Near Real Time Space Debris Tracking Using Lidar Onbard a Spin Stabilized Cubesat

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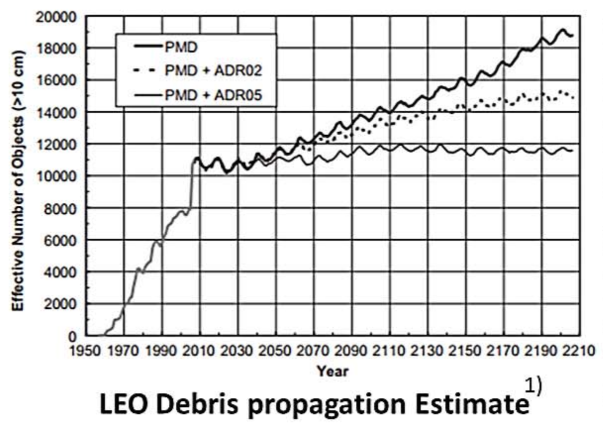
Background & Motivation

Increase in Debris Population



LEO Debris propagation Estimate[1]

Space debris are objects orbiting around the Earth including rocket debris, rocket bodies, payloads and payload mission related debris. Currently space objects in orbit are mainly being tracked by the United States Space Command in the Two-Line-Element(TLE) catalog are mainly maintained by the Space Surveillance Network(SSN). The TLE catalog is currently being maintained using ground based tracking facilities.

Numerical Studies have shown that the debris environment in the low earth orbit will continue to increase even without any additional launches to orbit, which will be caused by mutual collisions among orbiting objects. This means that the debris environment will change rapidly and there is a need for an ability to detect and to be able to respond to a changing debris environment.

Limitations of Ground Based Debris tracking systems

1) Ground based facilities require the object to be tracked to pass overhead. Currently tracking facilities use radars or optical measurements to track space debris, which requires the object to fly overhead.

2)Distance of target to tracking facility is relatively far

3) Detection should be through the atmosphere

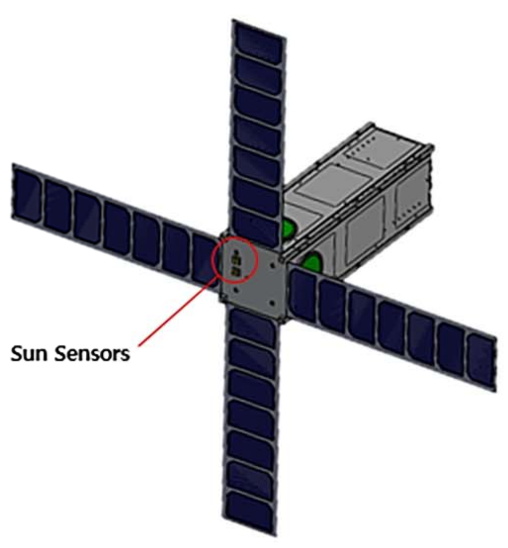
Mission Objectives

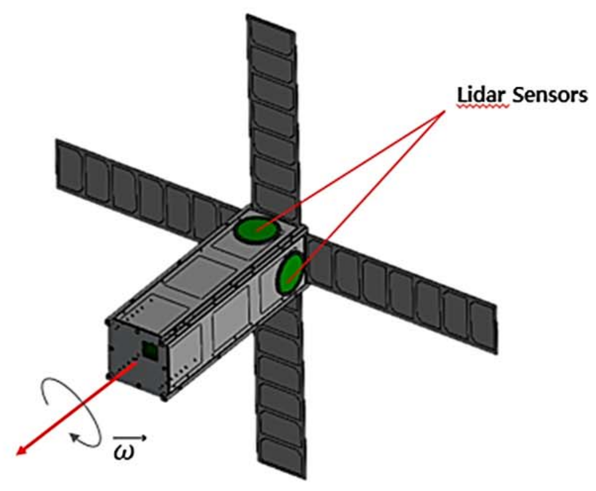
1. Demonstrate a lidar tracking constellation based on small satellites
2. Study feasibility of a lidar in space for space debris tracking
3. Demonstrate the measuring accuracy of detecting space objects using lidar

Need of Space Based Debris Tracking System

1. Pre-detection of Space debris as an support system for ground based tracking facilities
2. Fast detection of newly propagating debris
3. Decentralize the space debris tracking process

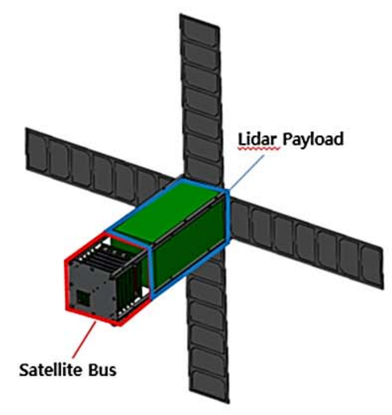
Space Segment



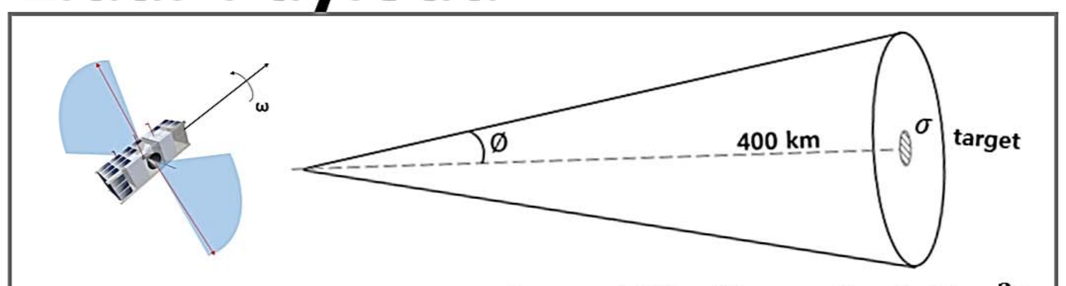


Mass	<4.00kg
Dimensions	100 × 100 × 227mm
Power Generation	29.2W

- 1U satellite bus, 2U Lidar payload
- Attitude Control is done by onboard reaction wheel for nutation damping
- Satellite spin axis is pointing towards the sun
- Spin Rate 1rev /s

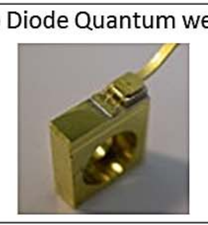


Lidar Payload



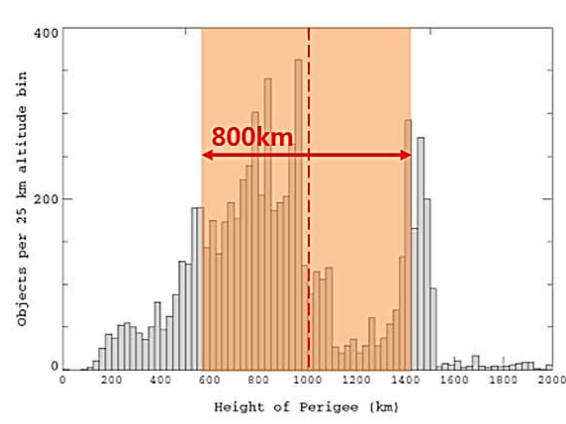
$$R = c(t_1 - t_2)$$

Range 400km(Target Size 0.01m^2)
Travel time <4ms

Laser Medium	GaInAsSb Diode Quantum well Laser 
Beam divergence Angle	2 μ rad
Wavelength	3030 nm
Detector Telescope Diameter	55mm
Detectability	1 (Assumption) $N_{pr} = \frac{E_p \sigma \rho \lambda A_{tel}}{hc\pi^2 R^4 \tan^2\phi}$
Energy per pulse	2.8mJ
Speed	350 Pulse/s
Power Consumption	9.8W (2 Onbaord)

Environment

Debris

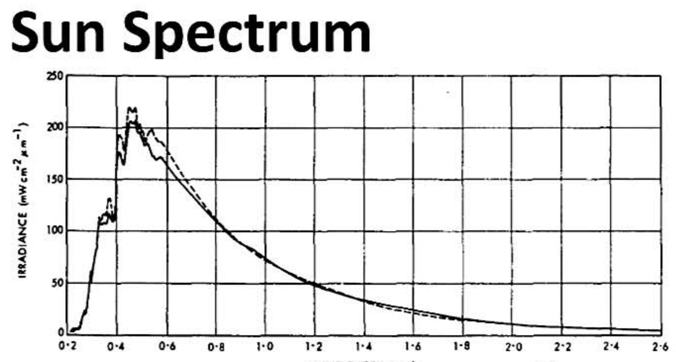


Lidar detection 400km Range (600km ~ 1400km Altitude)

Detects Debris and potential debris for satellites orbiting below 1000km

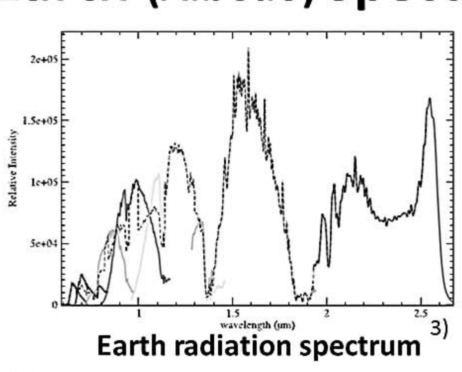
Space Station : 330 km~435 km

Sun Spectrum



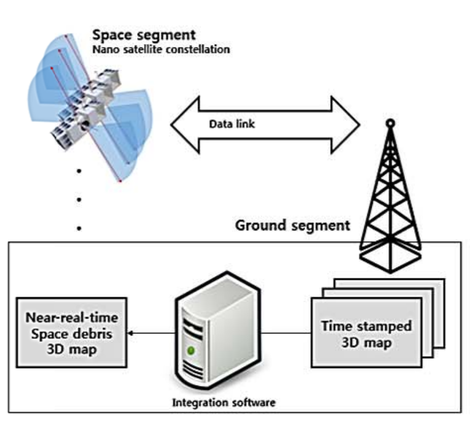
Solar radiation spectrum[2]

Earth (Albedo) Spectrum



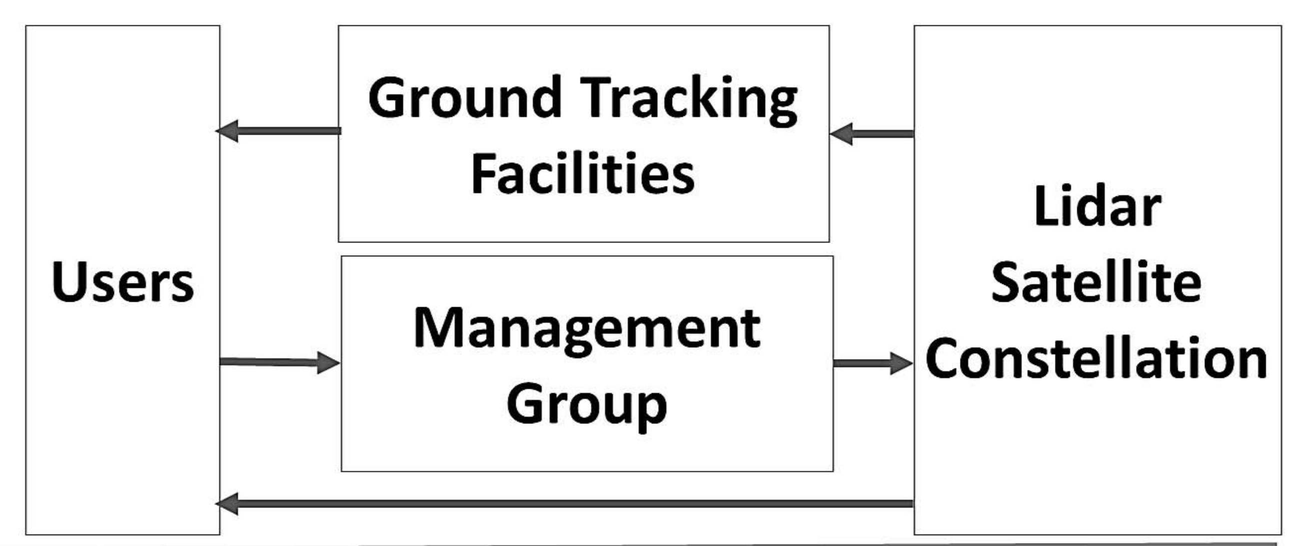
Earth radiation spectrum[3]

Orbit & Constellation



Deploy on potentially hazardous orbit of interest

Implementation Plan



Reference

1) Liou, J-C., Nicholas L. Johnson, and N. M. Hill. "Controlling the growth of future LEO debris populations with active debris removal." Acta Astronautica 66.5 (2010): 648-653
2) Thekaekara, M. P. "Solar energy outside the earth's atmosphere." *Solar Energy*14.2 (1973): 109-127.
3) Turnbull, Margaret C., et al. "Spectrum of a habitable world: Earthshine in the near-infrared." *The Astrophysical Journal* 644.1 (2006): 551.
4) Klinkrad, Heiner. Space debris: models and risk analysis. Springer, 2006.
5) CubeSat Design Specification Rev.13, The CubeSat Program, Cal Poly SLO