Safe Operations Above FL600

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Safe Operations Above Flight Level 6-0-0

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Abstract

With the increase in likelihood of near-term development of revenue-generating point-to-point suborbital flights and the increase in high-altitude-long-endurance commercial operations above FL600, the criticality of addressing operations above this altitude has never been more pressing. While the Federal Aviation Administration describes the National Airspace System, it doesn’t offer a description that includes a top and most descriptions do not address the altitude above FL600 at all leaving most to assume the top of the US National Airspace System is FL600. Technological, physiological, physical and administrative limitations have relegated most air operations to FL600 and below. As that changes, previous work on Space Traffic Management (STM) concepts begin to take on new life and add to sincere considerations for adaptation or changes in existing responsibilities, authorities and capabilities of STM stakeholders. As the FAA transitions to the NextGen architecture, those limitations that prevented humans from routinely operating above FL600 will being to dissolve and new legal and regulatory regimes will need to be developed and their impact on existing international agreements will require global consideration of STM implementation. Without the technical facility-limitations of Very High Frequency Omni-direction Ranges (VORs) as the primary navigation component of the National Airspace System, a satellite-based system opens up the possibility of redefining the top of Class A airspace and the top of the U.S. National Airspace System to, potentially, the Kármán line and providing the responsibility, authority, and capability the FAA currently lacks above FL600. This idea would foster routine, revenue-producing, point-to-point suborbital flights and help to sustain a safe, accessible space domain. The U.S. Senate has recently offered legislation to begin addressing the need for a STM concept and recent developments in the Department of Defense suggest a willingness to begin earnest efforts toward sharing the Joint Space Operations Center workload. Given the technological need and the willingness of the U.S. Government to begin to address the issue, a functioning STM capability is closer to reality than ever.
Introduction

Although technological advances are improving the performance of aerospace vehicles, the majority of 102,000 daily flight operations over the United States' take place between the surface and approximately 38,000 feet above mean sea level (MSL). The FAA helps to ensure the safety of these flights and the safety of the general public by maintaining and operating the National Airspace System. Above 18,000 feet (above mean sea level) the FAA considers altitudes to be “Flight Levels”. 18,000 feet to Flight Level 6-0-0 (FL600) are considered Class A airspace and represents a significant delineation between where most aerospace activities occur and the sparsely populated areas above. Until recently, aviation activities above FL600 were very rare, but as technology pushes the limits of aviation, the U.S. government and commercial interests have begun to develop and operate systems that operate, sometimes for weeks to months at a time, above the Class A airspace. These activities further blur the lines between aviation and space as well as suggest expansion of the FAA surveillance capabilities and involvement with regard to operations in the U.S. airspace above FL600. Some of this needed capability will be addressed under evolving FAA programs such as NextGen. Further consideration has to be given to the physical and electromagnetic deconfliction of operations above, below and across the Kármán Line. As these items are addressed the capabilities, authorities and responsibilities of existing stakeholder could evolve, shift or new capabilities, authorities or responsibilities might need to be created for existing, or even new stakeholders. Developing a method to handle increased atmospheric traffic will have to be done in conjunction with methods to maintain a safe, accessible and sustainable suborbital and orbital domain. Starting with previous work on the subject will help focus the effort and ensure a feasible STM concept can be developed in a manner so as to ensure the need for it stays ahead of the technological advances that create the requirement.

Why is FL600 significant?

Technical aspects of the National Airspace System, human physiology, as well as the laws of physics and economics relegate most traditional aviation to operations below FL600. Aside from the fact that, in the middle latitudes, FL600 is the approximate top of the troposphere, altitudes above this pose a much higher safety risk to commercial activities because it offers very little promise for survivability of humans without a full pressure suit in the event of malfunctions of aircraft systems (even if oxygen is available). Traditional aircraft engines also lose efficiency above the troposphere (surface to approximately 60,000 feet) and operating a vehicle at those altitudes poses significant aerodynamic issues that make commercial operations less profitable than traditional operations. As an aircraft approaches an altitude of approximately 327,000 feet (in the middle latitudes) the speed required to produce aerodynamic lift becomes greater than that required to achieve orbital velocity and the aircraft then becomes a
spacecraft. This altitude varies across the globe but is referred to as the Kármán Line after the Hungarian-American physicist Theodore von Kármán who first described it.

In addition to physiology, physics and economics, the navigation components that make up the National Airspace System were likely the driving factor for choosing FL600 as the top of the Class A airspace. The airspace above the Continental United States’ land mass is commonly referred to as being within the U.S. National Airspace System. Even though the Federal Aviation Administration (FAA) describes the National Airspace System in numerous publications, an attempt to find a valid description that defines its top at FL600 will prove to be impossible. An FAA description of the National Airspace System from the 2015 Pilot/Controller Glossary looks like this:

*NATIONAL AIRSPACE SYSTEM*— The common network of U.S. airspace; air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information and services; rules, regulations and procedures, technical information, and manpower and material. Included are system components shared jointly with the military.

Although technically inaccurate, a working definition by those most often involved in operating within the National Airspace System would include the top to be at the maximum altitude of the Class A airspace, or FL600. In fact, most graphics used to teach new aviators about airspace does not address altitudes above FL600 (See Fig 1).

![Figure 1: Airspace, FAA's Pilot's Handbook of Aeronautical Knowledge](image)

The top of the Class A airspace could have been chosen for any of the reasons mentioned above, but when considered as part of a “system”, the Class A airspace max altitude was most likely chosen based on limiting factors of other components of the system. The “Air Navigation Facilities” that served as the primary means of navigation
for National Airspace System users since 1946 has been the Very High Frequency Omni-Direction Range (VOR). The network of airways that crisscross the United States radiate from these facilities and serve as the primary means by which the majority of air traffic is moved around the country in an orderly manner. A detailed description of operational use of a VOR can be found in section 2 of the FAA’s Airman’s Information Manual. This description includes the top of the service volume for the high-altitude VORs, which is 60,000 feet above the VOR facility. Although this altitude is marginally different than the FL600 (because service volume is measured above ground level on which the VOR is placed), the top of the National Airspace System’s Class A airspace is uniform across the Continental United States and ensures any air traffic being routed at that altitude would have access to reliable VOR navigation capabilities.

This does not, however, mean that the FAA authority ends at FL600. Federal Aviation Regulations §71.71, Class E airspace, describes what FAA authority exists above FL600 by defining Class E airspace as:

The airspace of the United States, including that airspace overlying the waters within 12 nautical miles of the coast of the 48 contiguous states and Alaska, extending upward from 14,500 feet MSL up to, but not including 18,000 feet MSL, and the airspace above FL600, excluding The Alaska peninsula west of longitude 160°00'00" W. and the airspace below 1,500 feet above the surface of the earth.

To better understand operations above FL600 the information above must be considered in conjunction with the FAA’s authority and a study of 49 U.S. Code § 40103 - Sovereignty and use of airspace:
The Administrator of the Federal Aviation Administration shall develop plans and policy for the use of the navigable airspace and assign by regulation or order the use of the airspace necessary to ensure the safety of aircraft and the efficient use of airspace. The Administrator may modify or revoke an assignment when required in the public interest.

(2) The Administrator shall prescribe air traffic regulations on the flight of aircraft (including regulations on safe altitudes) for—

(A) navigating, protecting, and identifying aircraft
(B) protecting individuals and property on the ground;
(C) using the navigable airspace efficiently; and
(D) preventing collision between aircraft, between aircraft and land or water vehicles, and between aircraft and airborne objects.

A third piece to understanding this issue is a common set of terms and most critical is the definition of the term "aircraft". From 49 U.S. Code §1.1 "Aircraft means a device that is used or intended to be used for flight in the air". Using the definitions of Class E airspace, the FAA authority from 49 U.S. Code § 40103, and the term "aircraft", the argument could be made that the FAA has the authority to regulate air traffic from over the United States from just above the surface to a point where "the atmosphere becomes too thin to support aeronautical flight, or the Kármán line.

While no Air Traffic Control clearance or radio communication is required for VFR flight in class E airspace, it is still considered "controlled" airspace based on the International Civil Aviation Organization definition of "controlled airspace", which is "airspace in which flight under instrument flight rules is allowed". This means the FAA has both authority and responsibility for airspace above FL600. However, given the limitations of the current National Airspace System (VOR navigation limitations, tracking, and communications), it currently lacks the full capability to effectively control traffic or enforce regulations at these altitudes.

What is flying above FL600 right now?

There have been aircraft with the ability to fly between FL600 and the Kármán line for many years. Most notably, early experimental aircraft such as the North American X-15 which flew up to 62 miles (327,000 feet) above the Earth. During testing, F-15s were certified by the Department of Defense to fly at FL800 (with restrictions). F-22s routinely fly at FL600 to improve supersonic performance and Lockheed U-2s also routinely fly above FL600. Aside from these, and other manned military aircraft, there are Department of Defense Unmanned Vehicles, weather balloons, experimental governmental vehicles, and experimental commercial applications such as the Google Project Loon which are now common place in atmospheric operations above FL600.

Objects that transit the area between FL600 and the Kármán line are also becoming more frequent with testing of suborbital systems such as Virgin Galactic's Spaceship1,
XCOR’s Lynx vehicle and others. Additionally, commercial efforts to enter the more traditional spacelift market are growing in number as well. SpaceX, Armadillo Aerospace and Orbital Science are all in the testing phases of their respective programs. Each company is launching experimental systems above FL600 on a semi-regular basis. These programs also highlight that operations above FL600 are not restricted to operations below the Kármán line.

It’s important that during a discussion regarding operations above FL600 that a stark distinction between suborbital and orbital objects is not created in such a manner as to cause the management of each to be considered independently. While drastically different issues confront each area of operation, the overlaps between the two require that they be studied simultaneously, especially with the credible potential for near-term routine operations which span both areas as well as the pressing need for an orbital regime that provides for safe operation and sustainability of the space domain.

**What is the near-term need?**

The obvious near-term issues consist of existing organizations with on-going suborbital point-to-point efforts such as the Virgin Galactic effort. Additionally, corporations like BAE Systems is working hard on hypersonic air travel with a target operational capability timeframe of 2025\(^{iii}\). Above the Kármán line the number of objects orbiting the Earth has reached a point that now raises concerns about the effectiveness of relying on the “big sky theory” for preserving the ability to operate in the Space domain. The 2007 Chinese ASAT incident and the 2009 COSMOS-Iridium collision that followed increased frequency of close conjunctions between orbiting objects has led to the study of a need for a Space Traffic Management capability to be included in 2010 U.S. National Space Policy and, now, substantive discussions between stakeholders\(^{xiv}\). Additionally, the increased capability to produce data on orbital objects is likely to outpace the current U.S. Government ability to process the data\(^{xv}\). While steps are being taken to address some aspects of this issue, a whole-of-government approach is required to fully address the disparate issues that impact, or are impacted by, any potential solution to what is now a near-term need.

A complete consideration of this topic must take into account not only physical deconfliction of objects but also electromagnetic deconfliction as well as management of space situational awareness capabilities and how those could be used to ensure a sustainable, safe operating environment both below and above the Kármán line. The FAA foresaw this concern and addressed it in Table 5 of the 2010 Point-to-Point Commercial Space Transportation in National Aviation System report\(^{xvi}\) where specific areas of study integration between air and space vehicles were outlined in a phased approach culminating in detailed traffic management operational procedures for scheduled, revenue-generating commercial operations being developed by 2020. In October of 2004, the FAA, Air Force Space Command, NASA and representatives from the Department of Defense worked with Booz, Allen, Hamilton to develop a Space Vehicle Operators’ Concept of Operations that took the first steps toward addressing this
concept. Together, these documents lay out a need and potential courses of action for addressing the technological growth that is likely to result in an overlap between routine airborne, suborbital and orbital operations. When these documents were developed, the need for safe operations above FL600 was a far-term issue and implementation considerations were not as critical as today. This led to technical aspects of these concepts being the primary focus of each document. Events since publication of these documents have made policy and administrative considerations just as critical for discussion.

Possible Courses of Action

Any plans to address the need for a Space Traffic Management solution must begin with an end in mind and work back toward a solution. The 2006 COSMIC study on Space Traffic Management developed the most widely accepted definition to date:

...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. xvii

Starting from this point it is necessary to understand what it takes to have “access into outer space”. By comparing the similarities between air and space operations it is possible to break down process of each sortie into six distinct phases of operations: Planning, Processing, Departure Ops, Flight Operations, Return and Landing, and Refurbishment and Turnaround. These are depicted in the 2004 FIRST Space Vehicle Operators’ Concept of Operations (See Figure 3). Each of these phases become critical to understanding possible solutions as responsibilities, authorities, and capabilities are addressed across the multiple entities that have some connection to addressing an approach to developing a management regime (See Figure 4).

Figure 3: Six Phases of Space Flight Operations
The activities within each of these phases have been grouped in different manners in any number of studies, but the general concept remains consistent regardless of naming conventions. The similarities between space operations and aviation operations are evident even with the most cursory reviews of these phases and brings to the forefront, again, the idea that both future space and air operations should be studied in as a whole as opposed to orbital situational awareness and suborbital operations.

Any new studies should begin with an understanding of what currently exists and how those could be adapted or incorporated into a Space Traffic Management idea before considering how to develop a new concept. Each organization with responsibilities, authorities, or capabilities derives each initially from legislation or agreements. A review of the U.S. Codes that govern existing organizations as well as applicable international agreements is a principle consideration when studying potential methods of dealing with activities above FL600. With at least seven distinct areas of U.S. Code that govern different aspects of aviation and space flight it is inevitable that some changes would have to occur in order to most effectively implement any new concepts. Figure 5 highlights areas of the U.S. Code that address different, sometimes overlapping, aspects of aviation and space flight and offers suggestions as to where to consider changes.

![Figure 4: Responsibilities, Authorities and Capabilities for STM](image-url)

Each of the Executive Branch entities that currently, or potentially could, have responsibilities, authorities, or capabilities associated with some aspect of aviation or space operations will find that any new concept dealing with routine operations above FL600 will inevitably see recommendations for changes to their respective current...
responsibilities, authorities, or capabilities. Even if these changes are considered “acceptable”, the process for making any legislative or regulatory changes is very difficult and time consuming. The Government Accountability Office recently expressed their concern over this issue in a report when they stated “The FAA will need years to learn how to regulate space". While the FAA currently has Title 51 authorities and responsibilities, they primarily relate to terrestrial concepts such as licensing of launches and not the operational aspects of spaceflight similar to their authorities with respect to operational aspects of airborne operations. To further emphasize the concern, the Government Accountability Office comment was in reference to only small changes the FAA's current Title 51 responsibilities and authorities and not to significant changes being considered in many Space Traffic Management discussions.

![Figure 5: Responsibilities, Authorities Discussion Starting Point](image)

The US Senate has begun to work toward addressing some of these concerns by passing the US Commercial Space Launch Competitiveness Act (S.1297), which, if signed into law, requires the Director of Science and Technology Policy to identify appropriate oversight authorities for current and near-term, commercial, non-governmental activities conducted in space. This suggests there is enough backing from high-ranking individual in the US Government to begin looking for a focal point for discussing regulatory interactions required by the technological expansion of routine transportation above the current Class A airspace. As individuals begin looking at potential ways to meet the task this legislation will give them, it is likely they will employ expertise from the same organizations that developed the 2004 FIRST Space Vehicle Operators’ Concept of Operations. The red indicators in figure 5 indicate changes that might be recommended in order to consider a similar path to develop integrated control.
and management centers such as the ones in figure 6, the hierarchy of control centers. Many concepts have followed the 2004 ideas described in figure 6, however, the basic concept is consistent with the more matured discussions that have progressed beyond the general ideas and definitions associated with Space Traffic Management. The hierarchy of control centers depiction considers integration of routine point-to-point operations with existing global aviation activities as well as inclusion of orbital operations. However, it still regards the centers as Space Traffic “Control” centers while specifically categorizing each under a portion of a Space and Air Traffic Management System. A critical distinction between “Control” and “Management” is also established in the FIRST CONOP which delineates a tactical process of instructing owner/operators on how to avoid hitting other objects or craft and the operational-level process of planning for traffic flows, departures and arrivals.

![Hierachy of Control Centers Diagram](attachment:figure_6.png)

Figure 6: Hierarchy of Control Centers

Understanding the nuances in the nomenclature also aids in understanding the recommendations for specific changes to legislation depicted in figure 5. “Management”
of air and space traffic is not as difficult to develop as a “control” function simply based on the absence of authority that exists during the types of flights being considered in this paper. Domestic “control” authority for flights above FL600 was considered as part of the FIRST CONOPS (Figure 7) and development of this concept would be possible with changes to Title 49 and Title 51 authorities (at the most basic level). However, due to the altitudes and speeds involved, point-to-point transportation above FL600 is less likely to be domestic activity (although the potential does exist) and more likely to be international activities requiring adaptations to existing agreements or expansion of International Civil Aviation Organization roles in creating Standards and Recommended Procedures to be adopted by participating States. This possibility was also considered in the FIRST CONOPS (Figure 8) which describes how management and control of high-altitude, high-speed operations can be safely accomplished. Changes in the US national Airspace System have already began which lend to this concept becoming a reality.

Figure 7: Controlling Air and Space Traffic

In 2012, the FAA began to implement the Next Generation Air Transportation System (NextGen) airspace system in stages with an anticipated completion date of 2025. NextGen proposes to transform the NAS from ground-based navigation systems to a satellite-based systems. Without the service volume limitation of VORs, a satellite-based navigation system opens up the possibility of redefining the top of Class A
airspace and potentially defining the top of the U.S. National Airspace System as, potentially, the Kármán line. This effort would have to include providing the capability the FAA currently lacks above FL600 for communications and surveillance. This idea would enable the concepts in Figures 5, 6, and 7 and help to foster routine, revenue-producing, point-to-point suborbital flights. It would also raise the issue of defining “Space” as that area above the National Airspace System. Defining “space” creates a significant number of policy, treaty, and legal issues that would impact how the U.S. interacts with many countries around the globe. This was avoided previously by not providing a top to the class E airspace above FL600 as defined in Title 49 §71.71. For this reason, it is likely that any new laws, regulations, or policies developed by the U.S. would be crafted so as to continue to avoid defining “space”.

However, any attempt to fully address STM would need to include, at some later stage of development, at least the 191 member states to the ICAO convention. Just as the 22 Air Route Traffic Control Centers across the U.S. help sustain safe air operations above the United States, several regional centers would be needed around the world for any routine point-to-point high-altitude operations as well. This global, high-altitude concept was considered in the FIRST CONOP and is depicted in Figure 7 depicting the extent of the international cooperation involved in a successful routine point-to-point high altitude transportation concept.

Figure 8: Regional Control/Management Centers

In the recent past the International Civil Aviation Organization has shown interest in exploring global Space Traffic Management concepts when late President Emeritus of the ICAO Council, Assad Kotaite, recommended a new annex to the Chicago Convention to extend International Civil Aviation Organization responsibilities for
producing International Standards and Recommended Practices (SARPs) for suborbital and orbital civil space flights. Historically International Civil Aviation Organization initiatives have been led by the U.S. and given the vast technological lead in this area, the effort to develop and STM concept would benefit from U.S. leadership.

**Is STM a Pressing Concern?**

Over several decades many intelligent people have put a great deal of effort into thinking through the impending problems associated with the technological advances that enable safe and sustained routine travel above FL600. In that time, no event or issue has been urgent enough to cause the U.S., or any other country, to earnestly begin development of a means to manage these high-altitude operations. However recent announcements could suggest that the time for action is quickly approaching.

The FAA, as we know it, became a critical need following the public outcry after two airliners collided over the Grand Canyon in 1956. Although similar incidents have occurred in space, the public outcry was not as significant because there was no loss of life and no noticeable impact on Earth. In recent years the U.S. fiscal situation has limited initiatives that are not solutions to an immediate, critical issue and regardless of the seriousness of the concern by those who believe a catastrophic incident is inevitable, the fragile nature of the space domain is not easily understood by the general public and thus political pressure is not felt by decision-makers within the U.S. Government. In addition to the previously-mentioned U.S. Senate effort take specific actions toward addressing this need and the Department of Defense and the U.S. Intelligence Community have begun to consider threats to its assets in the space domain serious enough to apply scarce resources on developing a backup to their Joint Space Operations Center (JSpOC). The facility, known as the Joint Interagency Combined Space Operations Center (JICSpOC), is evidence that decision-makers have prioritized the sustainment and unimpeded exploitation of the space domain high enough to expend money and manpower. The JICSpOC and JSpOC are currently being designed to share the workload of tracking, cataloging, and predicting conjunction events of on-orbit objects. Additionally, the JSpOC currently accomplishes several activities that are specific to flights below the orbital areas of operation such as working with the FAA to de-conflict launch and return of space systems with air traffic within the national airspace system. Additionally the JSpOC provides collision avoidance data to commercial launch customers and occasionally to international launches.

The JICSpOC is not intended to take responsibilities from the JSpOC but rather to conduct experimentation and testing on concepts for countering threats to U.S. space capabilities from October 2015 to January 2017. It is highly likely that the during these studies of how to work with the JSpOC personnel will consider options similar to those raised during Space Traffic Management discussions over the last few decades. One Space Traffic Management study highlighted the non-military JSpOC activities that could be transitioned to another organization (See Figure 9).
On-going discussions between the Federal Aviation Administration and the Department of Defense have suggested multiple, widely-varying concepts for transitioning non-military responsibilities from the JSpOC. While no clear path has materialized, sincere discussions continue to be held on a fairly regular basis and offering some hope to those who believe the need for a transition of responsibilities is vital to an expanding industry. Additionally, commercial organizations such as the Space Data Association and AGI’s COMSpOC have made efforts to demonstrate a potential commercial option. While these alternatives offer a great deal of promise, the technical, security, and logistical hurdles makes this concept less appealing to the Air Force.

Summary

The airspace above the U.S. is the busiest and safest in the world. As technological advances push routine operations above FL600 it has become necessary to look back at work done in recent decades that consider methods of maintaining that level of safety. In addition, recent changes to the FAA’s effort to transition to a satellite-based primary navigation system within the National Airspace System will aid in addressing current and future commercial, government and soon civilian operations above the current Class A airspace. Stakeholders will also have to consider all responsibilities, authorities, and capabilities that are derived from existing laws, regulation and treaties as new ones are developed, or altered, to address the quickly advancing atmospheric operations as well.
as suborbital and orbital operations that are inextricably linked together. Transitioning current Department of Defense responsibilities for providing orbital conjunction warnings to satellite owner/operators to the FAA could be a start to developing an effective Space Traffic Management system that encompasses operations above, below and across the Kármán Line. Given the technological need and the willingness of the U.S. Government to begin to address the issue, a functioning STM capability is closer to reality than ever. Because of the work done in the past to address the art of the possible, the justification for the need for STM, and the effort to foresee future needs, the effort to convince is coming to a successful end. Today the question is not why or when… but how.


FAA, Federal Aviation Regulations §71.71, Class E airspace


49 U.S. Code § 40103 - Sovereignty and use of airspace


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