SPACE TRAFFIC MANAGEMENT

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PROMOTING COOPERATIVE SOLUTIONS FOR SPACE SUSTAINABILITY

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The Need for Space Traffic Management

The time of space traffic management has arrived

By Michael K. Simpson

As the number of orbiting objects increases with the launching of new applications and the accumulating debris of old ones, spacefarers like seafarers before them will need to agree on the codes of behavior that will permit them to ensure compliance with one critical law: two objects cannot occupy the same space at the same time.

With the relative utility of critical arcs such as geosynchronous, sun synchronous, and low earth orbits rising in relief against less crowded ones, the need to consider the location of other objects, both active and derelict, has taken on growing importance in planning and operating space missions. Closer to Earth's surface, the need to keep aircraft away from falling space debris is also commanding attention.

Although several countries have developed the capability to track objects in orbit well enough to decrease the odds of their satellites colliding with them, much of the world has come to rely on conjunction analyses provided by the USA's Joint Space Operation Center (JSpOC) for warnings of possible collisions or dangerously close approaches in orbit. While U.S. willingness to share analysis and provide a free service has earned it considerable praise and respect, there is a growing fear that leaving such an important function to any one country is risky in an era where 41 countries or international organizations have registered objects in Earth orbit. This has led to a growing call for a more robust, more modern, more widely dispersed system of tracking and analysis.

One response to this call has been the establishment in 2009 of the Space Data Association (SDA), a private, not-for-profit organization that links 14 satellite operators in a network of data sharing and analysis. This network is designed to coordinate operator-provided data and use it to supply the best possible estimates. The theory behind this Association is that no one knows better than the operators where their satellites are at any moment in time or where planned maneuvers will cause them to be at a specific future point in time. With maximum knowledge of satellite locations, the likelihood of accurate conjunction estimates is also maximized.

With a mission of promoting the sustainable use of space through international cooperation, the Secure World Foundation has taken a substantial interest in space situational awareness and its potential to facilitate peaceful, cooperative, and widespread use of space to meet human needs.

The Secure World Foundation has sponsored studies of space traffic management and has created a database of ground-based sensors whose data might eventually feed a more robust international system of informed conjunction analysis. We have also worked hard to increase awareness of the problems presented by space debris to our planet's ability to benefit from uninterrupted access to space-based services, and we have encouraged discussion of the impact space weather can have on the functioning and even on the location of objects in orbit.

Dr. Michael K. Simpson, Executive Director of Secure World Foundation.

Linking all our efforts in this domain is our belief that cooperative sharing of data, transparency in operations, and broad involvement of countries, institutions, and launch and satellite operators are critical to managing space activity without creating a fertile ground for conflict and tension.

We accepted the kind invitation of the International Association for the Advancement of Space Safety and of the International Space Safety Foundation to cooperate in developing the special report on "Space Traffic Management," because in space more than any other domain, safety and security represent the two sides of the same coin. Preventing further degradation of the space environment and promoting cooperation in space traffic management is at the center of our common action.

Sputnik-1 was completely unencumbered by concerns of conjunction analysis or reentry planning. Those concerns and many others have imposed themselves as satellites became larger and more numerous. This is perhaps the strangest measure of our evolution as a spacefaring species – the progressive loss of spontaneity in our use of orbital assets. The time of space traffic management has arrived.

Dr. Michael K. Simpson is the Executive Director of Secure World Foundation and former President of the International Space University (ISU).

What is Space Traffic Management?

The extreme challenge of predicting and avoiding collisions in real time

By Brian Weeden

Space Traffic Management (STM) is an important and challenging topic to discuss because of the many possible definitions of what STM is and all the potential misunderstandings of what is possible or even desirable given the unique aspects of orbital mechanics and the space environment. A brief overview of those unique aspects and a discussion of the major areas of focus for STM now and in the near future is necessary to really understand this topic.

It is important to clarify that it is actually impossible to actively monitor all objects in space all the time. The volume of space around the Earth between the lowest orbiting satellites and geostationary belt encompasses trillions of cubic kilometers. Current space situational awareness (SSA) techniques rely on periodic spot checks of space objects as they orbit around the Earth to build models of their motion. These models are then used to predict space objects' trajectories into the future.

The Joint Space Operations Center provides a focal point for the operational employment of worldwide joint space forces. - Credits: US STRATCOM

Prediction is important because it is extremely challenging to determine and avoid collisions between two space objects in real time. The relative speeds of such an encounter in low Earth orbit (LEO) routinely reach upwards of 10 kilometers per second. As a direct consequence, the closer two objects are to a possible collision, the larger a maneuver is needed to avoid it, at the expense of a satellite's limited fuel supply. Short-notice avoidance maneuvers can also disrupt services provided by that satellite and result in a new orbit which could potentially have an even more serious opportunity for collision.

These challenges have led to the current system of periodic checks of the location of space objects, maintenance of a catalog of their orbits, and predictions to determine close approaches called conjunctions. Data on the most dangerous close approaches is provided to satellite operators, who determine the probability of a collision and decide upon the best course of action. A decision on whether or not to maneuver is not easy. It is virtually impossible to predict a collision with certainty, and the farther into the future a conjunction is, the more uncertain it becomes.

In addition, there are two other categories of space activities which warrant more specialized STM procedures and higher levels of awareness and control. The first one is rendezvous and proximity operations (RPO) between two or more space objects, which includes formation flying of two or more satellites in close proximity to each other as well as docking maneuvers to space objects such as the International Space Station or with an orbital debris removal spacecraft. The second category is the interface between space traffic and air traffic, which includes both space launches and atmospheric reentry of space objects. Although space objects by definition are only in air spaces for a brief amount of time, they can present a significant hazard to air traffic and people and facilities on the ground.

While the advisability of having a single international entity to oversee all space traffic management is still debatable, there are important steps that should be taken in the meantime to improve the current situation. The first step is to enhance global SSA capabilities and increase information availability to all space actors. A second step is to encourage data sharing between space actors and improve the existing systems to detect potential collisions and warn satellite operators. A third step is to develop best practices and standard operating procedures for the two high risk categories of RPO and space object launch and reentry. Taking these steps will help prevent future collisions and accidents in space and is crucial to the future of safe and sustainable space activities.

Brian Weeden (bweeden@swfound.org) is the Technical Advisor for Secure World Foundation and a former US Air Force officer with a background in space surveillance.

Challenges of the Code of Conduct

A code of conduct risks running contrary to domestic space policies

By Michael J. Listner

The Code of Conduct for Outer Space Activities has taken many turns since the concept was introduced in 2008 by the European Council. The EU Code of Conduct in its modified form was presented to the nations of the world at the end of 2010 to facilitate discussion about space security. From the beginning, it was intended to be a non-binding measure, addressing matters of space security including space traffic management, protection of high value space assets, and space debris mitigation. Moreover, the Code of Conduct sought transparency among the space-faring nations in regards to their space policies both internal and external.

After a year of efforts by the European Council to promote the Code of Conduct to the nations of the world, support for the measure was scarce. A further blow to the EU Code was dealt when the United States withdrew its support for the measure in January 2012. Right after the announcement of its withdrawal, the United States began to work on its own version of the Code of Conduct, based on the EU draft, which was named the International Code of Conduct.

Artist's impression of the debris population in low Earth orbit (size of debris has been exaggerated as compared to Earth). - Credits: ESA

National Security

The first and foremost challenge of a code of conduct is national security interests of the various nations participating in it. The United States cited undisclosed national security concerns as its rationale for withdrawing from the EU Code effort and pursuing one of its own. However, as the United States presses forward to encourage other nations to adopt the measure, it will likely find resistance from many who will be reluctant specifically because of national security. Besides a nation's technical and military capabilities, national security includes internal policies and procedures as well. A code of conduct would encourage transparency for both the technical and internal policy side of a nation, something that may prove to be unpalatable to many nations. Furthermore, the space traffic management system envisioned by the Code of Conduct would implicate military and other sensitive space missions. To the extent that these missions would call into question the security of a nation, compliance would be in question.

Effect on Domestic and Foreign Policies

A code of conduct also poses the risk of running contrary to domestic space policies and regulation, or even of being redundant to them. For example, space debris mitigation was a high priority with the proposed EU Code of Conduct; however, nations that have placed a low emphasis on space debris mitigation, like China, may find the requirements running contrary to their domestic policies addressing the same problem. On the other hand, nations such as India may consider such a requirement to be redundant to their own measures.

In both instances, requirements from a non-legally binding code might be considered intrusive in domestic affairs, given that even though a code of conduct would be voluntary at the international level, the effect on domestic regulations would be mandatory. Additionally, as in the case of the United States, domestic political differences between two branches of government over a code of conduct could lead to a political stalemate whereby a code of conduct could be signed at the international level by one branch but prevented from being implemented domestically by another, nullifying the effectiveness of a code of conduct. This scenario is being played out now with the US Congress, wary of the influence a code of conduct could have on national security and interstate commerce – particularly the budding commercial space sector, already taking steps to block the implementation of any code of conduct signed by the current presidential administration.

An additional challenge is how a code of conduct would affect the foreign policy of a given nation. For instance, China and the Russian Federation have co-sponsored a treaty in the UN Conference of Disarmament dealing with the issue of space weapons. The Treaty on the Prevention of the Placement of Weapons in Outer Space (PPWT), which seeks to define and ban space-based weapons, has met considerable resistance from the United States and other nations for various reasons. Even though the PPWT will likely not become binding international law, both China and the Russian Federation have gleaned considerable soft-power benefits by continuing to promote it at the United Nations. Such a soft-power advantage translates into greater geopolitical prestige and influence for both nations. Yet, it has been suggested that if a code of conduct was adopted, the PPWT would be effectively neutralized, and with it the soft-power advantage it created.

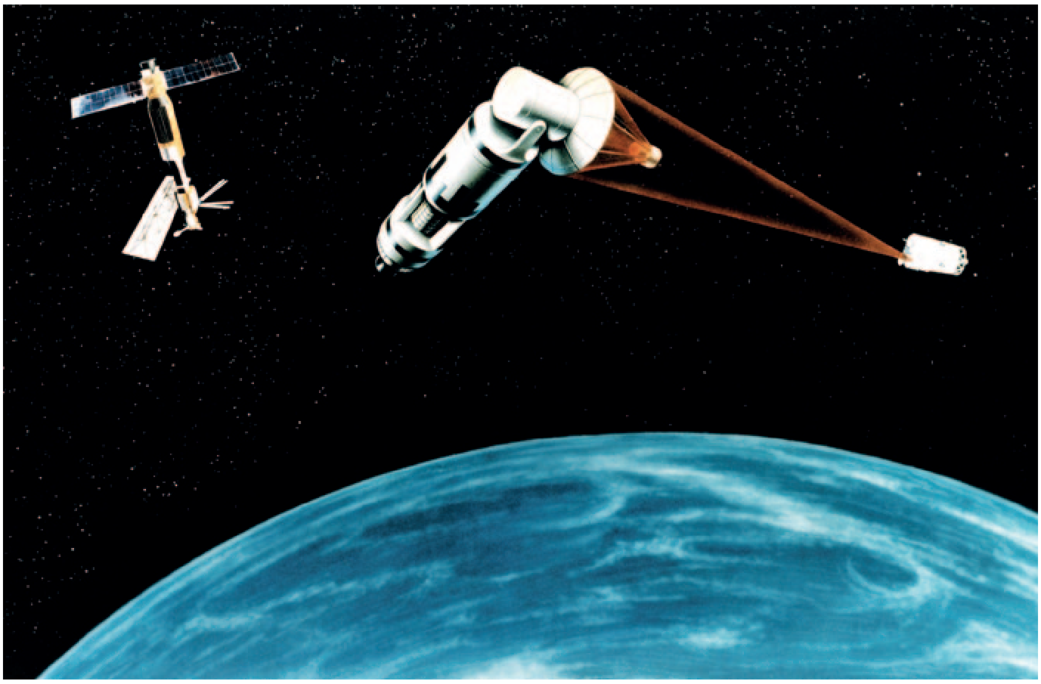
A code of conduct can be a positive step towards addressing security in outer space

Enforceability

Yet another concern among some nations is the enforceability of a code of conduct. The proposed code of conduct is voluntary in nature, and as such it would not have the legal force of a treaty. Several nations have expressed concern about its non-legal nature and the lack of an enforcement mechanism or penalties for a nation's failure to adhere. More onerous is the specter of multiple codes of conduct being proposed. The EU has announced its support of an International Code of Conduct through Council Decision 2012/281/CFSP, signed in Brussels on May 29, 2012 thereby extinguishing any concerns of discord from the countries that comprise it. However, there is the possibility that nations within the Asia-Pacific Region could propose their own code of conduct, which coupled with the proposed International Code could either result in harmonious co-existence or in a condition of inconsistency that would cause the very disorder they sought to avoid.

Conclusion

The implementation of a code of conduct can be a positive step towards addressing security in outer space, both to preserve the environment and to protect expensive national assets from harm. However, like any other facet of international relations, a code of conduct will be subject to the geopolitical interests of individual nations. While the underlying purpose of a code of conduct is to promote cooperation in outer space in order to promote general security, the fact remains that nations will first look to see how the provisions of a code of conduct will integrate with their own national interests, or whether those provisions will be incongruent to them. And because of the very nature of geopolitics, if an agreement is reached there is no guarantee that it will be applied or otherwise disregarded in the event of open conflict between nations.



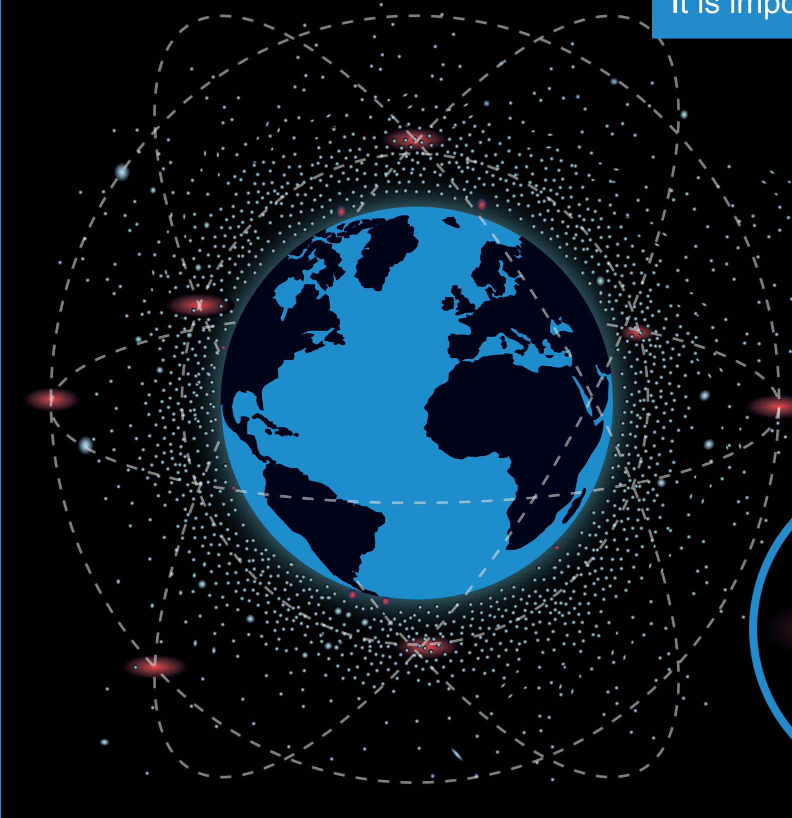
Artist's concept of a Space Laser Satellite Defense System. The space weapons policy is one of the major discussion points of the International Code of Conduct. - Credits: US Air Force

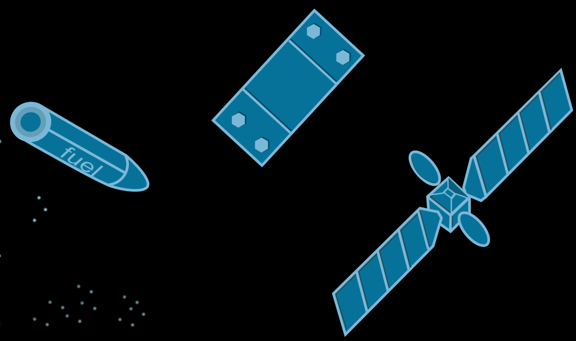
SPACE TRAFFIC MANAGEMENT

Infographic by Stanislav Lazarevic

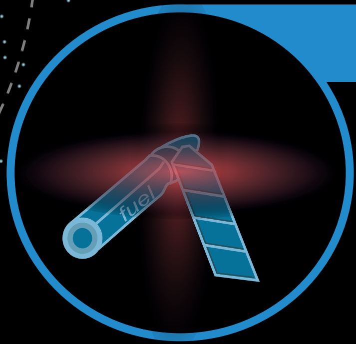
THE PROBLEM

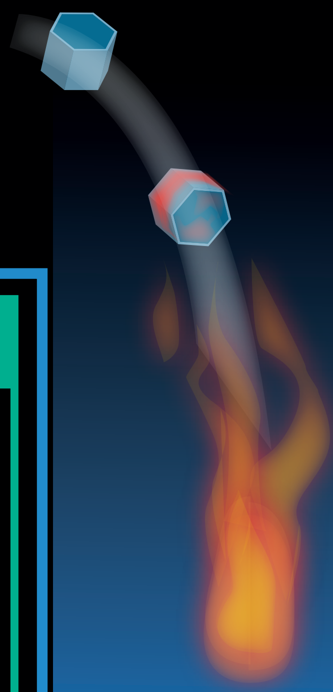
It is impossible to monitor all space objects all the time





Collision Risk

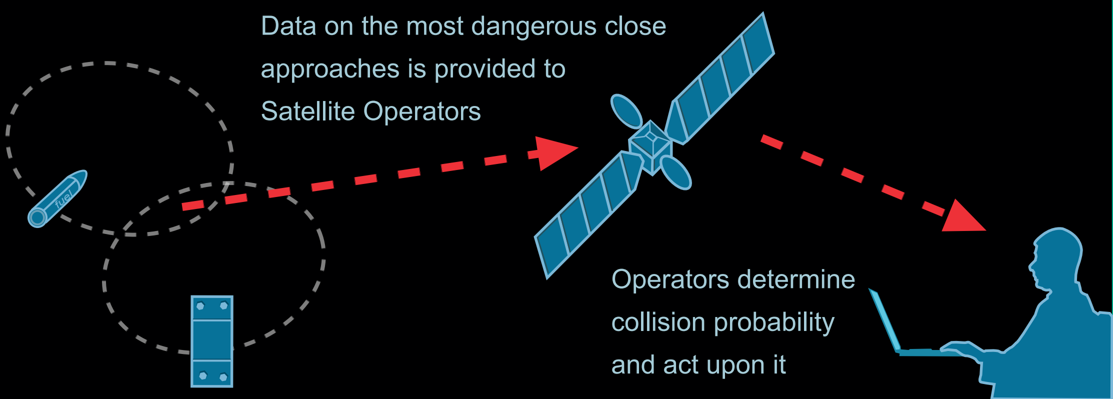




Hazard to air traffic, and people and facilities on ground and at sea

STM: CURRENT APPROACH

Periodic checks of the location of space objects



STEPS THAT SHOULD BE TAKEN

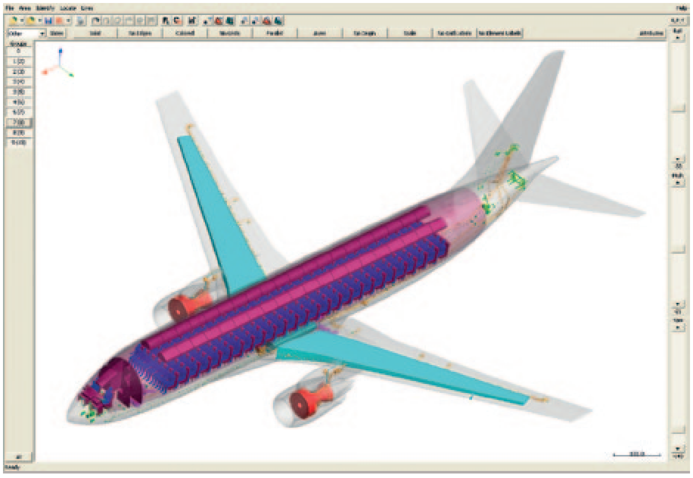
1 Enhance global SSA capabilities and increase information available to all space actors

2 Encourage data sharing among space actors and improving the existing systems to detect potential collisions and warn satellite operators

3 Develop best practices and standard operating procedures for rendezvous and proximity operations, launch, and reentry

Protecting Aircraft During Launch and Reentry

By Paul D. Wilde



Computer Model of a Commercial Transport Aircraft Used to Assess Debris Impact Vulnerability

The US Federal Aviation Administration (FAA) Office of Commercial Space Transportation (AST) was established, at least in part, to facilitate safe and efficient sharing of the National Air Space (NAS) by launch and reentry vehicles as well as aircraft. Aircraft are protected during US launch and reentry operations by implementation of temporary flight restrictions, special use airspace, altitude reservations, or notices to airmen (NOTAMs). There are four major elements of the aircraft protection approach applied in the US: safety criteria, aircraft vulnerability models, debris dispersion models, and mishap response systems.

Safety criteria allow establishing an appropriate level of protection for aircraft from launch or reentry vehicle hazards, such as collision with planned or accidental debris. The FAA requires that commercial launches and reentries operate at the same level of safety as government sponsored operations. Specific safety measures are designed to ensure that the general public is not exposed, individually or collectively, to a risk level greater than normal background risks. For example, an individual annual risk of casualty below one in a million is commonly seen as so low that it merges into the background risks of life. The aircraft protection requirements and guidelines published by the Range Commanders Council (RCC) in the consensus based 321-07 Standard and Supplement on "Common Risk Criteria Standards for National Test Ranges" describe how operators can meet those requirements. The aircraft protection measures put forward in RCC 321-07 include probability of impact limits for debris capable of causing a casualty, as well as explicit quantitative risk acceptability criteria, debris hazard thresholds, and vulnerability models for various classes of aircraft.

Aircraft Vulnerability Models (AVMs) are used to quantify the areas of aircraft susceptible to an undesirable outcome from a debris impact, such as a casualty due to a fragment that penetrates the fuselage or an uncontrolled landing following a ruptured fuel tank. The FAA-AST and US Department of Defense co-sponsored the development of AVMs for debris impacts on civilian aircraft, leveraging past work done to assess military aircraft survivability and the threat posed by potential fragments from an uncontained aircraft engine failure, such as turbine blades. These efforts produced improved AVMs for commercial transport and long range business jet aircraft adopted in RCC 321-07 after multiple independent reviews by recognized experts in various fields. The FAA continues to sponsor tests and analyses to produce more refined AVMs. Future AVMs will use more detailed information on the location and vulnerability of critical systems in commercial transport aircraft.

Debris dispersion models are sophisticated physics-based computer models that predict the probability of an impact on an aircraft by identifying four-dimensional regions (including time) where falling debris could impact an aircraft. These models account for various sources of debris dispersion, including launch or reentry vehicle trajectory deviations, break-up induced velocities applied to fragments, lift and drag uncertainties for irregular fragments, and atmospheric winds, as well as the likelihood of foreseeable debris generating events and a variety of vehicle fragmentation scenarios.

Mishap response systems are used to alert aircraft and rapidly clear potentially threatened airspace. In the event of an unplanned debris event, the FAA is immediately notified of the region potentially threatened by debris.

The FAA is currently expanding the real-time aircraft warning system based on containment for debris that exceeds aircraft hazard thresholds, a measure that was implemented in response to the Columbia accident, to more efficiently integrate launch and reentry vehicles into the NAS without compromising safety by activating aircraft hazard areas based on a probabilistic analyses.

Dr. Paul Wilde , Ph.D., P.E., is an IAASS founding fellow with over 20 years of experience in safety standards development, launch and reentry safety evaluations, explosive safety analysis, and launch operations. He is currently a technical advisor for the Chief Engineer in the FAA's Office of Commercial Space Transportation.