

Two Years of International Cooperation on Conjunction Mitigation

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Abstract. In an effort to mitigate the risks associated with satellite close approaches in the geostationary belt, several satellite operators came together in early 2008 to establish what is now known as the GEO Data Center. The GEO Data Center initially provided a framework for satellite operators to share orbital data for their fleets of satellites to be used to perform conjunction analysis and provide automated notification of close approaches via the SOCRATES-GEO system. After two years of operations, the GEO Data Center now has 14 members providing data for 184 satellites. Since the Iridium 33-Cosmos 2251 collision, a parallel system was set up with a LEO Data Center, which already has six members providing data for 101 satellites. These data centers have already shown the significant benefit of sharing orbital data, particularly in terms of reducing positional uncertainty and, thereby, the number of false alarms.

This paper will address the current framework for these efforts, highlighting how a service-oriented architecture is used to support orbital operations and increase efficiency of analysis and resolution of risk-mitigation tasks. It will show how the interactive work flow is used to quickly assess new maneuvers to determine whether they have successfully reduced the chances of a particular close approach without causing other close approaches elsewhere.

It will also show how independent space situational awareness organizations are being employed to provide a more complete picture of the threat from non-participating satellites and the debris population. Finally, a discussion of the ongoing research efforts to support further *improvements in space situational awareness will be addressed*.

INTRODUCTION

By now, we all have seen the statistics: Since the beginning of 2007, the number of objects in the public satellite catalog has grown from 10,136 objects in Earth orbit to 15,571 today—a 50 percent increase in less than three years. Over 80 percent of these new objects are the result of just two events: the January 2007 Chinese test of an anti-satellite weapon against FengYun 1C (2,841 objects) and the February 2009 collision of Iridium 33 and Cosmos 2251 (1,740 objects). As of today, only 3 percent of these debris objects have decayed from orbit and many will remain in orbit for decades or centuries to come, creating a continuing hazard for space operations.

In fact, the debris from these two events have already considerably complicated operations for satellite operators in low-Earth orbit—operating constellations such as the Iridium, Orbcomm, and Globalstar communications networks and many Earth resources satellites. For Iridium and Orbcomm alone, these debris now account for 50–60 percent of all predicted close approaches, or *conjunctions*, within 5 km of their satellites—or more than double the number from before 2007.

Obviously, the space operations community needs to work together now to reduce the likelihood of similar events happening again.

The good news is that the international community has already been working together since early 2008 to share orbital data with the goal of mitigating the risk of additional on-orbit collisions. In order to understand the benefits of this collaboration and see how to improve its effectiveness, we will need to first understand the limitations of today's space surveillance systems for helping to avoid conjunctions and how data sharing can overcome some of those limitations.

BACKGROUND

The statistics provided above were derived from the public data released from the US Space Surveillance Network (SSN) catalog. That network is a collection of dedicated, collateral, and contributing radar and optical sensors designed and built in the 1960s, 1970s, and 1980s for an entirely different purpose than collision avoidance—to track Soviet satellites and detect incoming ballistic missiles. To perform these missions, the radars of the SSN were designed to be capable of tracking objects 10 cm or larger in low-Earth orbit (LEO; out to 5,000 km) while the optical sensors (telescopes) are capable of tracking objects 1 meter or larger in geostationary orbit (GEO; around 36,000 km).

With these capabilities, the SSN currently tracks over 21,000 objects. Only 15,000 of these objects are in the public catalog, however, and available to satellite operators for screening close approaches with their satellites. The remaining 6,000 objects are kept in a separate catalog because they need additional work to refine their orbits and define their origin.¹ And NASA currently estimates more than 500,000 objects in Earth orbit 1–10 cm in diameter—each more than capable of disabling a satellite in a hypervelocity impact—few of which can be tracked by the SSN.²

To further complicate the problem, the SSN was specifically designed to use non-cooperative tracking—that is, tracking each space object without any type of active cooperation from the object itself. In order to provide tracking on as many objects as possible, the SSN obviously cannot rely on cooperative tracking from debris or satellites whose operators may not wish to cooperate. Non-cooperative tracking works reasonably well for debris objects, but presents significant limitations when tracking operational spacecraft, since this method must detect and process maneuvers after the fact—resulting in delays in providing updated orbits. And detecting maneuvers on GEO satellites can be even more challenging, since current ground-based optical systems are not capable of day-night, all-weather operations—potentially delaying the acquisition of observations immediately following a maneuver. Under such conditions, satellite orbit estimates can degrade, resulting in the SSN being unable to associate new observations with the correct satellite (cross-tagging) or even 'losing' the satellite. As a result, even the objects that can be tracked by the SSN may not be tracked accurately enough to provide satellite operators confidence in their conjunction predictions.

Given the current state of affairs, it would seem that there is little that satellite operators can do to protect their satellites. Yet, we will see that a more thorough review of existing complementary capabilities suggests that parts of the problem can be addressed through collaboration, freeing up more capable resources to focus on the particularly challenging aspects of providing improved space situational awareness (SSA).

METHODOLOGY

As with any complex problem, the solution to this problem will not be simple. There are many facets to improving SSA which provide opportunities to quickly leverage existing capabilities to move toward immediately mitigating the risk of on-orbit collisions. A judicious approach of starting with the most immediate opportunities, while identifying potential ways to address other shortcomings, should achieve the most expedient results.

We can begin by turning one of the primary limitations of the current SSN into an advantage by realizing that while each maneuvering satellite can be difficult to track using noncooperative tracking, that each of these satellites is operational—which means that there is an operator responsible for maintaining its orbit. Satellite operators must maintain accurate orbits for their satellites in order to be able to plan state-of-health contacts and support anomaly resolution, thermal and power management, attitude maintenance, and periodic orbit adjustments. In most cases, today's satellite operators use active ranging or onboard GPS to provide orbits, which have been shown to be an order of magnitude better than non-cooperative tracking can produce, and which ensure the proper identification (correlation) of the observations. And, of course, the satellite operator knows when maneuvers are planned to be conducted and what the post-maneuver nominal orbit should be.

In fact, this realization was the basis for establishing the current international data center, operated by the Center for Space Standards & Innovation (CSSI) on behalf of its members. The data center supports 20 satellite operators from at least 12 countries, as seen in Table 1. CSSI screens over 280 of their satellites—in both LEO and GEO—which represents over one-quarter of all operational satellites in Earth orbit. These conjunction screenings are automatically performed twice each day, using the best orbital data available, and take just over 20 minutes on a standard desktop computer. Each operator provides their own orbital data—including planned maneuvers—to CSSI for these conjunction assessments. CSSI ensures that all data is correctly transformed to standard orbital data formats for subsequent use. When combined with SSN data for non-member satellites and debris, it provides the best overall SSA for screening close approaches available today.

Operators are able to specify threshold conditions and values to be used in providing automated warnings (e.g., any object coming within 5 km of any of their satellites). Operators have full access to the conjunction analysis in a secure online system, which includes the orbital data used for the conjunction assessments, so that they can quickly and reliably perform additional analysis to determine whether they wish to perform a collision avoidance maneuver and what the most efficient maneuver would be, based upon their mission requirements.

Table 1. Current International Data Center Participants

Operator	HQ	Satellites	Operator	HQ	Satellites
Intelsat	Bermuda	61 GEO	Optus	Australia	3 GEO
Inmarsat	UK	11 GEO	Indovision	Indonesia	2 GEO
EchoStar	US	6* GEO	Sky Perfect JSAT	Japan	10 GEO
SES	Luxembourg	42 GEO	Telkom	Indonesia	2 GEO
NOAA	US	5 GEO	Iridium	US	74 LEO
Star One	Brazil	6 GEO	Orbcomm	US	18 LEO
Telesat	Canada	23 GEO, 1 LEO	GeoEye	US	2 LEO
EUMETSAT	Germany	4 GEO	DigitalGlobe	US	3 LEO
IAI	Israel	2 GEO	Canadian Space Agency	Canada	2 LEO
Paradigm	UK	7 GEO	GISTDA	Thailand	1 LEO
Total: 184 GEO, 101 LEO					

CONCLUSIONS

Not only does this approach provide improved SSA for satellite operators and support more efficient decision making, it could be used by the Joint Space Operations Center (JSpOC) at Vandenberg AFB to improve their SSA, too. Instead of having to dedicate additional resources to closely tracking and recovering maneuvering satellites, the JSpOC could simply use the SSN to verify reported orbits periodically, freeing up SSN resources for tracking non-cooperative objects. If problems were detected during verification of certain satellite orbits, the JSpOC would simply fall back to the standard non-cooperative tracking approach.

Of course, to encourage maximum participation by satellite operators in such a data sharing arrangement, the US must be willing to reciprocate by sharing the best available orbital data they have on as many objects as possible. That means US data policy should be changed to support the release of high-accuracy orbital data. Given that over 95 percent of the 21,000 objects currently tracked by the SSN are dead satellites or debris and less than 1 percent are operational US Department of Defense or intelligence satellites, why wouldn't the US want to share this data, if it meant helping to avoid a repeat of the Iridium 33 collision with Cosmos 2251—a dead Russian communications satellite. Sharing this data with the satellite operators would also allow the operators to perform their own conjunction screenings, reducing the need for the JSpOC to take on that task for them.

Having more accurate orbital data would significantly reduce the number of false alarms, which currently undermine operator confidence in conjunction assessments. An order of magnitude improvement in accuracy reduces the threat volume by a factor of 1,000 and makes the collision avoidance problem far more manageable.

Even if there were a problem with releasing the entire high-accuracy catalog to the public, allowing it to be used by the international data center for screening close approaches—and only releasing orbital data to satellite operators for individual conjunction events involving their satellites—would go a long way toward reducing the risk of another collision in orbit.

Need for Additional Collaboration

The establishment of the international data center in such a short period of time is a great step forward in developing a global network of satellite operators working together to reduce the risk of on-orbit collisions. But much work remains to be done to bring in other satellite operators into the system. After all, the more operators that participate in such a system, the more benefit will be seen by all.

Bringing in high-accuracy data from the SSN would also be a big step forward, particularly for LEO operations, in providing better SSA for the large amounts of orbital debris there. But the space surveillance networks of other major space players—most notably Europe, Russia, and China—would further enhance SSA. And there is potential to bring in research networks—such as the International Scientific Observing Network—which are using very capable systems to study the orbital debris population. In order to perform their research to detect hard-to-track objects, they must also maintain catalogs of other objects—all data which could be used by satellite operators to avoid conjunctions.

Of course, NASA and European Space Agency (ESA) studies showing very large numbers of objects smaller than can be currently tracked by current space surveillance systems point out the need for even more capable sensors and more effective correlation techniques to match observations with objects. Here again, international collaboration could help ensure funding and a robust global view of the near-Earth space environment.

Finally, there is a continuing need to establish standards for safer space operations. Current international standards which allow dead spacecraft to remain in Earth orbit for up to 25 years are simply too lax. Iridium 33 was destroyed by Cosmos 2251, which is believed to have ceased operations two years after being launched in 1993, and then drifted for another 14 years before the collision. Obviously, we need to be much better stewards of the space environment.

Moving Forward

Clearly, there are plenty of challenges to providing improved SSA and safer space operations. The good news is that the international community is already working hard to move forward on improving things today. The international data center and its members welcome participation from all satellite operators worldwide, together with national and research space surveillance networks, to help continue to improve things tomorrow.

REFERENCES

1. Space Track, *Satellite Situation Report*, 2010 April 5, www.space-track.org.
2. NASA, *Orbital Debris Frequently Asked Questions*, NASA Orbital Debris Program Office, 2009 July, <http://www.orbitaldebris.jsc.nasa.gov/faqs.html>.