Space Debris Net Launcher

Capture Mechanism for Uncooperative Resident Space Objects (RSOs)

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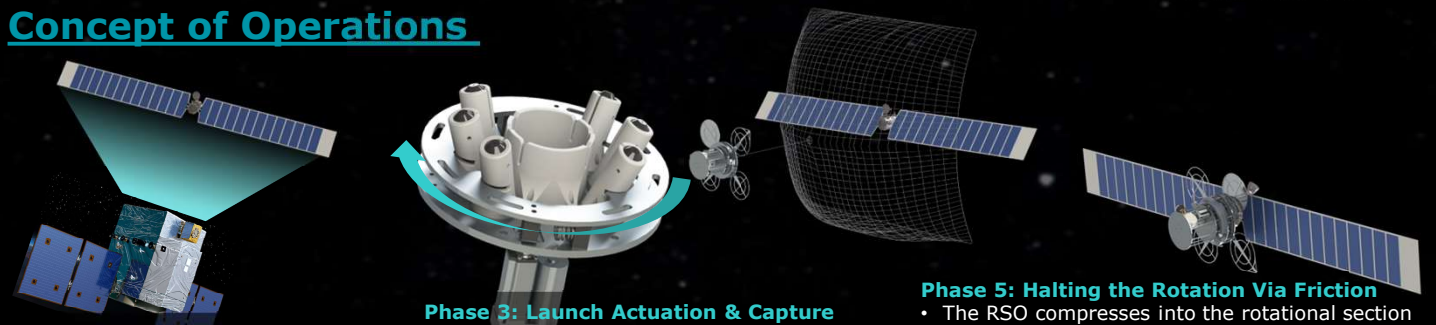
Introduction

This project aims to develop a mechanism for **identifying**, **capturing**, **damping**, and **retrieving** uncooperative **Resident Space Objects** (RSOs) to advance Sierra Space's position in **orbital debris removal**. Motivated by the threat of space debris to satellites and future missions, the solution utilizes a **spring-actuated net launcher** with **retraction** and **damping** mechanisms for controlled RSO manipulation.

Design-Driving Requirements

- ✓ *Capture **24"x28"x38"** RSO with **2 m** solar arrays.*
- ✓ *Capture RSO between **5 – 15 m** distance.*
- ✓ *Fully damp RSO in **2 axes** (6 rpm → 0 rpm).*
- ✓ *Force imparted on vehicle under **2 N**.*
- ✓ *Mechanism under **25 kg** in weight.*
- ✓ *Peak power under **1 kW** (28 ± 3 VDC limit).*
- ✓ *Hand safe for loading.*
- ◌ *Operate between **20 - 30 °C**, withstand **-25 – 60°C**.*
- ◌ *Natural frequency **≤ 80 Hz** in stowed position.*
- ✗ *Budget under **$2,000**.*

Concept of Operations



Phase 1: Approach & RSO Identification
- Use sensors to approach the targeted RSO

Phase 2: Hatch Door Release
- Top hatch doors unfold using a spring release and burn wire actuation

Phase 3: Launch Actuation & Capture
- Rotation of a toothed ring enables the preloaded springs to eject the weights
- Weights pull the net with them to entangle in the RSO

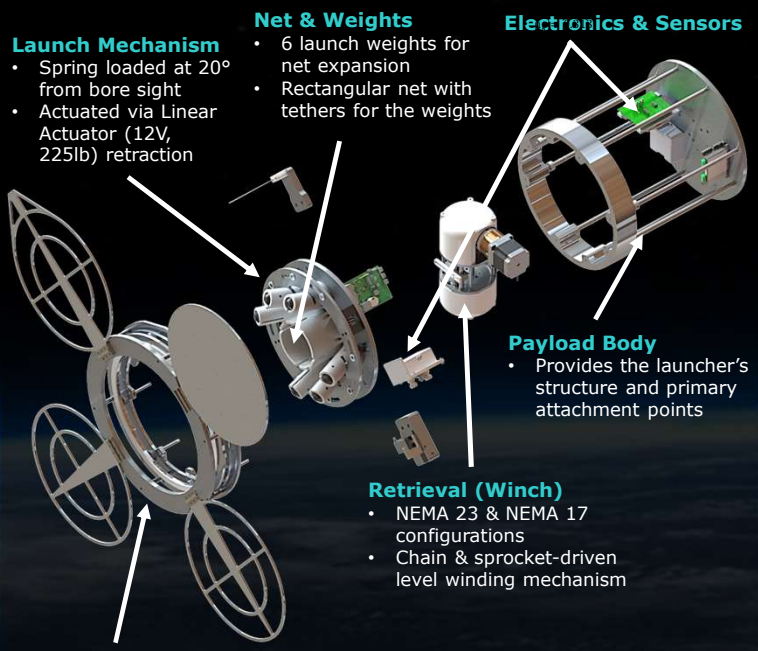
Phase 4: Damping the Rotation to 1 Axis
- Feedback loop coordinates gradual thrust maneuver to reduce rotation to 1 axis
- Sensors confirm single axis rotation, the winch begins to reel in the RSO

Phase 5: Halting the Rotation Via Friction
- The RSO compresses into the rotational section of the damping mechanism
- The force supplied by the winch retraction controls the friction force until rotation is halted

Launch Mechanism
- Spring loaded at 20° from bore sight
- Actuated via Linear Actuator (12V, 225lb) retraction

Net & Weights
- 6 launch weights for net expansion
- Rectangular net with tethers for the weights

Electronics & Sensors



Payload Body
- Provides the launcher's structure and primary attachment points

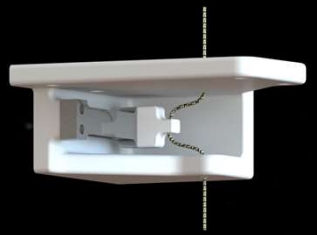
Retrieval (Winch)
- NEMA 23 & NEMA 17 configurations
- Chain & sprocket-driven level winding mechanism

Damping Mechanism
- *Dual Function*: Hatch doors and RSO damping
- Spring-resistance damps linear force
- RSO presses into damping surface with controlled applied moment to halt rotation

Electromechanical Systems

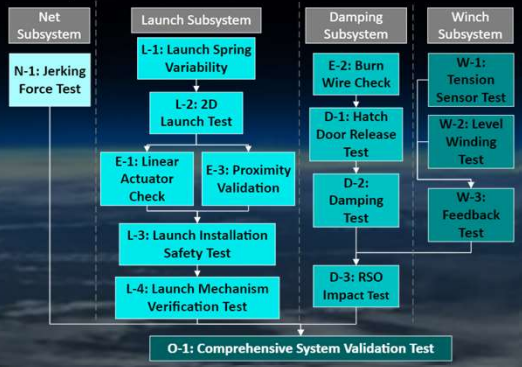
- Custom PCB
- Raspberry Pi Controls
- Custom Tension Sensor
- Control Panel
- Advanced coding implementation:
  - Proximity Sensor
  - Tension Sensor/Winch Feedback
    - PID = (0.5, 0.5, 2.3)
    - Max Motor Speed = 550 rpm

Custom Tension Sensor



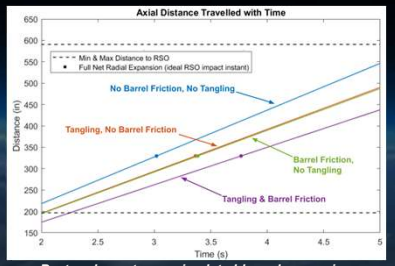
Test & Simulation Results

- **15 tests** iteratively confirmed the functionalities of the Space Debris Net Launcher:

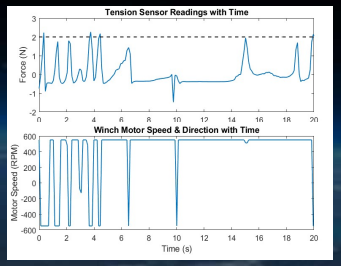


Notable Results
- Net withstands a jerking force of 22 lb
- Average exit velocity of weights**:** 179.33 in/s
- Tension Sensor accurate to ± 0.08 N
- Feedback loop keeps tension in tether at/under 2 N
- Friction present in rotational damping: μ = 0.313

Net Expansion Simulation
- Calculations predict net will fully expand to contact RSO if launched from ~26.5 ft (8.08 m) and will impact at ~3.4 s



Best and worst case simulated launch scenarios.



Sample PID Feedback results for a retraction trial.

Future Improvements

Design of "Flight Ready" Version
- Enclosed unit with proper flight hardware
- Analysis and testing of thermal and structural design

Potential Subsystem Redesign
- Use compressed air for weight launch
- Winch down-sizing

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