O.P.O.C.H.T.L.I

Orbital Pollutant Oriented Clean-Up Helped Through Laser Impulse

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Mission Purpose

O.P.O.C.H.T.L.I will monitor and detect small-sized space debris from a size range of 4 centimeters to 10 centimeters. An estimated 500,000 pieces of debris this size exist in Low Earth Orbit (LEO), posing a risk to satellites, launches, and other assets. Using a high-powered laser, this satellite will push the space debris into Earth's atmosphere over Point Nemo. Our primary objective is to monitor and track space debris from a size of 4 centimeters to 10 centimeters. Our secondary objective is to use a high-power pulse laser to send the space debris back down to Earth over Point Nemo.

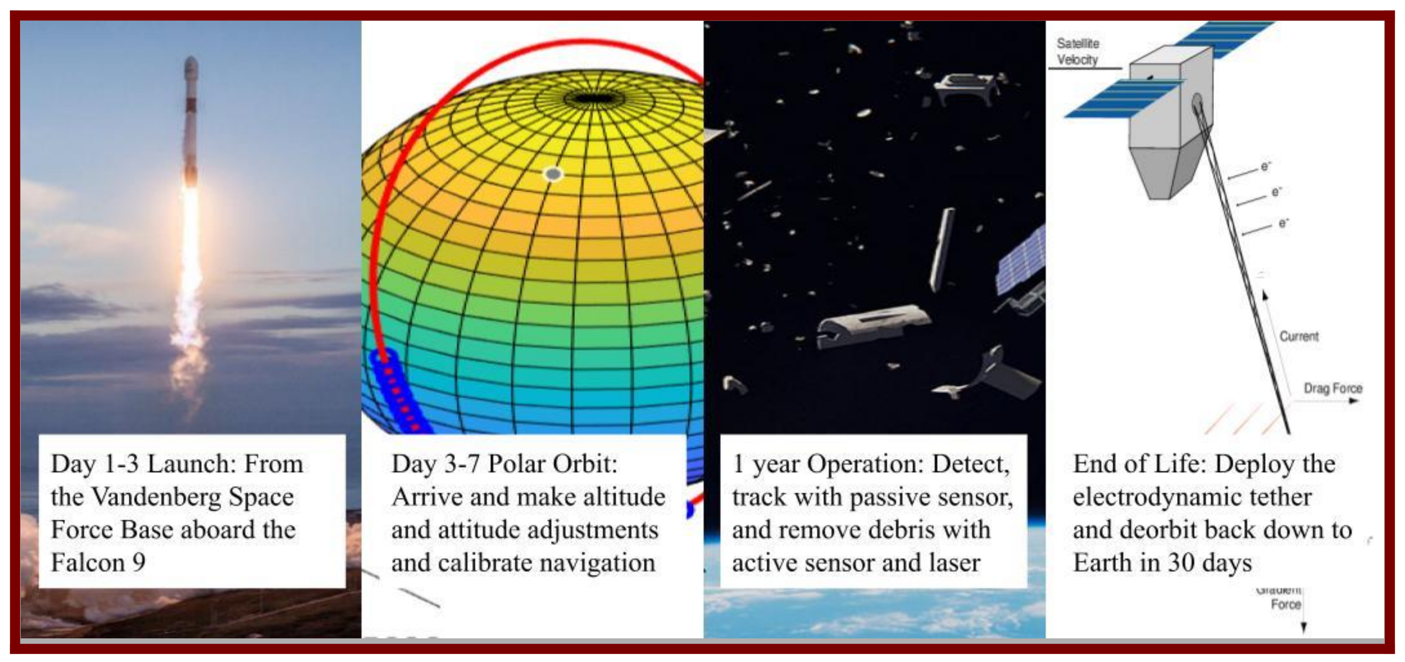
System Breakdown

Component	Mass	Power	Element	Cost
Solar Array	80.56 kg	n/a	Solar Array	31 M
Payload (Laser and Sensors)	4290 kg	21 kW	Detection and Removal	120-150 M
Electrical and Cooling System	1684 kg	15 kW	Operations	3M
Propulsion	613 kg	0.640 kW	Structures and Propulsion	270 M
Retirement	146 kg	0kW	Launch	65 M

Operational Requirements

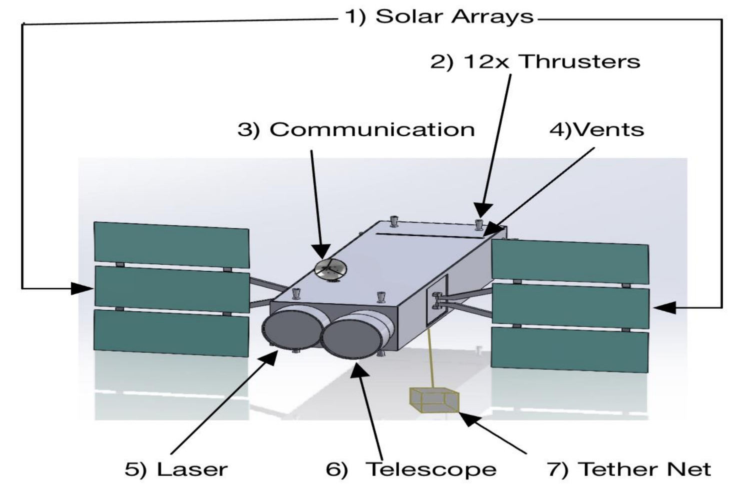
Requirements		Description
Debris Size	4 - 10 cm	We will be targeting small, hard-to-track debris
Satellite Altitude	560-960 km	This is where the highest concentration of space debris is located
Number of Debris Objects to Remove	100k pieces	Estimated that removing 100k small pieces will have great impact over time
Mission Lifetime	1 year	This gives the satellite time to monitor the debris and then allows for 4-5 months for the debris removal
Satellite Retirement	Orbital inclination below 75 degrees	To use the Electrodynamic tether the orbital inclination must be no higher than 75 degrees

Timeline



Satellite

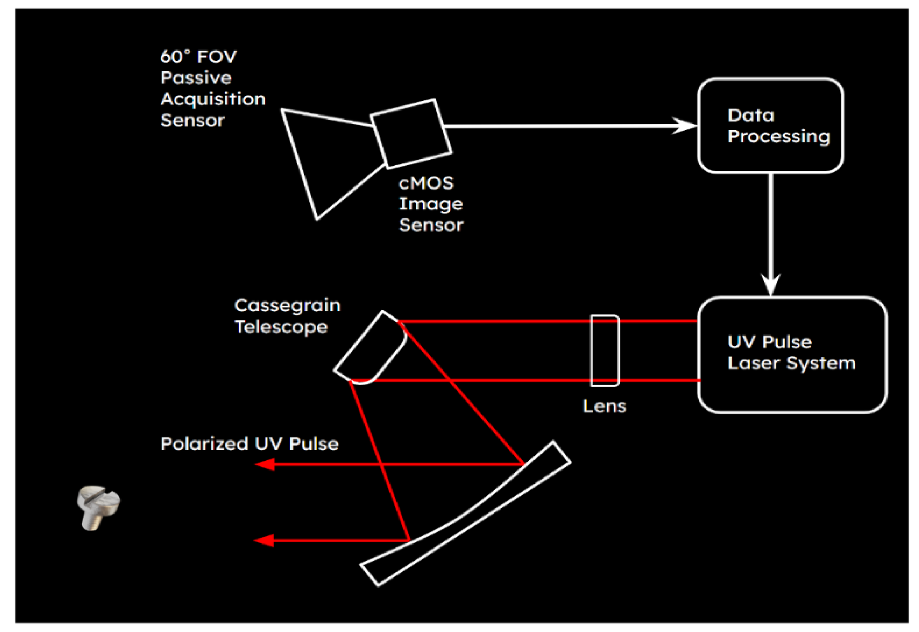
1. **Solar Arrays –** Generate electrical power from sunlight to provide energy for its operations.
2. **Thrusters** – Orient the satellite in the X,Y, and Z direction.
3. **Communication** – Transmit and receive data signals to communicate with Earth stations.
4. **Vents –** Regulate internal temperature and pressure.
5. **Laser** – Target and shoot small space debris'
6. **Telescope –** Track small space debris
7. **Tether net** – Electrodynamic tether deployed to return the satellite to Earth



Debris Removal Method

Why a laser? Most cost effective per debris removed. Most effective for dangerous small debris.

How it works: Two sensors: a catadioptric telescope and Cassegrain telescope/laser system. The catadioptric telescope works with cMOS image sensor to detect debris from a distance. The Cassegrain telescope receives debris location and has rotating mirrors which direct UV laser pulse. Momentum transfer causes debris to be pushed towards Earth where they burn up.

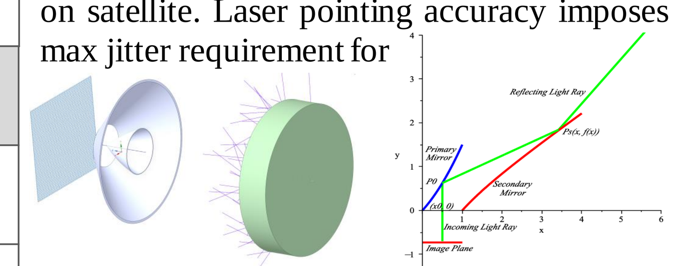


Payload Requirements

Active Acquisition Sensor Requirements	
Mass Laser System	2500 kg
Mass Active Mirror and Mounting	1000 kg
Size of Primary Mirror	1.5 m
Range	250 km
Pointing Accuracy	0.5 µrad
Field of View (FOV)	2 µrad
Wavelength	355 nm (Ultraviolet)

Laser Power Requirements	
Output Power (Burst)	21 kW
Average Pulse Energy	380 J
Pulse Repetition Frequency	56 Hz
Passive Acquisition Sensor Requirements	
Mass Passive Telescope System	790 kg
Size of Primary Mirror	1.5 m
Range	500 km
Field of View (FOV)	72 µrad

Passive sensor uses sunlight for visualization, so system runs maintenance during eclipse. Range for both sensors is at the minimum for reasonable working time of the laser. Primary mirror diameter imposes size restriction on satellite. Laser pointing accuracy imposes a max jitter requirement for



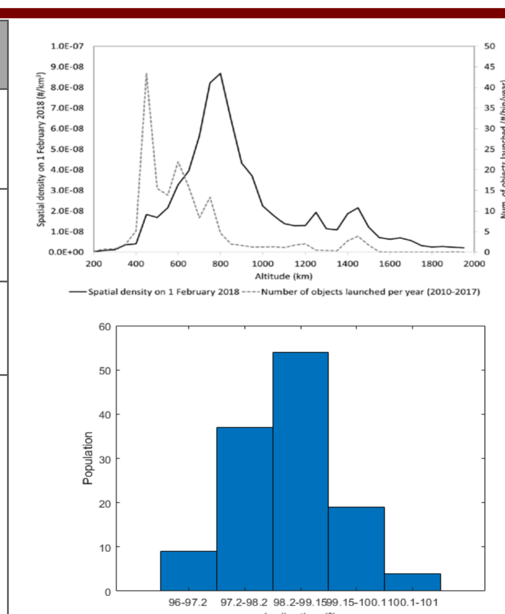
Catadioptric telescope is depicted (right) and mirrors were designed mathematically then analyzed using Ansys Speos (left).

Orbit and Debris Tracker

When deciding the orbit, we looked toward the population density of space debris. It was found that most small space debris pieces were found at an altitude of 550 to 1000 km. Additionally, it was also discovered that most of the space debris was found at an inclination between 75 degrees to 90 degrees, which fits the orbital parameters for a polar orbit.

Lastly, we were also looking for an orbit that had sufficient sun coverage to help the laser telescope system detect space debris quickly and more efficiently. By operating in a polar orbit, the satellite can have frequent contact with space debris in LEO.

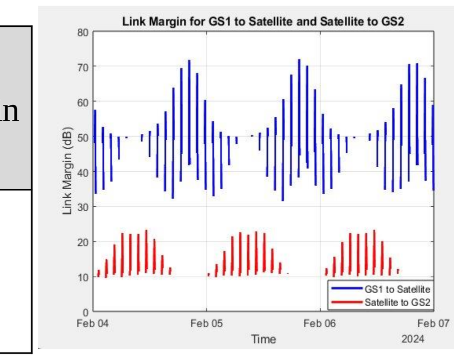
Orbit	Polar Orbit
Altitude	560 – 960 km
Trajectory	60-90° inclination of the equator
Number of Space Debris	~100.000
Detection Characteristics	Semi major axis: 7117 km Semi minor axis: 7114.2 km Eccentricity: 0.028 Inclination: 75° Eclipse duration: 31.8 min Time Period: 99.6 min



Communications

To maintain constant communication, the satellite will use two KSAT ground stations, SvalSat in Norway and Trollsat in Antarctica. It was found that having two ground stations was sufficient for having total communication coverage.

	Frequency	Power	Antenna Diameter	Link Budget	Margin
KSAT S Band	2.2 GHz	3.0 W	0.2 m	25.9 dB	10.9



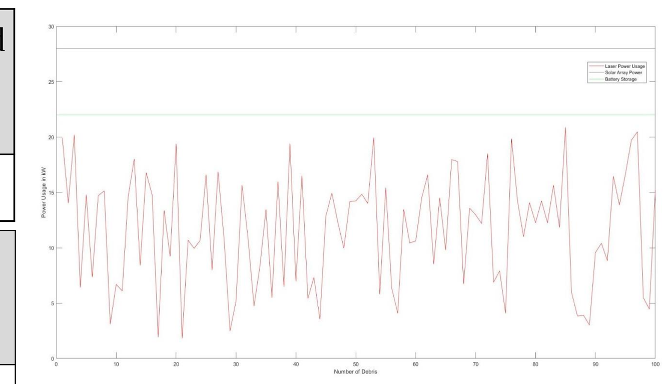
Power

OPOCHTLI will require a maximum power of 22 kW during operation.

Solar Array Power Output (W/m²)	Solar Array Size (m²)	Power Produced by Solar Array (kW)
22	58	28

Maximum Battery Storage (kW)	Number of Lithium-Ion Batteries	Time to Charge Batteries (min)
22	115	25.6

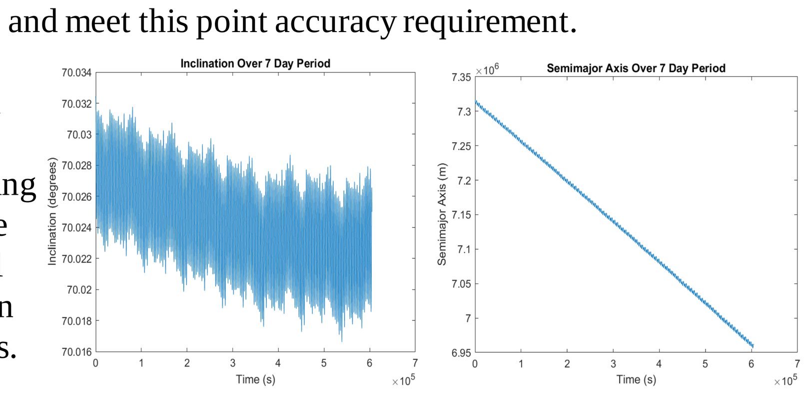
Example of power usage for removal of 100 pieces of debris



Guidance, Navigation, and Control

The purpose of our Attitude Determination and Control system is to actuate the satellite to its desired orientation. It will utilize a sun sensor and an inertial reaction unit to determine the satellite's orientation. The telescope places a requirement of 0.5 µrad or 0.103 arcsec of pointing accuracy on the ACDS. The gain of the reaction wheels was analyzed to ensure they can overcome the torque caused by gravity and meet this point accuracy requirement.

The on-board propulsions systems will be responsible for maintaining the satellite's target orbit as well as providing supplementary control authority for the ACDS. The degeneration of the orbital characteristics of the satellite have been simulated to estimate fuel requirements.



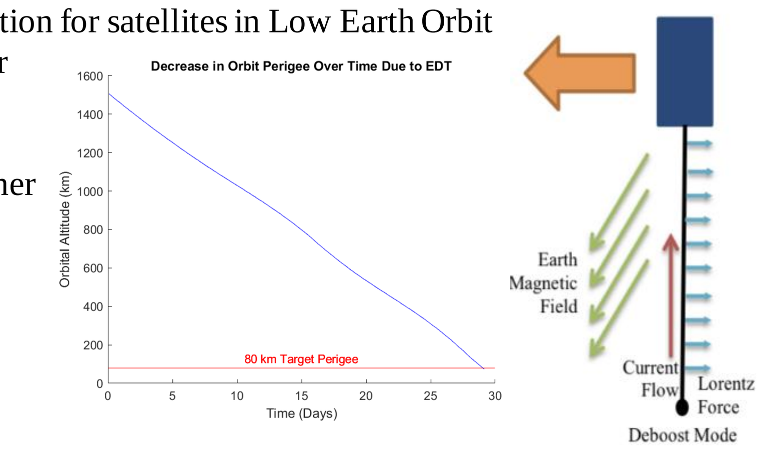
Retirement

Importance: Comply with FCC regulation for satellites in Low Earth Orbit and not contribute to more space clutter

Strategy for De-orbit: Using an Electrodynamic Tether, deorbit the Satellite by extending a 10 km long tether which will deorbit the satellite within 30 days.

Why an Electrodynamic Tether?

- 24x faster deorbit time
- No need for reserve fuel to deorbit
- Small mass requirement



Acknowledgements

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