Title: Real time space debris tracking using LIDAR onboard high spin stabilized Cubesat
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Need

Space debris are objects orbiting around the Earth including rocket debris, rocket bodies, payloads and payload mission related debris. Due to the high speed space debris moving in orbit, debris can be fatal for space systems. To avoid collisions with debris, planning a mitigation plan and tracking the debris is very important in carrying out space missions. There has been a dramatic increase in space debris in the LEO as the number of small satellite launched has increased in the last couple of years. Currently tracking information is provided by a few organizations such as the North American Aerospace Defense Command (NORAD), ESA Space Debris Telescope, TIRA system, etc. These facilities are based on ground tracking facilities. As only a few organization provides tracking information, tracking data that is not within the organazation's interest may not be accurate. Moreover, ground based tracking facilities are large and costly to maintain.

Space debris tracking based on space is advantageous as space debris can be tracked using relatively small power. There is a need to decentralize the process and make the space tracking data more open to everybody. This can be done by developing a space based low cost platform tracking space debris. CubeSat based small satellite is proposed to track space debris in real time using LIDAR which will be capable of providing near real time 3D mapping data of space debris.

Mission Objectives

Real time space debris tracking using LIDAR onboard a high spin stabilized cubesat mission is proposed to demonstrate the feasibility and the performance to track and monitor the low earth orbit debris in near real time. Mission objectives are as below.

1. Demonstrate a lidar mapping network based on the high spin rate spin stabilization of the satellite bus
2. Study on the feasibility of a lidar in space for space debris tracking
3. Demonstrate the measuring accuracy of detecting space objects using lidar

As the satellite has lidar onboard, we name the satellite lidarsat.

Concept of Operations

Space based lidar tracking system is more advantageous as the attenuation of laser by the atmosphere is small, a longer tracking range can be established by smaller power.

Lidar data is stored onboard the satellite as a 3 dimensional positions of objects around the satellite respect to time. The data is downlinked to the ground station on the pass. The 3D mapping data is downlinked from the space segment to the ground station which the map sent from 14 different satellites are integrated in to one big map. To reduce the lead time of receiving the mapping data, multiple ground station networks are needed.

The constellation shall be deployed to the orbit in interest to detect potential threats for future launches or current operations of satellites. The orbit will be of altitude 600km polar orbit as the interest region to track debris is 300~1000km shown in figure 2.

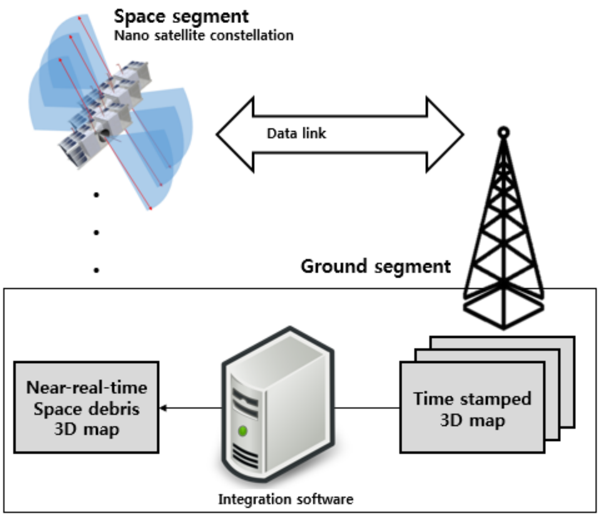


Figure 1 System overview of Lidarsat

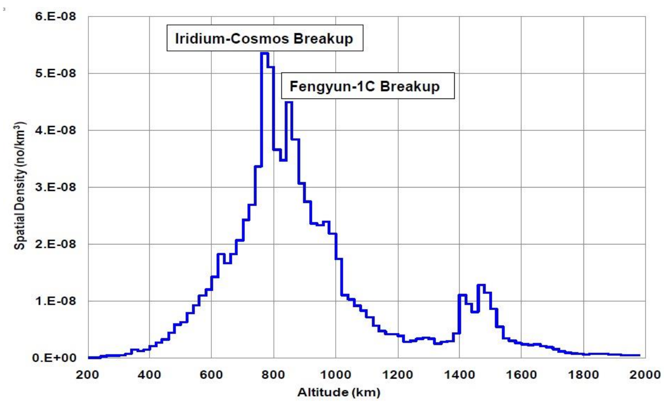


Figure 2 Spacial density of LEO space debris by altitude according to NASA report to UNOOSA of 2011[1]

Key Performance Parameters

For reference, we refer the specifications of the lidar sensor developed matches the HDL-32E lidar sensor which is being manufactured by Velodyne. The assumption is made that as the satellite can spin, the sensor can eventually fit in the satellite. The specifications for the sensor is written on the table below.

1

Laser	- 905nm wavelength=
Sensor	- 32 laser/detector pairs - +10.67 to −30.67 degrees field of view(vertical) - 10Hz frame rate - operating temperature -10° C to +60° C - Accuracy: <2cm (one sigma at 25m)
Output	- Approximately 700,000 points/second
Sensor Weight	- 1.3kg(with housing)

1. Tracking resolution

Sampling rate of the sensor is critical in defining the resolution of the sensor as satellites move in high speed and the detecting objects are far away in space. The sampling rate is 70,000 points per second. Resolution shall be smaller than 10 cm in 400km distance to be able to track CubeSats.

2. Field of view

Field of view of the lidar sensor is important to define the spin rate and the tracking range of the satellite. The field of view from the HDL-32E which is +10.67° to -30.67° degrees. This is because the HDL-32E was developed to be used in ground based systems. Lidar sat shall use a lidar sensor with a field of view of ±10°. The sensor will track space objects of distance 10km~400km.

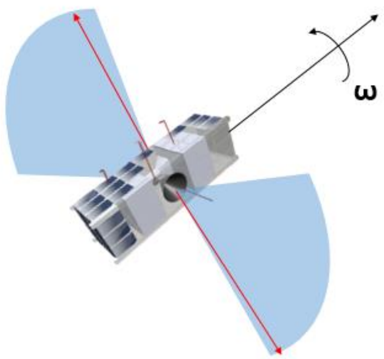
3. Spin stabilization accuracy

The attitude is important as a small angle of nutation may result in a big instability in the field of view. Thus, it is important that the satellite is well balanced and within the constellation have a good accuracy of spin stabilization.

4. Position estimation accuracy

As the satellite is measuring the relative position of space debris along the orbit, it is important to know precisely where the satellite's position is.

Space Segment Description



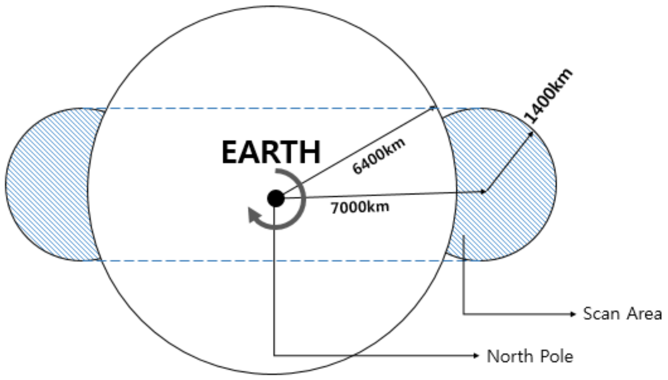
The satellite is based on a 3 unit Cubesat which has no deployables that can cause dynamic instability or vibration from the high spin rate of the satellite. The satellite bus is equipped with two lidar sensors on each sides. The satellite is spun along the z axis which is aligned with the pole direction of the earth. This is to maximize the scan area as the spin axis may stay aligned throughout the orbit.

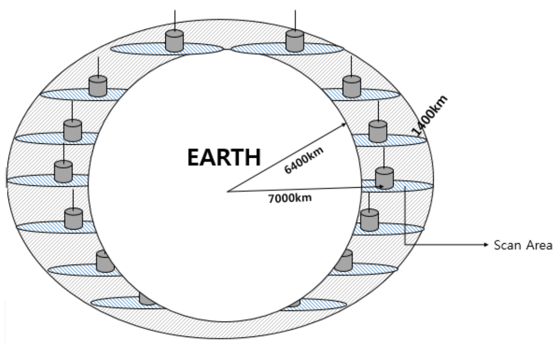
The 3D data is stored as 70,000 points per second, which a single orbit takes 1hour 37 minutes, results in 6.79*10^10 points. The data is stored as distance of the detection points which the resolution shall be smaller than 10cm in 400km range. Thus, distance data shall be stored in a data form bigger than 22bits. Assuming each point is saved in a data form of 22bits, the amount of data generated by the satellite is 186.73 Gbytes. This data shall be downlinked through on a single pass. The data is too large to downlink on a single pass, so that the data shall be compressed. The data is compressed by not sending the values that has a null value. The density of the number of space debris of the 600km~1000km orbit is around 9*10^-8 no/km^3. As the scan volume of the lidarsat on a single orbit is 2.2108e+10km^3. According to the density, the predicted interest points that shall be detected by lidarsat is 2000 points. This results in 5.5kbytes of data from a single orbit.

Assuming the spin axis to be aligned with the spin axis of the earth, the maximum translational velocity in the spin axis direction is 7.54km/s at 600 km altitude circular orbit. Thus, to scan the space debris without losing it while the field of view is rotating along the satellite, The satellite shall be able to rotate faster than 1 rev/s.

Orbit/Constellation Description

Real time space debris are tracked using lidar sensing onboard the satellite which the information is gathered using a constellation network of satellites. The satellites itself. This is done by storing the 3-Dimentional data onboard the satellite and downlinking the raw data which the data will be processed on the ground. The constellation network consists of 14 satellites in the same orbit having the same rotation axis.





The orbital plane of the satellite shall include the spin axis of the satellite. This way, the satellite can maximize it's scanning area around earth orbit. This way, the satellite will have a 3D model of objects floating around earth with 7 layers which the layer spacing will be with 6.9 minutes interval.

Implementation Plan

Currently space debris tracking is mainly dependant to large organizations. This is because space debris tracking from ground requires complex and expensive equipments and significant amount opreating of cost. This is not good as the priority of interest objects to track is determined within the organization which other organizations may suffer. For example, Cubesat tracking TLE datas are relatively inaccurate comparing to commercial satellites as the tracking update rate is slower.

A real time space based lidar system is a cheap and more accurate way to monitor space debris. The cost for the lidarsat network will be much cheaper with a higher update rate compared to the ground based tracking facilities.

The network involves a lot of ground station networks and satellites. This shall be implemented by a joint work of universities, institutes so that the space debris tracking data shall be more open and accessible.

Risks for the project may be of the accuracy and the identification of space debris. Lidar scanning data will not provide the identification of objects.

References

(1) "USA Space Debris Envinronment, Operations, and Policy Updates". NASA. UNOOSA. Retrieved 1 October 2011

(2) V.Riot(2012), Tracking space debris from space, Science Technology Review April/May 2012