Space Traffic Control: Data Access Defines the Future

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Abstract

The evolution of space traffic control services will be strongly affected by how issues related to data access and protection are resolved. Several governments and many private companies own portions of the data required for these services, but the best quality services require that data from all sources be merged. One possible solution is the formation of an international nonprofit or equivalent organization, with responsibilities, data access, and services defined by agreement of space faring nations.

Introduction

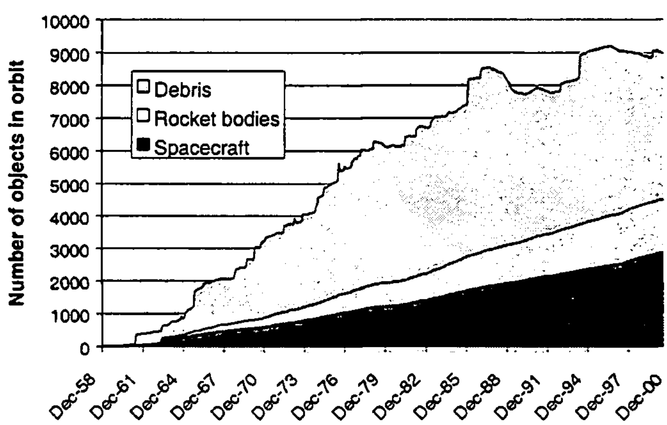
Given the increasing number of operating satellites and associated debris, it is inevitable that collisions in space will seriously damage or destroy operating vehicles. It is also likely that a collision involving a critical asset will lead to the institution of a "space traffic control" system designed to help operating satellites avoid collisions. The question is: how might such a system evolve?

Background

Over the last 40 years, mankind has launched over 20,000 metric tons[1] of material into orbit around our planet Earth. While much of this has come back to Earth, some of this material is still in orbit and will remain there for a few years to millions of years.

We're adding new satellites and creating new debris at a rapid rate. Some estimates put the total number of operating satellites at over 2000 by the year 2020—an increase of nearly 300% from the approximately 700 satellites operating today.

Typically, operating satellites release debris as they are launched and placed into their operating orbits. This debris ranges from spent stages to hardware required for deployment, to lens covers and the like. In addition, satellites and stages that are currently in orbit can create debris by accidentally exploding or colliding with other objects.

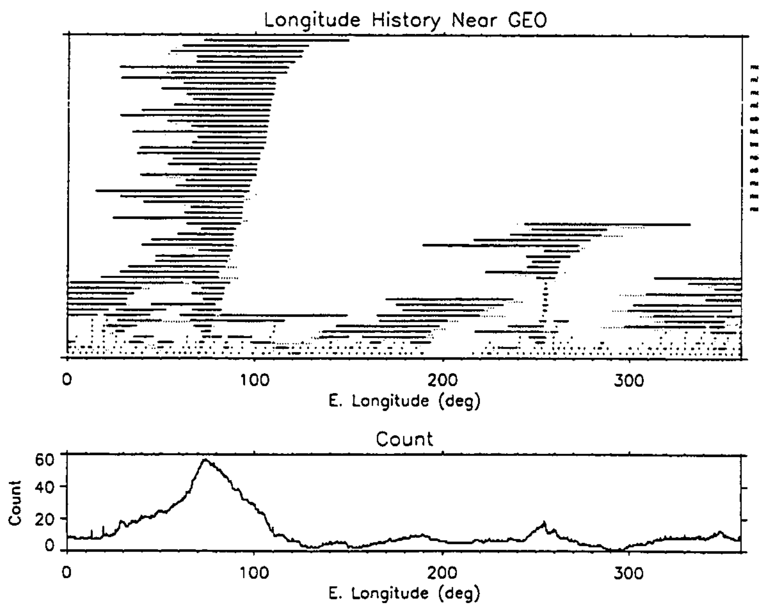


The number of spacecraft and rocket bodies is increasing steadily while debris mitigation efforts and increased cleansing of debris in low orbit due to solar storm-induced atmospheric density increases are decreasing the population of debris.

As a result, the population of non-operating hardware and debris can also be expected to increase from the approximately 9,000 currently tracked (generally, tracked objects are larger than a 10-30 cm in low earth orbit and a meter and larger at geosychronous equatorial orbit (GEO) altitude[2]).

Fortunately, some objects in low earth orbit will slowly be removed from orbit by atmospheric drag.

In addition, there are efforts among space-faring nations to develop regulations to reduce the quantity of debris. Current drafts call for satellite operators to move their vehicles to disposal orbits (or remove them from orbit altogether) and to vent propellant tanks and discharge batteries at end of life to prevent later explosions. The emerging regulations will also require that debris created during deployment and operations be minimized.



These figures show the number of satellites sharing the same region of space. The bottom figure shows the number of GEO satellites as a function of longitude; the upper figure shows the range of longitudes over which each satellite operates. Operational satellites tend to have much smaller longitude variations (near the bottom of the upper plot).

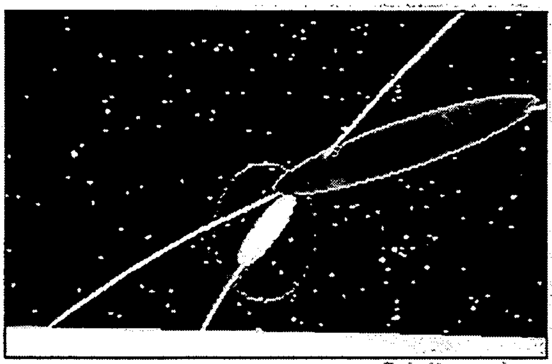
There are also efforts to track and catalog more of the debris in orbit (at orbital velocities, even a centimeter-sized fragment represents a serious threat to the International Space Station and operating satellites). The United States Space Command (USSPACECOM) maintains the 9000-object Resident Space Object (RSO) catalog that includes information on each object's orbit so that its position may be predicted at times in the future. Other countries maintain similar catalogs. It is estimated that adding information on smaller objects would increase the number of objects in the RSO catalog to over 100,000.

Information in the RSO catalog has been used for several years to provide information on objects passing close to the Space Shuttle, the former Mir Space Station, and now the International Space Station. Analysts have used this information to move these satellites—the Shuttle has been moved eight times to date, the Space Station three times, and the Mir cosmonauts moved to their escape pod at least once because of concern with passing objects.

Many satellite operators believe that the chance of collision is so small that they need not worry about collision avoidance. For example, the probability of collision at GEO for a single active satellite is approximately one in 3000 over a 10-year mission; however, the collective probability of a collision involving an active GEO satellite over the next 10 years is approximately one in 10. Other operators realize that their satellites are frequently approached by debris as well as by satellites operated by others and are interested in knowing if and when a threat exists.

As with the manned vehicles, some operators have chosen to move their satellites to decrease the possibility of a collision. In some cases, however, such moves have been ill advised based on the relatively poor quality of the tracking data used for the predictions.

Given this background, the 1999 AIAA workshop on International Space Cooperation: Solving Global Problems has called for the creation of an "internationally recognized entity" to provide collision avoidance and other services.[3] This group also noted that available "catalogs [of tracked objects] must be greatly improved" to enable effective collision avoidance.[4] Reference 5 raises a number of questions and issues about this service, and Ref. 6 proposes an organizational structure.



Ellipsoids are used to represent position uncertainties of two converging objects. The size of the ellipsoids, sometimes exceeding several kilometers in length, reflects the uncertainty in the position of each object. Collision avoidance analysis produces a probability that the two objects within the ellipsoids will actually collide.

Accurate, meaningful predictions of satellite close approaches require that:

- Tracking data be generated in a manner that is suitable for this application; that is, the catalog of orbiting objects must be maintained with observations of a quality and frequency that permits collision risk reduction using a reasonable number of avoidance maneuvers for each satellite.[7]
- Data used for predicting future collisions must incorporate operator data, including operator estimates of orbital ephemeris and information on upcoming station keeping or other planned maneuvers. Without knowledge of where a satellite is going, collision avoidance predictions are impossible.

Operator data and predictions are also critical for satellites that use low thrust motors to move to operational orbits or for orbit transfer maneuvers. It may be difficult or impossible to develop reliable predictions of future locations of such satellites without such input.

Data May Define Directions

One of the areas that must receive substantial focus, and will ultimately play an important role in the architecture of these types of services, is the catalog itself. The data collection, maintenance, and use of this information database, and the controls established to limit its use and availability, will have important implications for the quality of service available to worldwide operators.

Some examples of how this data may be used illustrate this point:

- Governments can use information on satellite orbits to assess whether operators are abiding by end-of-life disposal rules, to determine if operators are violating guidelines about release of debris during deployment and operations, to assure compliance with regulations in other areas, or to see what other governments are doing in space.
- Companies can use information to establish the health of a competitor's constellation or to gain insight into a competitor's technological status or business plan for communications or other services
- Lawyers and insurance companies can use this information to assign blame and collect damages in the event of an on-orbit collision with another company's satellite or launch vehicle or debris
- Investors can gain insight on the health of a company by looking at the company's constellation of satellites and determining whether satellites are maintaining their station correctly, if the constellation is fully populated and has on-orbit spares, etc.
- Service providers can offer radio frequency interference and other

services to help operators avoid problems and minimize liabilities.

Of course, the data required for all of these activities can come from many sources. Operators in each of the space faring nations maintain perhaps the best and most up-to-date information on their own vehicles.

Private companies like Intelsat and Iridium maintain data on their satellites and constellations. Governments and amateurs track satellites and maintain catalogs. Information on many tracked objects is available for free on the World Wide Web.

There are some indications that private companies may be moving to establish tracking stations to catalog data on orbiting objects. This independent tracking data could be provided to operators for a fee.

Evolutionary Paths

Given the fact that collision avoidance services require the best information on all objects, and given the fact that the best information is not available from a single source, how might collision avoidance services evolve?

The highest priority service to be provided would be close approach warnings and collision avoidance. Services could evolve to include launch collision avoidance, collision avoidance for maneuvering and deorbiting spacecraft, and potentially radio frequency interference, laser impingement avoidance, and other services dependent on the RSO database. It is possible that overall "situational awareness" services, providing operators information on space weather conditions local to their spacecraft, would also emerge as part of this evolution.

The evolutionary pathways for the service provider depend on how access-to-data issues are resolved. For example, one can envision the following options:

1. **Data could be made available for free for anyone to use.** Potentially sensitive information would be available to everyone. Commercial companies would most likely develop and market services based on this data, would contract with satellite operators and receive maneuver plans for those under contract, and each would provide services affecting only a portion of the operating satellites. A drawback is that no entity would have full information on all objects, potentially increasing the chance of a satellite managed by one company being unaware of potentially hazardous situations caused by maneuvers of a satellite managed by another. In addition, companies or nations who wished to protect data would most likely elect not to participate in this approach, further limiting the quality of the services possible.

2. **One or more commercial companies could be authorized to bid for the right to provide services using government-supplied data.** By this approach, a commercial company or companies would charge for services and would interact with the government for additional data required for close approach and other assessments.

   Under this scenario, the company would have access to proprietary information that could, by merger or acquisition, find its way to a competitor. Also, if the company selected was a subsidiary of or had financial or other ties to a satellite manufacturer or operator, it could be viewed as having a conflict of interest in certain close approach situations, possibly raising questions about its recommendations.

   Again, based on concern about these factors, some commercial companies would elect to use in-house capabilities, or none at all, rather than participate.

   Finally, there will be issues to be resolved regarding the government, in effect, subsidizing a for-profit company both by providing data and by providing support to requests for additional data from government owned and operated sensors.

3. **One government and government agency could take responsibility for the data and services.** There are complicating factors to this option, as well. For example, would the government agree to make services available even in a time of war? Would that government agree to pay for services to everyone, or if not, how would fees be set? Would other governments and companies agree to give data despite concerns that the data might conceivably be used to put the data provider in a less favorable position? Would the government guarantee financial support required to assure good-quality service? Could the government agency guarantee to protect an operator's proprietary data from release to other companies or other government agencies to the satisfaction of commercial operators?

4. **A private, nonprofit organization could be chartered in the United States to utilize government-supplied RSO catalog data, incorporate customer-supplied satellite orbit information and maneuver plans, and provide basic collision avoidance services to all.**

   The organization must be considered a "trusted agent" by both government and operators. For example, the government would establish rules for how government-supplied information would be handled and released, and satellite operators would use legal agreements to establish similar restrictions for their data. As a nonprofit, the organization would be free of potential conflicts-of-interests noted earlier.

   This entity would offer services for a nominal fee—critical to assuring the satellite operators that the services they need would be available, and allowing each operator to control and customize the services provided.

   Another factor to be considered is the cost for services. Given the "public benefit" nature of this work and the desire to encourage satellite operators to participate, the government might decide to subsidize the service, or even provide a basic level of service for free. The fee might apply only to services above the basic level. The government could work closely with the nonprofit entity to structure a fee schedule to accomplish this goal.

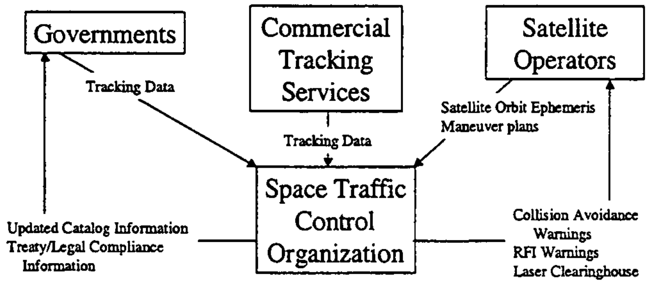
   An advantage of this approach, and to some degree that of Options 1 and 2, is the potential for assuring that the services remain state-of-the-art. As a private company, the nonprofit can remain flexible and can grow quickly to meet operator requirements (sometimes a challenge for a government agency). In addition, as a nonprofit, any "profits" from providing these services can be rolled back into research and new tools and capabilities.

   Problems to be worked with this concept include refining the nature of the organization, developing a working relationship with government agencies responsible for tracking and other data, establishing an agreed-on set of services and fee structure, assuring that export licensing issues are expedited, and assuring the permanence of the organization so that it will remain a trusted agent over the long term.

   This latter point means that operators must be assured that the entity will not be taken over or go out of business, potentially putting their data and services at risk. Similarly, government must be confident in the special access relationship critical to the work.

5. **Nations could jointly establish an international nonprofit, or equivalent, entity to maintain the data and provide services.**

   In this case, international agreements would define the operational, funding, fee structure, data access, and data protection issues. For example, the agreement would establish the ground rules under which data would be released to governments (as noted earlier, governments may wish to use catalog data to assure that operators are abiding by regulations or for other purposes).



The conceptual international space traffic control organization[6] would receive data from several sources and provide processed results and data to commercial satellite operators and government organizations.

The organization would be funded by governments and potentially by fees charged to satellite operators (a portion of a government's contribution could be in the form of tracking data or other "in kind" support). It would receive tracking data from government, private sources, and satellite operators, would develop an integrated database, and would use this database to provide agreed-upon services.

It is likely that governments will withhold from this organization information on some sensitive satellites, so that the database will never actually be "complete." Thus, the entity would probably provide a set of agreed-on data to governments for their use in protecting sensitive assets and regulatory enforcement. The use of an incomplete database could hamper the overall development and acceptance of this approach.

While the organization itself would provide technical services, its operations, services, and output would be governed by international agreements. This fact may mean that it may be challenging for the organization to be innovative and provide state-of-the-art services to the satellite operations community.

Another challenging area will be data protection: operators and governments must be confident that their data will be secure and protected in accordance with prior agreements. The organization would need to be established with this as a paramount concern and requirement.

Near Term Possibilities

The obvious challenge in agreeing on and negotiating the framework for an international entity, assuring its funding, providing tracking data from multiple nations and operators, etc., as suggested in Option 5, suggests a phased approach for space traffic control should the international approach be the desired end point.

For example, at present the nonprofit organization suggested in Option 4 might be the most palatable approach. It maintains the "government function" nature of this work, allowing the government to be closely involved with the evolution and structure while a more mature understanding of data protection issues develops. It also assures all satellite operators that the services provided are the most complete and accurate possible at the earliest date.

As services under an Option 4 approach evolve, the organization could be transitioned to another form. For example, if negotiations on the international entity have progressed to the point of agreement, the existing organization could be the basis and model for the new international service provider. Properly established, the government would have maximum flexibility in long-term options by this approach.

In the Meantime...

There are increasing calls for debris avoidance and collision avoidance services. At present, such services are provided by USSPACECOM for manned vehicles, with The Aerospace Corporation and the European Space Agency offering prototype services and MIT/Lincoln Laboratory conducting cooperative research with several GEO operators.

Over the next several years, research and prototype services in areas related to collision avoidance will continue to develop requirements for these services. Progress toward and demand for generally available services would be dramatically increased should there be a high-profile collision in orbit.

[1] Johnson NL, "Monitoring and Controlling Space Debris," Scientific American, August 1998, p. 62-67.

[2] Spencer DB, "Orbital Debris and the Environmental Restoration of Space: A Report to the Congressional Defense Committees," AFRL-VS-PS-TR-1998-1024, Air Force Research Laboratory, February 1998.

[3] "International Space Cooperation: Solving Global Problems," AIAA, Report of an AIAA, UN/OOSA, CEAS, CASI Workshop, April 1999.

[4] "International Space Cooperation: Addressing Challenges of the New Millennium," AIAA, Report of an AIAA, UN/OOSA, CEAS, CASI Workshop, March 2001.

[5] Ailor WH, "Controlling Space Traffic," Aerospace America, November 1999, p. 34-38.

[6] Ailor WH, "Space Traffic Control: A View of the Future," to be published in Space Policy.

[7] Jenkin AB, "Effect of Orbit Data Quality on the Operational Cost of Collision Risk Management," Paper No. AIAA 2002-1810, SatMax 2002, Arlington, Virginia, April 22, 2002.