**Commercial Management of the Space Environment**

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The commercial satellite industry has billions of dollars of assets in space and relies on this unique environment for the development and growth of its business. As a result, safety and the sustainment of the space environment are two of the satellite industry's highest priorities. In this paper I would like to provide a quick survey of past and current industry space traffic control practices and to discuss a few key initiatives that the industry is developing in this area.

**Background**

The commercial satellite industry has been providing essential space services for almost as long as humans have been exploring space. Over the decades, this industry has played an active role in developing technology, worked collaboratively to set standards, and partnered with government to develop successful international regulatory regimes. Success in both commercial and government space programs has meant that new demands are being placed on the space environment. This has resulted in orbital crowding, an increase in space debris, and greater demand for limited frequency resources. The successful management of these issues will require a strong partnership between government and industry and the careful, experience-based expansion of international law and diplomacy.

Throughout the years, the satellite industry has never taken for granted the remarkable environment in which it works. Industry has invested heavily in technology and sought out the best and brightest minds to allow the full, but sustainable exploitation of the space environment. Where problems have arisen, such as space debris or electronic interference, industry has taken the initiative to deploy new technologies and adopt new practices to minimize negative consequences.

In the late 1970s and early to mid 1980s, both Russia and the United States engaged in the testing of anti-satellite weapon systems. Both countries abandoned these efforts, in part because the creation of additional space debris was inconsistent with their plans for the full exploration and exploitation of the space environment. Similarly, the future preservation of the space environment will rely on every nation's appreciation that its own self-interest lies in preserving this precious common good.

The major commercial satellite operators routinely share information and resources with each other and with governments to help ensure the protection of the unique and irreplaceable space environment. Intelsat operates a fleet of more than 50 satellites -- the largest geostationary commercial fleet ever assembled. In response to business opportunities and changing market needs, Intelsat regularly replaces satellites and relocates satellites in orbit. Recently, in response to a request from DoD, Intelsat moved a satellite that had been operating over the United States to the other side of the world in order to provide critical UAV services in Afghanistan and Iraq.

The Intelsat fleet operates from geostationary orbit. This orbit is 32,000 km above the earth in a region where the movement of our satellites exactly matches the rotation of the earth, thereby making the satellite seem "fixed" in the heavens. To change the orbital location of a satellite, Intelsat must delicately move a minibus-sized, multi-ton object, traveling thousands of kilometers per hour, through the crowded geostationary arc, avoiding the potential for collisions with, or for disturbing the radio communications of, any of the more than 250 other commercial communications satellites in that orbit. Other satellite companies that operate in lower earth orbits – some a few hundred kilometers above the earth – must deal with many more operational objects and a substantially increased debris environment. The recent collision between the Iridium satellite and a non-operational Russian satellite took place in this lower earth orbit.

With the exception of the initial grant of approval by a national regulator, by and large, the management of satellite operations takes place without governmental regulation or oversight, using rules developed through experience and implemented by consensus among the commercial operators themselves. This process has been used effectively and without incident since the commercial satellite communications era began in the 1960s. This remarkable example of international and inter-company cooperation and self-reliance is premised on a simple realization that the results of a collision could be catastrophic.

In low earth orbits (generally 200 – 1000 km above Earth), objects and debris will slowly, over a decade or so, re-enter the Earth's atmosphere. In the narrow geostationary orbit (approx. 35,000 km above the earth) the debris from a collision would endure for tens of thousands of years, effectively rendering a portion of the geo arc useless.

**Space Traffic Control - Past and Future**

I would like to take a moment and describe Intelsat's past and current approach to space operations. I would also like to describe the current state of data-sharing among commercial satellite operators and suggest a new paradigm for easing critical communications among operators and between operators and governments.

As I alluded to above, commercial satellite operators, working with limited government oversight, have over the years developed their own internal protocols and procedures to ensure the safe operation of their fleets. Operators have also become adept at informal coordination and information exchange with operators who are 'flying' satellites adjacent to or near their satellites.

At the beginning of the space age and through most of the 1970's and 1980's there was no serious examination of ‘space traffic control’ since there was a great deal of space and, quite literally, no traffic to control. As the world entered the 1990’s deregulation, privatization, and the rapid expansion of the video market all served to power a growth in communication and broadcast satellite activity. By the late 1990s, Intelsat decided that it would be prudent to gather better information on the space environment, so it contracted with the Aerospace Corporation via the Space Operation Support Office (SOPSO) to conduct close-approach monitoring.

The Aerospace Corporation developed a fully automated two-tier program that determined satellite close approaches based on miss-distances and conjunction probabilities. The initial detection was based on the publicly available NORAD data known as the Two Line Element sets (TLE). Once a potential conjunction between two space objects was identified, Aerospace would request the more accurate special perturbation (SP) ephemeris data from the Air Force to confirm the conjunction. The Aerospace Corporation shut down the SOPSO office abruptly in November 2002.

In 2003 Intelsat contracted MIT Lincoln Lab to perform close-approach analysis. It was a semi-automated system and the conjunction detection was based on miss-distances only. Because MIT had a contractual relationship with the Air Force, and therefore direct access to the more precise observations from the deep space surveillance network, the conjunction monitoring was based on a single-tier process. However, the monitoring was restricted to non-active space objects, such as debris. This restriction was due to the difficulties in detecting past maneuvers and predicting future maneuvers of active satellites. Such maneuvers tend to invalidate longer term close-approach predictions.

Since January 2007, Intelsat has relied on an in-house close approach monitoring system. This system follows the two-tier model and relies on the US Joint Space Operations Center

(JSpOC) to validate potential conjunctions detected using the TLE data that is available through the US Government's *"Spacetrack.org"* website. We routinely screen our satellites using the TLE data, and, during special activities such as satellite relocations and transfer orbit missions, we also exchange data with other satellite operators whose satellites are operating near or adjacent to our satellites. The exchanged information usually consists of the latest orbital information, near-term maneuver plans, frequency information and contact information for further discussion.

There are drawbacks to the current close-approach monitoring process. In addition to a lack of standards for TLE modeling, TLE data do not have the required accuracy for credible collision detection. An operator that is forced to rely on TLE data must increase the calculated collision margin to avoid potential close approaches. In most cases, threats identified using the basic TLE data are downgraded after coordination with other operators or further evaluation with more precise orbital data. In addition to the inaccuracies of the TLE data, these data also lack reliable maneuver information. This limits the usefulness of the TLE for longer-term predictions, since maneuver information is necessary to properly predict the orbital location of active satellites. Today, operators relying on chemical propulsion systems will maneuver about once every two weeks to maintain their orbital position. Accurately predicting the orbital location of a satellite will become more difficult as more satellites employ ionic propulsion systems and are, essentially, constantly maneuvering.

Adding complexity to this problem is the fact that there is no single standard for representing the position of an object in space. Different operators characterize the orbital position of their satellites differently, depending on the software they use for flight operations. In addition, there is no one agreed upon protocol for sharing information, and coordinating operators must be prepared to accommodate the practices of other operators. To do this, operators must maintain redundant file-transfer protocols and tools to convert and reformat information so that it is consistent with other owners'/operators' software systems for computing close approaches. Separate tools are necessary to exchange data with each operator. Some operators write their own software tools for monitoring and predicting the close approach of other spacecraft while others contract with third parties for this service. The magnitude of the effort to maintain "space situational awareness" grows quickly as the number of coordinating operators increases. Unfortunately many operators are not able or willing to participate in close approach monitoring due to lack of resources or capabilities.

Because of the relatively imprecise nature of the TLE data, the US Air Force established the "Interim CFE Data/Analysis Redistribution Approval Process" (Commonly referred to as the Form 1 Process) for granting operators access to information that goes beyond the basic TLEs. Through the Form 1 Process, operators can request additional information (the special perturbation, or SP, data) on specific 'close approach' situations. Although helpful, it is cumbersome to rely on the Form 1 Process as an operational tool because it requires advance notice, which is often impossible in emergency situations. In addition, conjunction events often require close cooperation and interactive communication. Today, the Form 1 Process relies primarily on email as a method of communication and the US Government does not guarantee the rapid turnaround necessary in most cases.

The US Government is currently reviewing its policies on the distribution of TLE data. One proposal would require the negotiation of individual "tailored agreements" between the US Government and satellite operators requesting information. Other proposals have suggested that the US Government might be willing to provide additional conjunction assessment services on a reimbursable basis. At this writing, it is unclear how or whether the CFE program, which was originally scheduled to terminate this year, will continue.

Recently, Intelsat conducted an informal survey of satellite operator professionals who routinely interact with the JSpOC and the CFE process. Their reaction indicated that there are a few key areas where the current process could be immediately improved:

1. ***Clarify the Process*** -- To manage expectations, publicly clarify the process that should occur from the moment a Form 1 request is submitted to JSpOC until the analysis is returned to the operator. The JSpOC should also designate a point-of-contact for questions.
2. ***Make the Process Interactive*** – To reduce uncertainty, JSpOC should provide a receipt to acknowledge that the operator request has been received (or that JSpOC has received the information it requested) and provide notification of status change as operator requests go through the system, or as the JSpOC responds to perceived threats.
3. ***Distinguish between Routine and Emergency Requests*** – Allow operators to include a priority flag for time-sensitive requests so critical issues can receive attention first.
4. ***Where Possible, Indicate Data Quality*** – To assist the operators in making decisions, provide quality flags, where possible, to indicate the quality of the data used by the JSpOC in conducting their analysis.

**Data Center Proposal**

In response to the shortcomings of the current TLE-based CFE program and the recognition that better inter-operator communication is desirable in and of itself, a number of satellite operators have recently begun a broad dialogue on how to best ensure information-sharing within the satellite communication industry. One proposal currently being discussed in the international operators' community is the "Data Center". As conceptualized, the Data Center would be an interactive repository for commercial satellite orbit, maneuver and frequency information. Satellite operators would routinely deposit their fleet information into the Data

Center and retrieve information from other member operators when necessary. The Data Center would allow operators to augment existing Two Line Element (TLE) data with precision orbit data and maneuver plans from the operator's fleets. The Data Center would also:

- Perform data conversion and reformatting tasks allowing operators to share orbital element and/or ephemeris data in different formats;
- Adopt common usage and definition of terminologies;
- Develop common operational protocols for handling routine and emergency situations;
- Exchange operator personnel contact information and protocols in advance of need.

If the Data Center were to gain acceptance, it could perform additional functions, such as the close-approach monitoring tasks currently being conducted by the operators. In this phase, US Government-provided TLE data could be augmented by the more precise data available from the operators. This would improve the accuracy of the Center's conjunction monitoring and could provide a standardized way for operators to share information with the US Government and other governments. In the early stages, information on non-operational space objects would still need to be supplemented by TLE data from the Air Force CFE program and/or other government programs. US Government, or other government support would still be required when precise information is needed to conduct avoidance maneuver planning.

A prototype active Data Center was established to study the feasibility of such an approach following workshops of the major commercial owners/operators held in February 2008 in Washington DC and December 2008 in Ottawa. A majority of the operators present agreed on the need to simplify the data exchange process to minimize risk for safety of flight and on the importance of creating a common Data Center. The operators agreed to work on a prototype Data Center as a proof-of-concept to improve coordination for conjunction monitoring.

The prototype Data Center expanded quickly and today 7 operators are participating and regularly contributing data from over 120 satellites in geostationary orbit. The participating operators receive daily close-approach alerts when the miss-distances and conjunction probabilities fall below certain thresholds and a daily neighborhood watch report showing the projected separations of satellites that are flying in an adjacent control box. The participating operators provide their ephemeris data in the reference frames and time systems generated in their flight software and the Data Center performs the transformation and reformatting to a common frame for close-approach analysis. This greatly simplifies the efforts and reduces the burden on individual operators and thus encourages participation. A strict data policy has been put in place to ensure privacy of the data. The Data Center is not allowed to redistribute the data received from the owners/operators without approval from the owners of the data. While there is still significant work left to refine the process, the initial results from the Data Center prototype are very promising.

The principal goal of the Data Center is to promote safety in space operations by encouraging coordination and communication among commercial operators. The Data Center could also serve as a means to facilitate communication between operators and governments. Details on the implementation of the Data Center, services to be provided, usage policies, structure of the organization and by-laws have yet to be determined and would ultimately require agreement among the member operators. The development of a Data Center could provide new visibility and awareness of the geostationary orbit, allow all satellites to be flown in a safer manner and reduce the likelihood of an accidental international incident in space.

The Data Center is a tool for commercial operators to exchange information about their active spacecraft. However, the operators must still rely on the US Government to monitor dead satellites and other objects drifting in geostationary orbit, that could collide with an active satellite. The safety of commercial space activities can be ensured only if there is a commitment from the US Government, and other governments equipped with the same type of radar or optical observation capabilities, to monitor uncontrolled space objects and to alert commercial operators, in real time, of the risks of collision with their operational satellites.

To be sure, the motivations behind the civil and military space activities of nations are far more complex than those of the commercial satellite industry. However, the central goal of preserving the operational space environment binds all space participants with a common purpose. It is important to note, in particular, the very critical role played by the geostationary orbit. Should this unique circular orbit be polluted by a space collision, the impact on military and commercial communications would be devastating.

For all of these reasons, the governments need to play a leadership role on the issue of Space Traffic Control. In pursuit of this objective, we would offer the following specific recommendations:

- **Provide adequate funding for Space Situational Awareness** — Space Situational Awareness (SSA) is the ability to monitor and understand the constantly changing space environment. The task of locating and tracking active satellites and space debris is one of the most challenging aspects of SSA. Currently, the US Air Force's JSpOC plays a key role internationally in tracking, and reporting on, all man-made objects in orbit. The JSpOC receives on-orbit positional data from the Space Surveillance Network, which is composed of both optical and radar sensors throughout the world. This allows the JSpOC to attempt to maintain accurate data on every man-made object currently in orbit. Today the JSpOC is tracking more than 10,000 objects in space. Like all parts of the Pentagon budget, funding for expansion of the Space Surveillance Network is under pressure. In light of recent events, Congress and the Air Force need to provide higher priority for this funding. Other space faring nations need to join the US in making space surveillance investments a priority.

- **Develop new mechanisms for sharing space traffic information between nations** – In addition to the United State, Russia, several European states, China, Australia, and others are making investments in SSA capabilities. Each of these data sets, taken alone, is not likely to solve the emerging space traffic problems. It is also critical that nations strive to create rapid, reliable, and non-bureaucratic institutions for sharing the new data they are collecting.
- **Maintain and expand the US Commercial and Foreign Entities (CFE) program** — Established by the US Congress as a pilot program, CFE now provides a limited but essential set of U.S. government data on existing space objects for release to certain commercial and foreign entities. Although CFE has been advantageous for governments and industry, the accuracy of the data currently provided is not sufficient for precise collision detection/assessments, support of launch operations, end of life/re-entry analyses, or anomaly resolution. The CFE pilot program was originally set to expire this year. It is essential that the current program be formalized and expanded to meet the evolving needs of global space operators.
- **Take advantage of the data readily available from commercial satellite operators -** It would be extremely valuable if satellite operators and governments could find a way to share their collected data in an organized, cooperative fashion. Such a sharing process could result in the creation of a "Global Data Warehouse" for space information. Governments and operators might be encouraged to submit information on the orbital

elements of space objects as well as their maneuver plans and operational frequencies. If information were gathered in a central depository, warning and alert messages could be distributed automatically in a common format to participating operators, while protecting sensitive commercial or government data. Intelsat, along with other satellite operators, has offered to share its information, free of charge, with the US Government.

- **Be creative in the development of new data sources** – As I mentioned previously, most commercial operators rely on the Air Force Space Command's "JSpOC", for tracking man-made objects and debris in orbit. The JSpOC receives satellite position data primarily from the global Space Surveillance Network. As upgrades to this network are likely to be expensive and long-term in nature, it is important that we look at creative solutions to respond to our growing needs. As an alternative to expensive terrestrial infrastructure and dedicated government programs, DoD should try to take creative advantage of every commercial platform going to orbit. Every commercial launch is an opportunity for a technology test-bed, or the deployment of a novel operational capability. Rather than develop and launch dedicated assets to address this problem, the Air Force should consider launching low-cost sensors on every satellite going to orbit. By including commercial and scientific satellites in this endeavor, it would be possible to obtain a holistic view of the space environment in a few years, with little government investment. Intelsat alone has 10 satellites currently under construction or in development. Our colleagues and competitors in the industry are similarly positioned with respect to their new spacecraft investments. Imagine, if you will, the improvement to our understanding of the space environment if every satellite launched over the next 5 years were part of an integrated, global monitoring system for space.

- **Begin an international dialogue on 'Rules of the Road' for space** — Although there are reasonable differences of opinion regarding the value of additional laws or international agreements, there seems to be general acceptance among space operators that certain guidelines or norms developed by consensus may play a useful role in ordering our future space activities. A good example is the space debris guidelines developed by the Inter-Agency Space Debris Coordinating Committee, an intergovernmental body created to exchange information on space debris research and mitigation measures. The development of other non-binding guidelines should be investigated. Such non-binding guidelines might include:
    - A formalization of existing rules regarding the movement of spacecraft between orbital locations;
    - Protocols for informing other operators when one of their spacecraft could potentially cause damage to other space objects;
    - Protocols for managing the loss of control of a satellite.

Within the next decade, many more countries will gain the ability to exploit space for commercial, scientific and governmental purposes. It is essential that the world's governments provide leadership on space management issues today in order to protect the space activities of tomorrow. Bad decisions and short-term thinking will create problems that will last for generations. Wise decisions and the careful nurturing of our precious space resource will ensure that the tremendous benefits from the peaceful use and exploration of outer space are enjoyed by those who follow in our footsteps in the decades to come.