Design and Development of an Autonomous Payload Return Vehicle

Sean Widmier, Thomas Salverson, An Nguyen, Colin Oberthur, Sean Mitchell,
Daniel Velasco, Kyle Daigle, Trystan May

RAPTOR

Space Hardware Club is a student-led engineering organization involved in CubeSat, rocketry, and High-Altitude Ballooning (HAB) projects. HAB projects typically involve carrying expensive payloads into the upper atmosphere to conduct scientific experiments. Currently HAB payloads are returned by unguided parachutes and frequently land in areas that make retrieval difficult or dangerous.

Ram-**A**ir **P**arafoil **T**argeted **O**bject **R**eturn (RAPTOR) is an autonomous system designed for the simplification and cost reduction of HAB payload recoveries. RAPTOR is designed to autonomously guide HAB payloads to a predetermined landing site using a mechanically articulated parafoil. The project draws inspiration from the Joint Precision Airdrop Delivery System (JPADS), developed by the US Army and Air Force.

Design

To achieve the project goal, RAPTOR aims to resolve at least the following requirements:

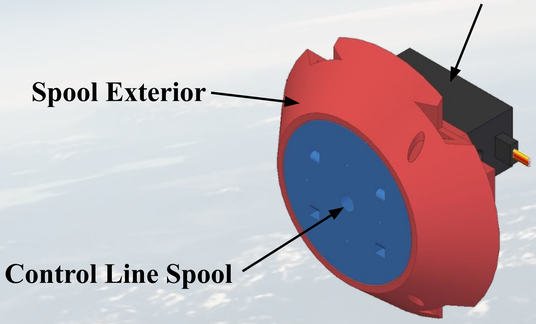
- Remain under FAA limit of 1.8 kg, with parafoil able to keep descent speed under 7 m/s
- Release from balloon line at specific altitude
- Achieve parafoil deployment during flight
- Autonomously guide the payload train to a suitable landing location

RAPTOR will serve as a reliable and reusable flight recovery system for future club HAB projects.To fulfill this along with solving the above design problems, RAPTOR uses the following:

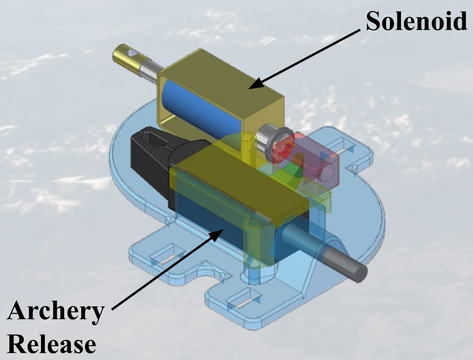
- Easily replaceable additively manufactured components reduces weight
- Readily available electrical components reduces cost
- Large (3 meter) brake-line control hobby kite parafoils
- Externally secured parafoil, semi-rigid frame to ease parafoil inflation at high altitudes
- Solenoid based release for reliable cutdown from balloon line at needed altitude
- Basic flight algorithms and inertial guidance system to be replaced by feed-forward neural network and data-driven PID controller

Team Photo after Overjoyed Recovery

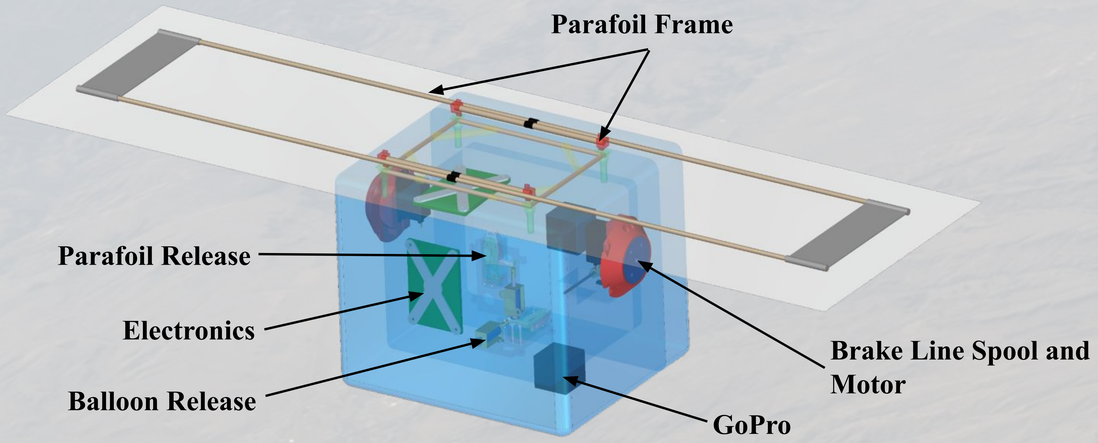
RAPTOR Falcon Under Development



Motor and Control Line Spool



Release Mechanism



Overall System

Kestrel

- **Flight Objectives**
  - Construct flight ready payload
  - Prototype various subsystems
  - Verify component function at high altitude
- **Flight Results**
  - Incremental mechanical design improvements
  - Revealed lack of brown-out resilience
  - Verified system was operational at low temperature
  - Sensor and data acquisition was successful

Falcon

- **Flight Objectives**
  - Initial active parafoil descent control
  - Very low (300 meter) target altitude
  - Collect data regarding parafoil flight characteristics
- **Flight Results**
  - Inconsistent mechanical release prototype
  - Successful parafoil deployment
  - Unable to achieve steady-flight
  - Increased flight hardware and software capabilities
  - Gained knowledge of parafoil behavior
  - Payload was lost to a tree during 5th flight

Phoenix

- **Phoenix Objectives**
  - Cumulative design incorporating knowledge from Kestrel and Falcon
  - Low and high altitude flight capability
  - Stand-alone payload flight with improved guidance
  - Develop a parafoil flight characteristic model
- **Major Improvements**
  - Single battery power source and use of a custom Printed Circuit Board (PCB)
  - New primary release mechanism
  - Improved flight software error handling
  - Increased parafoil size and lift capacity
  - More rigorous testing and flight procedures

Future Iterations

- **Future Project Development**
  - *Hawk:* Ability to carry a payload train
  - *Eagle:* Culmination of RAPTOR design improvements and final product
- **Project Variant**
  - *Thunderbird:* Design for returning high-power and model rockets

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