How to reach an International Civil Aviation Organization role in Space Traffic Management

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How to Reach an International Civil Aviation Organization Role in Space Traffic Management

Stephen K. Hunter

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Introduction

During a May 2014 House Science, Space and Technology Committee hearing, Federal Aviation Administration and Federal Communications Commission officials and technical and legal experts from those organizations testified alongside U.S. Air Force Lt. Gen. John W. “Jay” Raymond, commander of 14th Air Force, and Air Force Space Command’s and U.S. Strategic Command’s Joint Force Component Command for Space (JFCC Space). These witnesses’ testimonies highlighted the difficulty of operating in unregulated, crowded critical orbits filled with dangerous debris and the ever present danger of collisions potentially making those orbits unusable. Lt General Raymond also noted that JFCC Space “provides emergency warning of impending orbital collisions to all of the world’s spacefaring governments and companies, though it collaborates closely in space primarily with Australia, Canada and the United Kingdom.” He also explained that JFCC Space maintains a catalogue of all known orbiting systems and debris. As nations join the ranks of the space-faring, the number of trackable objects grows quickly and makes Lt General Raymond’s task more complex. “All of the witnesses who testified at this committee meeting stated that the United States must improve domestic space traffic management (STM), and move quickly to foster international agreement on use of space.” Governments and organizations across the globe have expressed this same concern for many years now. The European Union has produced “Rules of the Road” for space operations intended to be agreements between space-faring nations to mitigate debris and preserve the fragile environment above our atmosphere. Even the late President Emeritus of the ICAO Council, Assad Kotaite, recommended a new annex to the Chicago Convention to extend ICAO responsibilities for producing International Standards and Recommended Practices (SARPs) for suborbital and orbital civil space flights. His conclusion that the current SARPs should be expanded highlights the criticality of including tropospheric transition of space-faring vehicles and commercial point-to-point suborbital transportation as considerations when developing new SARPs. Although integration with tropospheric traffic has been studied for decades, the current operational environment has begun to bring previously disparate pieces of STM into a more focused concept. With current global economic dependence on space capabilities and the ever-increasing international economic interdependence, all nations have an interest in maintaining access to space-based capabilities. With strong U.S. leadership and support from other nations, a reasonable pathway to an ICAO role in STM is attainable.
What is STM?

Even after decades of substantive literature produced on the subject, any group discussion of STM eventually reverts to a consideration of the concept’s definition. Space Traffic “Control” is not the same as STM and Space and Air Traffic Management (SATM), a term coined by the Federal Aviation Administration in May of 2001, described the overall concept but focuses primarily on integration of space-transportation vehicles into the National Airspace System (NAS). A very few, if any, of other attempts to name and define the overarching concept often include additional, critical aspects of space travel such as electro-magnetic interference (EMI) concerns and end-of-life considerations. In recent years the interested academic and Executive Branch communities have come to recognize and refer to the central idea as “STM”. While there is still debate on the specifics, the most widely accepted definition is from the 2006 International Academy of Astronautics, Cosmic Study on Space Traffic Management:

...the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free of physical or radio-frequency interference.

While concise, this definition covers an exceptionally broad array of ideas related to four distinct stages of flight of aerospace vehicles (Figure 1).

Figure 1: Four Phases of Space Flight
Each phase requires its own understanding of existing regulatory environments, fluid dynamics, Keplarian physics, Space Situational Awareness, international policy subtleties, and legislative finesse. The complexity and number of disparate organizations involved helps explain why a STM concept would be best served if it evolved in a deliberate, phased approach along a similar path as current global air traffic management systems. However, in order to make a final STM capability easier to realize, each step toward its development should be taken with the end state of a globally-standardized capability in mind.

Why STM?
As technological advances make routine suborbital transportation realistic and space becomes more contested, congested and competitive, losing access to space-based capabilities becomes a critical concern to nations and individuals around the globe. Space capabilities play a role in everything from buying gas to national defense. Disruption in access to space-reliant services potentially range from minor inconveniences to catastrophic global economic collapse. Though it is not that easy for the average global citizen to see the potential impact day-to-day, looking back at similar historical developments helps to clarify why the world needs STM.

Today any pilots that land aircraft at airports owned by any of the 191 member nations/organizations that subscribe to the ICAO SARPs understand the standard lighting, markings, navigation systems, phrases and single language used to ensure safety of those flights. It is hard to imagine how much more difficult and dangerous international travel would be today without those standards. The parallels between early aviation’s need for standardized air traffic management and today’s need for STM are easily discernable. In the early days of aviation collisions between aircraft were very infrequent. The “big sky” theory (low probability of running into one of the few other aircraft in a large area) protected airborne travelers for almost two decades. As commercial aviation became more common place the network of airports, airways and air traffic control facilities grew to keep pace with the increased activity (Figure 2).
A series of studies by the U.S. government led to the founding of the ICAO as a result of the Chicago Convention of 1944. A tipping-point in the focus on air safety came after the 1956 mid-air collision between United Airlines and Trans World Airlines (TWA) passenger airliners in uncontrolled airspace. This incident resulted in 128 fatalities and the destruction of both aircraft. As tragic as this crash was, it fortunately precipitated recognition of an increasing danger to the public and the potential impact to the U.S. economy due to the rise in unregulated commercial air traffic. The result was the Federal Aviation Act of 1958, which created today’s Federal Aviation Administration (FAA) and led to the most advanced and safest airspace system in the world.

Just as this tragedy resulted in increased awareness of air traffic problems, recent events have prompted increased awareness of space traffic issues. The February 2009 collision between the commercial Iridium and Russian Cosmos communications satellites was a similar watershed event for space-faring nations. Although there was no loss of human life, this event highlighted the need for the U.S. Government to consider how best to conduct safe and responsible operations in space and promote those practices internationally. Similar to the 1956 mid-air collision, the potentially catastrophic effects a large-scale satellite collision may pose to the accessibility of the space domain, the resultant second-order effects on world economies, information systems, and national security systems is now being fully recognized by senior world leaders.

After decades of progress the U.S. National Airspace System (NAS) is still improving even today with the Federal Aviation Administration’s NEXTGEN Air Transportation System which is adapting the current...
system to new technology and increased demands of more, faster and higher capacity aircraft\textsuperscript{10}. But safe passage in the area above the NAS still relies on the “big sky theory” for protection of critical systems and sustainability of the space domain.

The U.S. government officially recognized the increased activity in space in the 2011 U.S. National Security Space Strategy where it states that the “current and future strategic environment is driven by three trends – space is becoming increasingly congested, contested and competitive.”\textsuperscript{11} The most telling indicator in this analysis is the growth of the satellite catalog which the U.S. government updates daily using Satellite Surveillance Network (SSN) sensors around the world. Figure 3 depicts the growth of the approximate number of unique catalog items being tracked from 1958 through 2010.

![Satellite Catalog Growth](image)

**Figure 3: Satellite Catalog Growth**\textsuperscript{12}

What isn’t apparent in figure 3 is the exponential growth in the number of trackable objects when the highly anticipated space fence becomes operational within the next five years. When this occurs, the number of cataloged items will increase from the tens-of-thousands to the hundreds-of-thousands range and current processing systems and manpower would be quickly overcome by the magnitude of data available to be analyzed. Fortunately, increment 2 of the JSpOC Mission System (JMS) is expected to be available in 2016 and will be capable of ingesting and analyzing this volume of information, however, conjunction
summaries developed from these data will still need to be distributed appropriately outside of the Department of Defense\textsuperscript{13}.

In addition to the increase in debris and new entrants to the commercial space market place, many companies and governmental organizations world-wide are beginning to have a growing interest in very small, single function satellites better known as cubesats. Cubesats are small (approx. 10cm x 10cm x 10cm), relatively inexpensive satellites that have become more prevalent in recent years due to rapid increases in technology that allow owner/operators to launch a satellite with a single, specific mission and a short lifespan. Although tracking these items is still possible, many don’t carry transponders of any type, so identification of individual systems becomes complicated. In 2012, cubesats represented almost 10\% of the Low Earth Orbit (LEO) catalog, but as launch and cluster deployment systems advance to keep pace proposals are being made to deploy as many as 50 cubesats from a single launch leading to 25\% of the LEO population being made up of cubesats by 2017\textsuperscript{14}. The number of actors operating outside Earth’s atmosphere has also increased from only a handful of nations in the recent past to over 60 nations and government consortia today.\textsuperscript{15} Along with these new entrants comes the increasing congestion in electromagnetic spectrums with as many as 9,000 satellite communications transponders are expected to be in orbit by 2015.\textsuperscript{16}

![Figure 4: Congested, Competitive and Contested](image-url)
New technologies and commercial ventures continue to expand the frontier of space and make point-to-point suborbital travel a realistic possibility in the next decade. The Federal Aviation Administration has been preparing for integration of suborbital flight transitions through the NAS since 2001 in their Concept of Operations for Commercial Space Transportation in the National Airspace System\textsuperscript{17} and more recently in their report titled Point-to-Point Commercial Transportation in the National Aviation System.\textsuperscript{18} While these studies are useful in considering tropospheric deconfliction of traffic, they both avoid considerations outside of the Department of Transportation’s purview. The number of entities which have some authority, responsibility or capability in each area of space flight must be considered carefully before any planning begins toward development of policies or procedures. Figure 5 depicts a generic concept of those entities that would be involved in consideration toward new policies and procedures required to develop a working STM concept.

Figure 5: Entities Involved in STM Concept Development
The information presented in figure 5 could lead a reader to conclude the U.S. is has an existing, although incoherent, STM capability today. The individual parts exist in disparate organizations scattered throughout the Executive Branch as well as in treaties and policies that loosely work together to provide protection for today’s volume of activity.

In addition to the immense technical hurdles involved in space operations, a U.S. owner/operator has to understand the requirements of each responsible organization in figure 5 and implications of their actions in relation to treaties to which the U.S. is a party. There is no single point of contact within the U.S. government that consolidates this information or ensures compliance with all requirements prior to operation. An owner/operator is responsible for obtaining approvals and ensuring compliance where necessary, and developing their own methods of protecting their system in the unregulated aspects of operations where necessary.

As a safety precaution, many commercial owner/operators have agreements with U.S. Strategic Command that allow them to receive warnings of potential conjunctions. In 2011 the JSpOC voluntarily made 4,331 notifications to satellite owners/operators regarding potential conjunctions and based on these notifications owner/operators of space systems made 85 collision avoidance maneuvers. The conjunction notifications and resulting maneuver screenings have increased dramatically since the 2009 Iridium/Cosmos collision and this level of non U.S. Government owner/operator interaction was not originally intended to be part of the JSpOC mission. 10 US Code § 2274 has been added to allow the JSpOC to perform these functions but as this aspect of the JSpOC activity grows, the demand for resources to execute their traditional Title 10 responsibilities competes directly with a non-mission requirement of maintaining safety and sustainability of the domain for commercial and non-U.S. Government owner/operators. Although the JSpOC Space Situational Awareness (SSA) services represent only a portion of the overall U.S. STM activity (see figure 6), the criticality of these services requires an entity whose sole focus is the operational safety and sustainability of vital benefits derived from operations in the space domain.
Any single point-of-contact “store-front” entity would require the ability to coordinate all the existing responsibilities, authorities and capabilities, across all strata of the aerospace domain, into a concise coordination point for current and future owner/operators of aerospace systems that travel through and above the tropospheric.

Implementation

Much thought and effort from all over the globe has gone into developing a coherent “way ahead” for STM. In 2004 the U.S. Department of Defense, NASA and the Federal Aviation Administration designed and published a Space Vehicle Operators Concept of Operations that detailed how a Space and Air Traffic Management System (SATMS) could bring different agencies together for the purpose of dealing with the contested, congested and competitive space domain we are seeing emerge today. Following the publication of the U.S. National Space Policy in 2010, Executive Branch organizations met to further examine the need, and possible designs, for a U.S. STM capability. Although earnest efforts were made toward developing a realistic operational concept, the complexity of implementation raised the threshold for taking deliberate actions toward developing a U.S. STM capability. Today technology is pushing us closer to a saturated LEO environment while at the same time Department of Defense fiscal realities and increased geo-political activity necessitate prioritizing Title 10 missions over voluntary conjunction summary message distribution...
to non-defense-related owner/operators. The incoherent U.S. STM capability is finding new supporters who champion a new, focused STM “store front” with full knowledge that international participation is soon to follow.

Once a decision is made to pursue implementation, much of the previous work on the subject can be updated and used as a basis for a design. However, in the near-term, resolution is needed regarding what entity will represent the “store front” to the rapidly growing population of owner/operators. The two primary options that have risen to the forefront of discussions have been a lead federal agency and a commercial entity. While a lead federal agency has its benefits, the ability to evolve quickly to meet the needs of a changing industry is seldom found in a governmental organization. The more favorable entity would be one that can use the current technology to quickly adapt to needs of a persistently-changing domain.

A commercial entity with full support of the U.S. Government would be better able to exploit the emerging JSpOC Mission System (JMS) capability to quickly and efficiently transition non-traditional Title 10 responsibilities from the Department of Defense while improving support to owner/operators to help ensure stability and sustainability of the space domain. The ability to make tactical decisions and quickly fund and implement updates to existing capabilities will be critical in staying current with the ever-changing needs of the aerospace industry. The Federal Aviation Administration has already dealt with this issue with supporting aviation when, in 2005, they chose Lockheed Martin to transition Flight Service Station responsibilities out of the federal agency’s purview\textsuperscript{21}. While Lockheed Martin serves as the interface between pilots for planning, the Federal Aviation Administration continues to regulate, inspect and meet their regulatory responsibilities while no longer being burdened by the bureaucracy required to maintain and operate this capability. A similar construct would allow owner/operators of aerospace vehicles and satellite systems to interact with a “store front” organization through the four phases of flight listed in figure 1.

Once a decision has been made to pursue an STM capability using a commercial entity as a “store front”, an outline of a phased approach to implementation would resemble the outline in figure 7.
The first phase of implementation would consist of preparation for transitions of responsibilities. This phase will require strong leadership in order to bring disparate Executive Branch organizations together and focus them all on one goal with a single set of objectives. As planning begins and the end goals are agreed-upon, legislative changes could become necessary to enable what have been inherently governmental responsibilities to be adapted to fit a new construct. As these changes begin to take root, a “store front” can begin to take shape with tools and data from existing organizations being used to establish the capabilities of the resulting entity.

Once established, manned and functional, responsibilities for preventing airspace conflicts between transitioning space traffic and existing aviation traffic would evolve from existing procedures used for launch and re-entry of systems like the Space Shuttle and the X-37 program. Currently these procedures are established on a case-by-case basis with coordination between the JSpOC and the Federal Aviation Administration. As the number of launches and suborbital point-to-point flights increase a more established procedure will be required in order to minimize impact on both the aviation and space operators. Figure 8 highlights some of the potential legislative areas that could be impacted by these types of changes. Airspace designations, right of way rules in the NAS, pilot-in-command responsibilities for see-and-avoid as well as passenger carrier regulations all could be impacted. In these areas the Federal Aviation Administration still
has Title 14 regulatory enforcement capability for vehicles operating in the NAS. End-of-life, de-orbit, and launch support are areas in which Federal Aviation Administration has Title 51 enforcement capability. This type of enforcement capability for U.S. systems might be expanded to include enforcement capability to ensure compliance with an STM entity’s direction to maneuver to avoid collisions.

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Figure 8: U.S. Legislative Implications of STM

The second phase of implementation would begin with the transition of traditionally Department of Defense-provided services such as conjunction assessment, collision avoidance, anomaly resolution and Electro-Magnetic Interference (EMI) support. In many of these areas the owner/operator lacks the responsibility or even the ability to comply with any direction provided by an enforcement organization. Most maneuvers decrease the lifespan of an orbital vehicle, which leaves an owner/operator being forced to decide between decreasing the time-on-orbit or avoiding the risk of a collision. The final decision has to be a coordinated effort between the owners/operators of the two objects predicted to be involved in the conjunction because no enforcement mechanism, and sometimes no compliance capability, exists. With no existing regulatory regime or accepted SARPs, even the notification of a potential conjunction is voluntary based on JSpOC workload even if a current agreement is enforce between the owner/operator and U.S. Strategic Command. New SARPs dealing with these and similar circumstances would likely precipitate changes or additions to Title 51 in order to operate a U.S.-flagged space system. Moreover, the National Transportation Safety Board could also be drawn into investigating incidents involving U.S.-flagged space-
capable systems thus producing a need to adapt existing Title 49 regulations in order to ensure the U.S. has a designated agency to investigate space system incidents.

Phase 3 would include a collaboration between the JSpOC the new “store front”. In phase 2 conjunction assessments are completed by the JSpOC and provided to the new organization for distribution. In phase 3 the new organization will begin to conduct conjunction predictions then produce and distribute conjunction summary messages to owner/operators. Providing a non-governmental entity full access to the JSpOC catalog is problematic for national security reasons. Enabling this new organization to develop methods of conducting and distributing conjunction summary messages is a possibility, but will require a great deal of additional effort once a new organization is established and is operating. Distribution of the conjunction summary messages would also be improved through additional international agreements that could eventually evolve further into established SARPs.

However, just as current SARPs grew from U.S. leadership in aviation, the SARPs for STM will grow out of an effective U.S. example and confident U.S. leadership in implementing an overall concept intended to ensure a stable, safe space environment for future operations. It has not been the U.S. that has taken the leadership role to this point, however. The desire to preserve the space domain prompted the European Union to evolve their Transparency and Confidence-Building Measures (TCBMs) into the International Code of Conduct for Outer Space Activities. Although the U.S. has agreed with the principles outlined in the European recommendation, their implementation methods potentially impeded U.S. national security measures and the effort has progressed very little despite years of effort from the European Union. Other countries and commercial entities have also made strides in developing a STM capability, but none have been able to move into a deliberate planning stage.

Initially this impasse appears to suggest that developing a STM concept would prove very difficult. However, in reality it exposes this path to be a departure from the historically successful route, discussed earlier, by which aviation SARPs were developed. A successful implementation strategy would parallel the course which resulted in current ICAO SARPs and participating country codification of those accepted practices. This route also will require a U.S. leadership role given the preponderance of technical capability which resides in the U.S. Department of Defense for tracking orbital objects as well as the demonstrated U.S. capability in developing and issuing conjunction summary messages to commercial and foreign government owner/operators. A stable, proven U.S.-based capability could easily serve as a basis, just as it has in the past, for a successful implementation of international standards that will help preserve access to space-based capabilities for people around the globe.
Conclusion

For decades, academic discussions regarding the concept of STM have led to a more well-understood idea of what near-term realistic technological advances and current orbital congestion require to ensure space-based capabilities continue to be available. Those theoretical concepts have become much more important in recent years as aerospace leaders and experts from around the world have begun to publicly acknowledge an impending need for an effective STM capability and the expansion of ICAO aviation SARPs which address activities through and above traditional ICAO atmospheric strata. While the U.S. Government has the preponderance of global STM-like technical capabilities, it is spread among disparate organizations and agencies with no single customer interface that is primarily responsible for safe passage to, through and from the space domain. Strong U.S. leadership is required to expand current U.S. capabilities into a rules, verification and enforcement entity which can serve as a basis for ICAO involvement and a global STM capability. A safe aerospace domain will help lower cost and foster growth of the involved industries, and help ensure continued availability of space-based capabilities to the global populous. All of this must begin with the decision to move away from a hypothetical discussion and take the first step toward leading the way to a sustainable, effective STM capability.