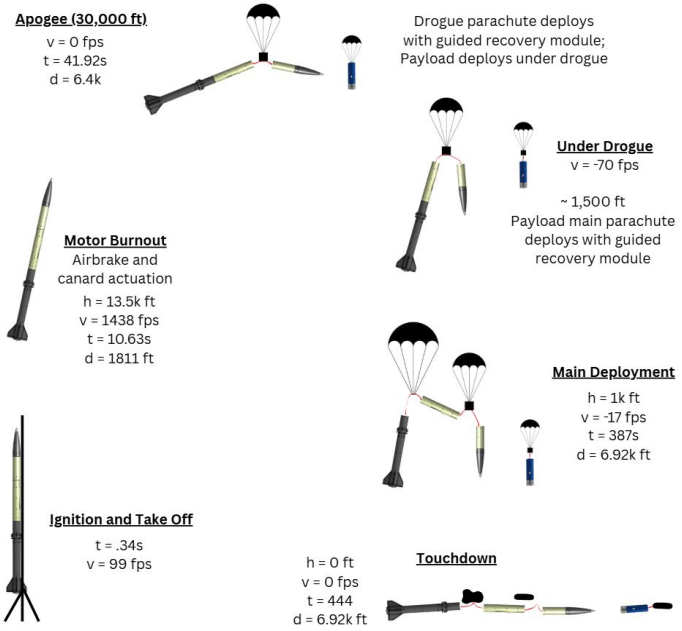


Fig. 1 Launch CONOPS

Parachute Construction

- 1.1 oz zero-porosity ripstop nylon
  - Low permeability, tear resistant, and durable
- Reinforced hems, stitched load paths, and braided suspension lines
- Hand-sewn in student design space

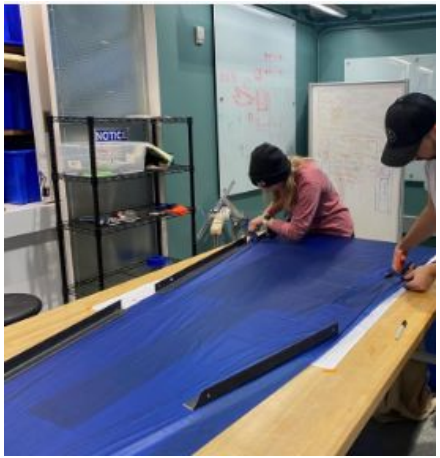


Fig. 2 Students cut nylon for main

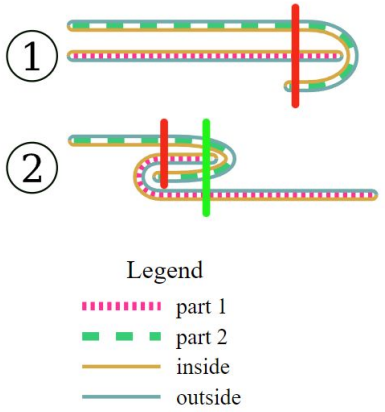


Fig. 3 Stitching diagram

Main Parachute

- Goal terminal velocity: 15-20 ft/s
- Canopy shape: semi-elliptical → C_d = 1.6
- Aspect ratio b/a = 0.707 → most favorable stress distribution in canopy
- Diameter is 14 ft with v_t = 18.8 ft/s

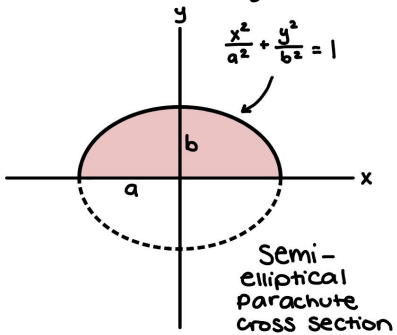


Fig. 4 Main design

Fig. 5 Deployed main chute during testing

Drogue Parachute

- Cruciform design made up of two 7.5 x 2.5 ft panels
- Experimental drag coefficient calculated through scaled-down wind tunnel testing → $C_D = 0.52$

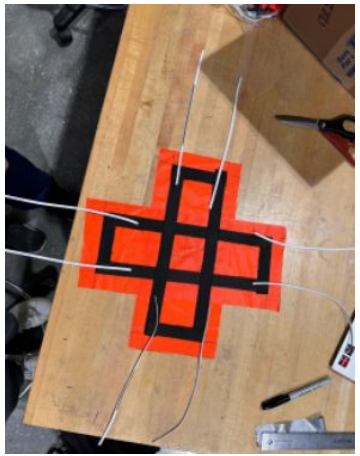
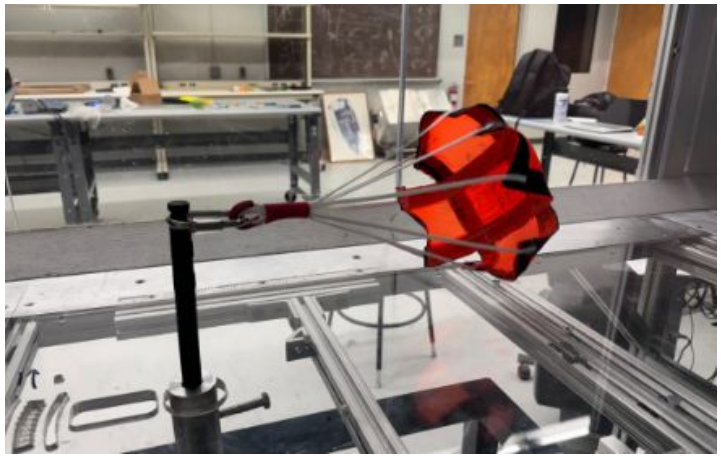




Fig. 6 Drogue and scaled model in wind tunnel

Tensile Testing

Fig. 7 Nylon Ripstop after tensile test

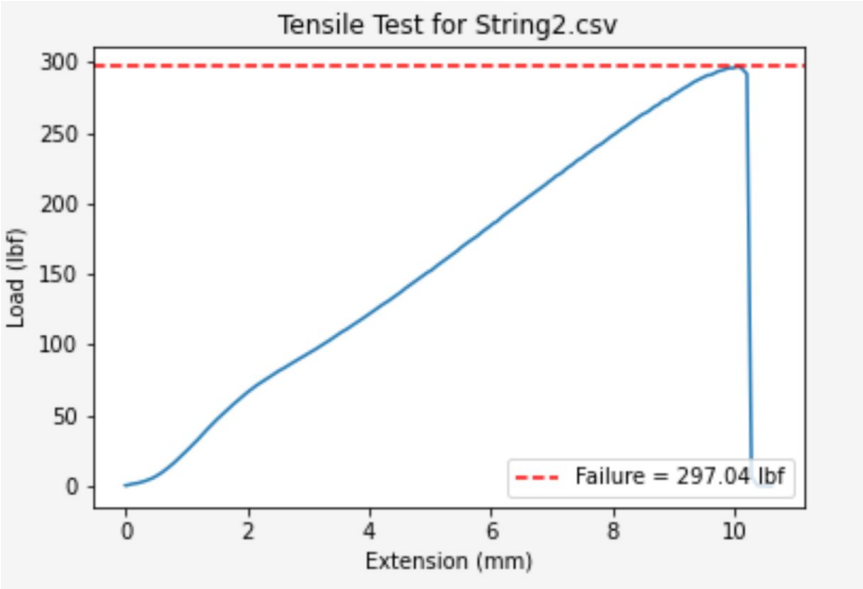


Fig. 8 Shroud line tensile test results

Car Pull Testing

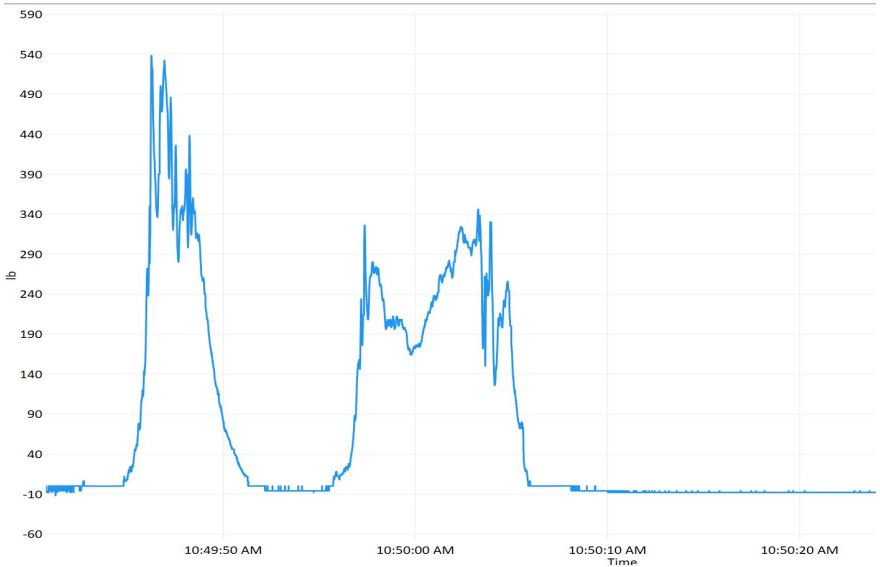


Fig. 9 Snatch force data from car pull test

Fig. 10 Car pull test

Directional Recovery

- Steers rocket in a helical pattern while falling under drogue
- Differential tension on dynamic chute lines
- Demonstrate autonomous control while adhering to IREC guidelines

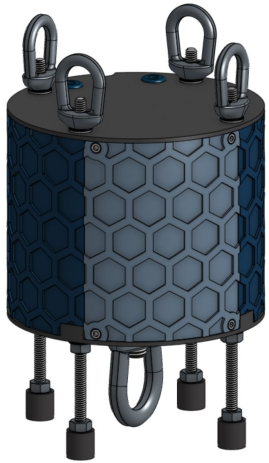


Fig. 11 Directional unit

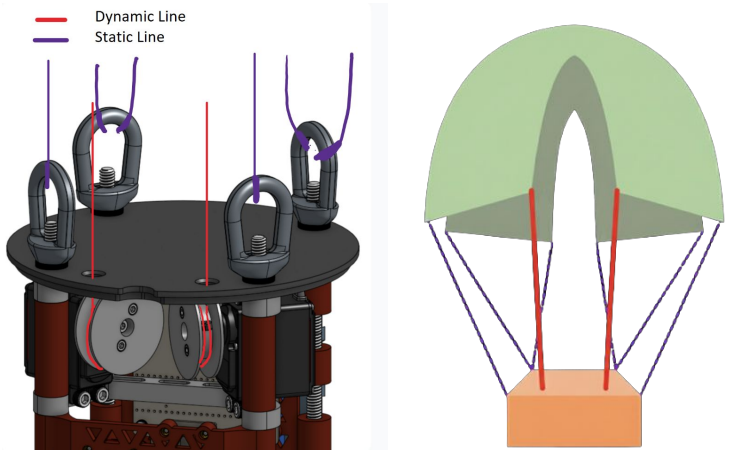


Fig. 12 Dynamic control theory

Manufacturing

- Bulkheads and servo mounts CNC-milled **in-house**
- **6061-T6 aluminum** selected for strength-to-weight and machinability
- Machining operations included: facing, pocketing, and tapping
- Other components were manuctured using an SLS process with Nylon 12

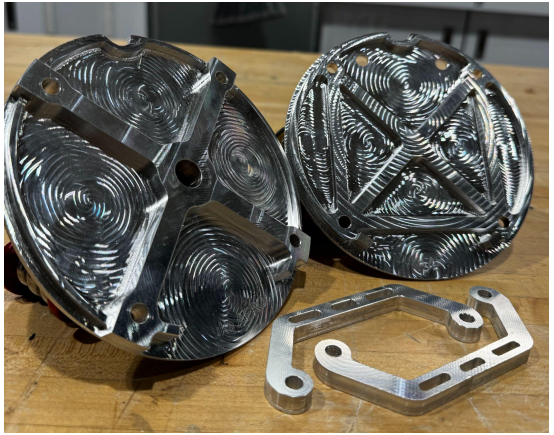


Fig. 13 Machined bulkheads and servo mounts

Fig. 14 SLS Nylon servo reels

Fig. 15 Full unit prototype

Chute Guider Computer

- Closed-loop PID control uses magnetometer data to command servo motion
- The PCB features a *Teensy 4.1 MCU* for control and datalogging, a *Bosch BMM350 magnetometer*, and qwiic connectors to support additional external sensors.

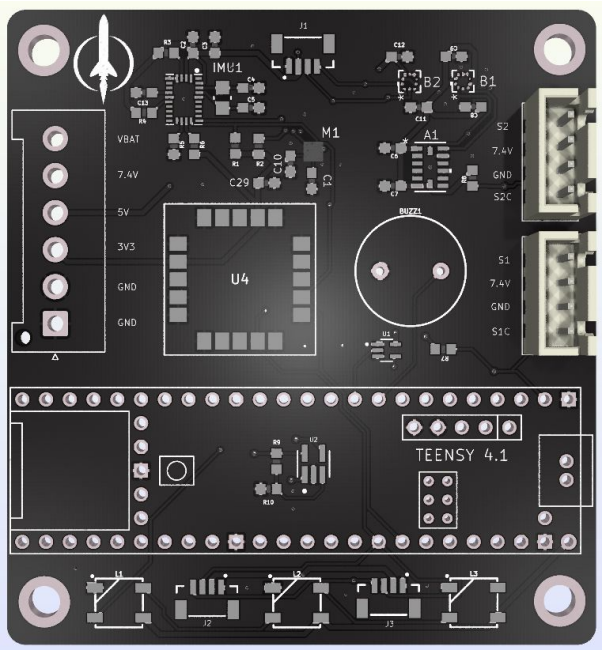


Fig. 16 Chute guider PCB

Note: The PCB features additional IMUs, barometers, and a GPS module for use in out-of-competition launches.

Servo Response Testing

- Hanging rig test demonstrated expected servo response to turns
- 80 ft drop test proved ability to pull dynamic lines in free fall

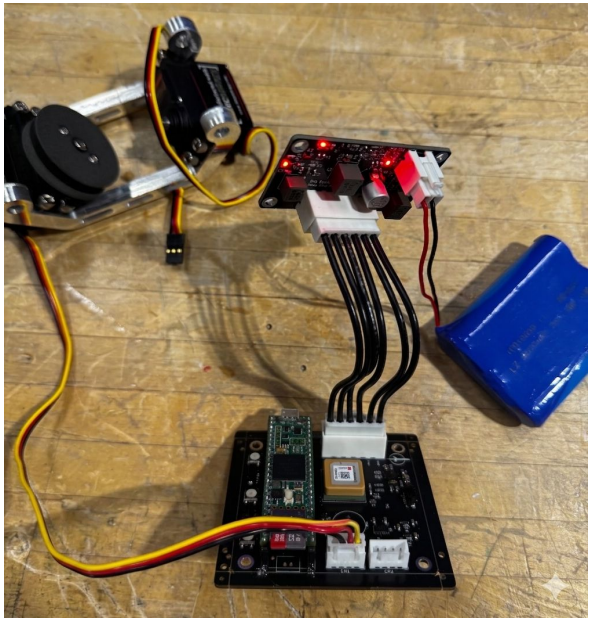


Fig. 17 Electronics package

Fig. 18 Hanging rig test

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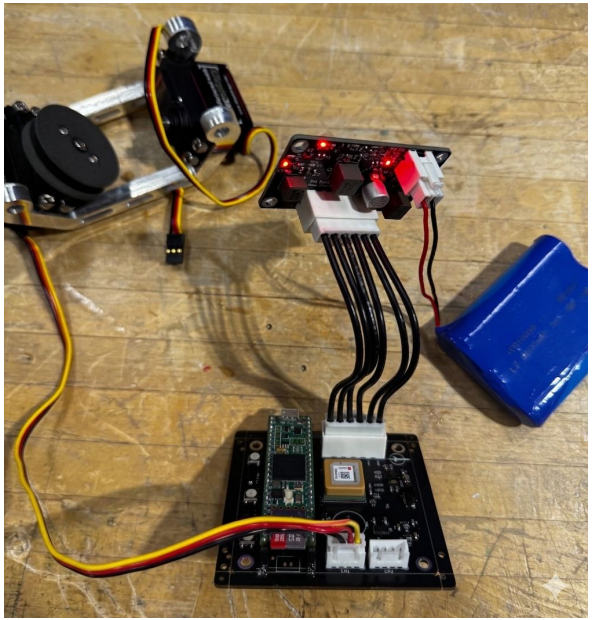


Fig. 17 Electronics package

Fig. 18 Hanging rig test

Blast Disk

- Custom separation enhancement bulkhead
  - Pressurization chamber volume reduction

Fig. 19 Blast disk

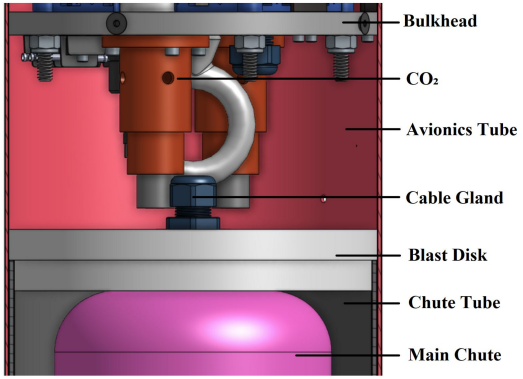


Fig. 20 Blast disk placement

Fig. 21 ⅜” NPT tapping

- HDPE selected for low coefficient of friction and good yield strength
- Multiple sealed wiring and cord pass through

Blast Disk Testing

- Thickness iteration through FEA → FoS of 1.5
- Significant increase in separation strength

Fig. 22 Full separation test

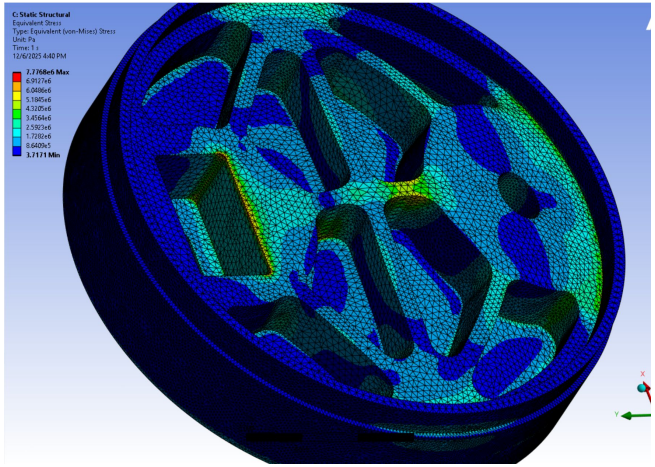
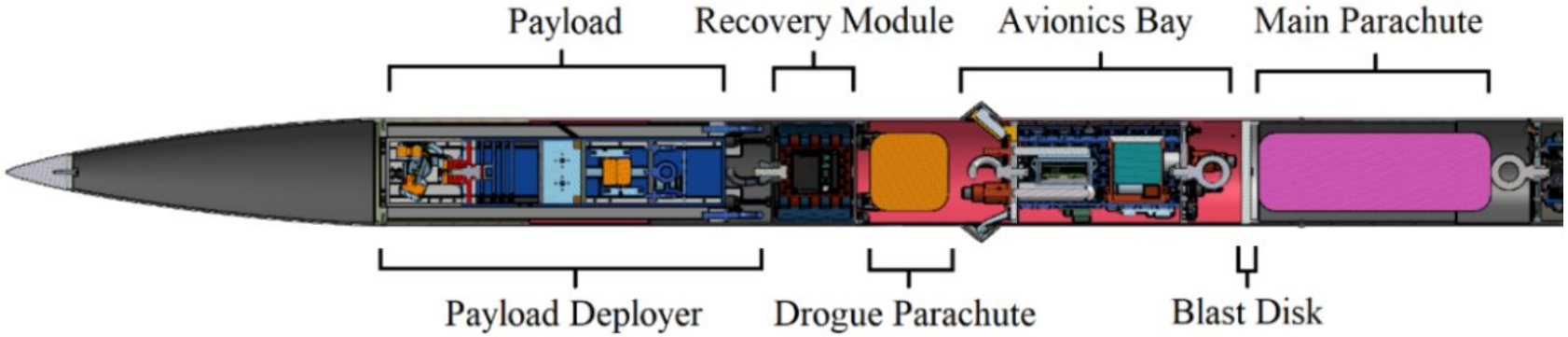


Fig. 23 Blast disk FEA

System Integration



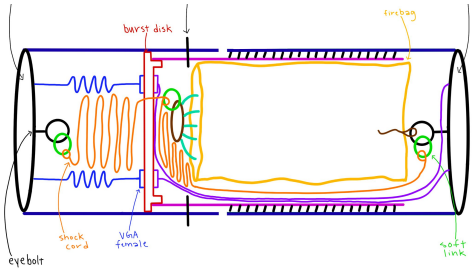


Fig. 24 Main Chute internal diagram

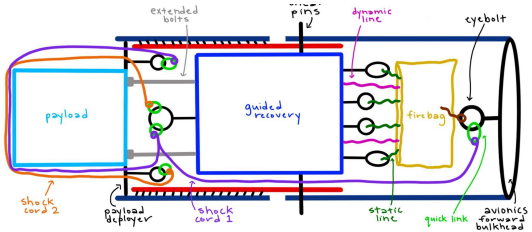


Fig. 25 Drogue internal diagram

Future Work

- Full-scale integrated flight test at IREC 2026
- Further tuning of directional recovery control algorithm
- Log descent rate data to experimentally validate main C_D
- Development of two-stage reefing system

Fig. 26 Early stage reefed testing

THANK YOU

Does anyone have any questions?

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dukerocketry.com

@duke_aero

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Contact us at
dukerocketry@gmail.com

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Contributions from previous AERO members including:
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