Market for High Precision Debris Data

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Abstract

Debris objects in Earth orbits constitute 95% of the published catalog and are responsible for most conjunctions with operational satellites. It is generally recognized that the accuracy of published two-line element (TLE) data is not sufficient for conjunction analysis, and that much more precise data is needed to ensure the safety of commercial and civil spacecraft. National surveillance networks have more precise data on certain objects, but it is typically restricted and not readily available. It is also limited in scope because of limited coverage of particular networks. Sharing of precise data between national catalogs is not easily achieved because it could reveal capabilities of military sensors. Besides tracked debris objects, there are many times more debris fragments that are not tracked by national surveillance networks, but can disable spacecraft. They need to be discovered and tracked. This, however, will overburden the existing military space surveillance sensors.

A number of new tracking methods, technologies, and systems have been developed recently and more are in development by the industry. It has been shown that impressive accuracies can be achieved even with small telescopes, resulting in state vector estimations up to two orders of magnitude more accurate than derived from TLE data. Traditionally, commercial players will be attempting to sell these technologies and systems to their governments. Some of them will be absorbed by national surveillance networks, and data produced by the new instruments will become restricted, as dictated by the defense functions of these networks.

Debris data, however, has a much wider market. This market was essentially created when NORAD started publishing TLE data, but it is still overlooked. Cued by TLE data, commercial entities can produce very precise orbital data on debris, which dominates the published catalog. There is no inherent reason why debris data obtained by commercial instruments outside surveillance networks may need to be restricted, and all national space agencies will benefit greatly from having such data, because they do not have comprehensive sets of high precision debris data at this time.

Thus, we have potential interested buyers and potential capable sellers. What is missing is a legitimate trading floor for high precision debris data. The debris threat is indiscriminate, and spacefaring nations can recognize neutrality and utility of this solution and find a suitable form of its implementation. This will be a potent measure for debris threat mitigation. IADC could lead the way, or the industry could create this market on its own.

New Initiatives

- Commercial Space Operations Center (ComSpOC) by AGI aims to provide commercial and civil satellite operators with a variety of space situational awareness services, including conjunction analysis. ComSpOC has essentially jump-started the market for observation data by creating a commercial demand for it. The data supplier chain is still emerging.
- ExoAnalytic Solutions offers now a software suite called ExoAnalytic Space Operations Center (ESpOC). It can process and interpret optical data from small telescopes in real time. and will allow any company or organization to build their own data processing pipeline.
- The USAF Academy Center for Space Situational Awareness is deploying its Falcon Telescope Network that will involve twelve universities around the world. It is stated that besides university students, K-12 educators will be able to submit observational requests to the network, and there will be a database of publicly available images.
- International Scientific Optical Network (ISON) currently joins 35 observation facilities of various affiliations with 80 telescopes in 15 countries. The network is open for new members and collaboration. The primary focus is on GEO, Recently, ISON has started deploying specially designed mini-observatories.
- A consortium of Lawrence Livermore National Laboratory, Naval Postgraduate School, and Texas A&M University started deploying its Space-based Telescopes for the Actionable Refinement of Ephemeris (STARE). The goal is to have a constellation of 18 3U Cubesats in low Earth orbits observing objects that are predicted to have close conjunctions with valuable assets.
- Canadian Space Agency launched its Near Earth Object Surveillance Satellite (NEOSSat) carrying a 6" telescope. One of the mission goals is to observe and track debris objects in high orbits.
- And many others—the area of space situational awareness is very dynamic and is rapidly transforming.

Coverage Analysis

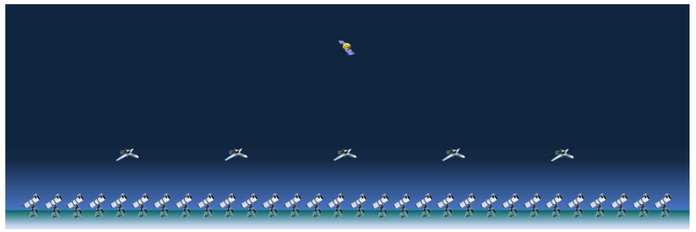

Fig. 1. The coverage pyramid: from 30 ground sites to 5 UAVs or 1 spacecraft

- A sample international network of 30 ground sites distributed over all continents except Antarctica, with weather being suitable 40% of the time, will observe on average 96% of the cataloged LEO debris objects daily. The average number of viewable passes per object per day varied from 4.1 in summer to 6 in winter. In many cases, the daily coverage was as high as 98-99%, but in other cases, it dropped below 90%.
- An optimally balanced 5-UAV configuration consists of two UAVs near 50°N, two UAVs near 50°S, and one near the equator, all spread longitudinally. They will provide 98% daily coverage of the LEO debris, with an average number of viewable passes per object per day varying from 4.5 in summer and winter to 6.5 in spring and fall. UAVs can be solar planes.
- If the optical instruments were placed on ISS, they would see 96% of the LEO debris daily, with an average of 5.8 viewable passes per object per day. From a satellite in a high-inclination orbit at 500 km, the instruments will see close to 93% of the LEO debris daily, with an average of 6 viewable passes per object per day.
- All these configurations can provide full coverage of debris in high orbits as well.

Optical Instruments and Data

- Rocket bodies and satellites in LEO can be tracked even with 4" telescopes and debris fragments larger than roughly 10 cm can be tracked even with 6-8" telescopes. Such telescopes with computerized mounts are available off-the-shelf and are owned by many.
- An arcsecond level of observation data precision has been demonstrated for small apertures.
- To capture at least three data points for every viewable pass of every cataloged debris object, the data acquisition rates should be ~1 data point/sec for the ground sites, ~2 data points/sec for the airborne platforms, and ~3 data points/sec for the spacecraft. These rates will go up with time, as more debris fragments are discovered and cataloged.
- As a more efficient alternative to conventional telescopes designed for astronomy, we have considered specially designed optical instruments that are optimized to perform the task of debris tracking with arcsecond precision and achieve high throughputs in all configurations described above.
- The new design substantially relaxes restrictions on the attitude motion of the airborne platforms or spacecraft carrying the instruments.
- A set of six instruments mounted on a common platform could satisfy the coverage requirements for ground sites and airborne platforms. Each instrument will be assigned its observation sector.
- A candidate layout of a space-based debris tracking system contains twelve instruments. Once the astrometric data is extracted, the images are discarded. The data points are sent to the ground frequently to calculate state vectors by fitting the orbits to several days of data.
- There could be two or three such spacecraft placed in different orbital planes in LEO for better coverage. A constellation of three spacecraft could produce over half a million observation data points every day, densely covering debris in the current catalog.
- In the most populated regions of LEO, state vector estimations at the time of the last measurement could be accurate to a few meters in position and a few mm/s in velocity—incomparably better than from the published TLEs.

Discovering Untracked Debris

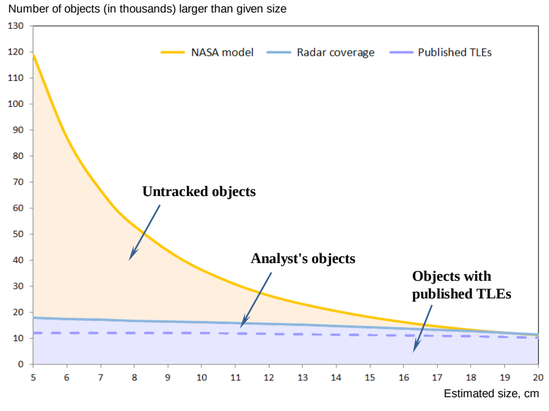

Fig. 2. Distribution of LEO debris objects by size

- Radars miss a substantial fraction of debris objects in the 10-15 cm range and a much larger fraction of objects smaller than 10 cm, but even sub-centimeter fragments can seriously damage spacecraft.
- There are tens of thousands of untracked debris fragments in the 5-15 cm range in LEO detectable by small telescopes, and there are methods to discover them.
- Even without new collisions, the existing catalog is set for an explosive growth due to the discovery of many thousands of currently untracked debris fragments.

The Market

- The markets for SSA products and services already exist, but they are in most cases restricted to national marketplaces because of national security concerns.
- It is time to recognize that the debris threat is indiscriminate, and that high precision debris data obtained by commercial sensors outside of the military surveillance networks can be traded globally to the benefit of all spacefaring nations.
- One of the primary concerns has been that high precision data on operational military satellites could also be acquired and distributed. To address this concern, consider a stock exchange as a legal regulated trading model. Let us say we have a hypothetical Debris Data Exchange that operates like a stock exchange, where all cataloged debris objects are listed for data trading, but operational satellites are not listed. In this environment, you can buy and sell only debris data, but cannot buy or sell data on operational military or other satellites simply because they are not listed.
- Another common concern is the quality of the data. This concern can be addressed by cross-verification of data from different providers and by a due process of certification of the data providers.
- All spacefaring nations want to have their own catalogs to support their missions, and their space agencies should be very interested in acquiring accurate debris data.
- Commercial operators may become indirect buyers through organizations like Space Data Association or ComSpOC providing conjunction analysis for them. Universities may obtain data for research purposes.
- The members of the Inter-Agency Space Debris Coordination Committee (IADC) stated their concern about the debris problem and could therefore be expected to at least support the development of a global market for debris data, or lead the way in its creation.
- Or the global market for debris data can shape itself, as it happened in many other areas.