The FAA's Current Approach to Integrating Commercial Space Operations into the National Airspace System

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The U.S. Federal Aviation Administration (FAA) has developed an approach to integrating commercial space launch and reentry operations into the National Airspace System (NAS). This approach seeks to capitalize on upfront planning in order to minimize the effect of a launch or reentry operation on the system's performance without jeopardizing the vehicle operator's opportunity for mission success. The FAA has successfully applied this approach to a number of launch, reentry, and amateur rocket activities. This paper provides an overview of that approach and some of the steps that the FAA has taken to implement it. As enabling technologies are developed and implemented, tactical options will become more broadly applicable and effective. Over time, the FAA is seeking to transition from an approach that protects from failure using preemptive airspace restrictions to an approach that operates for success through limited airspace restrictions, increased mission monitoring capabilities, and the ability to effectively respond to contingencies.

BACKGROUND

The U.S. space program today has three sectors: civil, military, and commercial. The commercial sector had its official start in 1984 with the passage of the Commercial Space Launch Act (CSLA). Regulatory oversight for the commercial sector was given to the Office of Commercial Space Transportation, which was originally a staff office within the U.S. Department of Transportation. Today, the Office of Commercial Space Transportation (AST) is one of four lines of business within the Federal Aviation Administration (FAA), which include the Air Traffic Organization (ATO), the Office of Aviation Safety (AVS), and the Office of Airports (ARP). AST's mission is to ensure the protection of the public, property, and the national security and foreign policy interests of the United States during commercial launch and reentry activities, and to encourage, facilitate, and promote U.S. commercial space transportation.

The CSLA requires U.S. citizens to obtain a license before conducting the commercial launch of a launch vehicle or the commercial reentry of a reentry vehicle. The only exception is for missions conducted by and for the U.S. government, such as launches by the National Aeronautics and Space Administration (NASA) or the U.S. Air Force. The operators of commercial reusable suborbital rockets may otherwise obtain an experimental permit,

authorizing them to conduct suborbital launches for research and development, crew training, or demonstrating compliance with other regulations.

Altogether, the FAA has licensed or permitted nearly 250 launches and licensed five reentries from orbit. All of these operations have been conducted without any fatalities, serious injuries, or property damage to the public. The FAA has also licensed the operations of eight launch sites, commonly referred to as spaceports.

INTEGRATING COMMERCIAL SPACE INTO THE NATIONAL AIRSPACE SYSTEM

The FAA continues to address a number of challenges associated with the growth and expansion of commercial space transportation. Principal among future challenges is integrating commercial space transportation into the U.S. National Airspace System (NAS). As commercial space launch and reentry operations continue to increase in frequency and to occur from new locations within the U.S., the FAA has devoted increasing attention to the manner in which these operations can be safely and efficiently accommodated within the airspace. Recently published market forecasts[1] have predicted order of magnitude increases in the rates of commercial space operations over the next five to ten years. At the same time, there are hundreds of amateur rocket activities currently taking place from various locations across the U.S. The scope of many of these activities has expanded to the point where they present many of the same issues to the NAS as permitted or licensed commercial launches and reentries.

OVERVIEW OF APPROACH

Given the current state of commercial space transportation, the FAA must segregate space launch and reentry operations and amateur rocket activities, both on the ground and within the airspace, from the public in order to effectively manage the hazards that these operations can pose to public safety. Specifically with regard to air traffic, the FAA uses relatively large volumes of airspace known as aircraft hazard areas that extend from the surface to infinity and are sized to contain the hazard of falling debris to an acceptable level of risk. The FAA restricts other users of the airspace from using these areas for the duration of time in which the hazards may exist. While the extent to which space launch and reentry operations must be segregated varies depending on vehicle and mission-specific factors, they frequently present conflicts between space operators and other NAS stakeholders for access to the airspace and to areas on the ground at or near airports.

The FAA does not have a formal policy that balances the priority of mutually exclusive operations in the NAS. In the absence of such a policy, the FAA has developed a case-by-case assessment process for space launch and reentry operations that seeks to accomplish the following goal:

> Uphold the required level of public safety and minimize the effect of space operations on the overall efficiency and capacity of the NAS without jeopardizing the space vehicle operator's opportunity for mission success.

A small team comprised of representatives from AST and the ATO works collaboratively with space vehicle operators on a mission-by-mission basis. Through a series of meetings and discussions, the team seeks to understand the vehicle operator's needs, identify the operator's constraints and those of the airspace system and its other users, and develop airspace management strategies for safely supporting the mission.

Given the unique aspects of each mission, the effectiveness of a particular strategy will vary. However, the team has compiled a growing list of airspace management strategies to consider for each mission. These strategies include the following:

1. Minimizing the duration of the launch or reentry operation's window (i.e., the amount of time that airspace restrictions must be in place).
2. Moving the operation window away from peak traffic times.
3. Altering the launch or reentry trajectory, to the extent possible, to avoid placing airspace restrictions in congested airspace.
4. Negotiating with the using agencies of adjacent special use airspace to release their airspace during the operation, reducing reroute mileage of affected aircraft and alleviating choke points.
5. Inserting corridors in an aircraft hazard area that allow aircraft to traverse the area in a controlled manner that does not exceed acceptable safety limits.
6. Implementing a responsive approach to airspace management in which the FAA monitors a launch or reentry operation in real-time and relies on a capability to compute and distribute a realtime aircraft hazard area to tactically respond to a contingency scenario rather than preemptively closing the airspace. This also includes using hotlines with the vehicle operator, air traffic control (ATC) facilities, and other parties to expedite the direct communication of cancellations, delays, and contingencies. The FAA successfully implemented such an approach for all 22 NASA Space Shuttle reentries after the *Columbia* accident[2] and has adapted this approach for all SpaceX *Dragon* reentries.

Certainly, not every strategy can be applied to every mission. For example, launches to the International Space Station must be undertaken at specific times on specific days in order to meet the constraints imposed by orbital dynamics for rendezvous and to have any chance of being successful. For missions such as these, the first two strategies on the list above may be ineffective. Therefore, close coordination between the FAA team and the launch or reentry vehicle operator is imperative to identifying available opportunities that meet the goal stated above. Often times, unique strategies are identified for particular launches or reentries. As we

consider new launch and reentry proposals, we identify new strategies and add them to the list above.

ROLES AND RESPONSIBILITIES

The FAA's implementation of this approach is split between AST and the ATO. As part of its responsibility for licensing or permitting commercial launches or reentries, AST representatives interface directly with the operators of commercial space launch and reentry vehicles and sites and AST analysts compute aircraft hazard areas. AST has published a number of papers describing this topic[3,4]. Complementing AST's role, the ATO interfaces directly with representatives of the other users of the NAS, and ATO traffic managers and controllers manage the airspace surrounding launch and reentry operations.

While some similarities exist between space and aviation operations, the relative differences in dynamics and operational techniques require two distinct skill sets. Recognizing these differences, AST and ATO subject matter experts work collaboratively to leverage their two distinct skill sets of space operations and air traffic management. For example, the ATO has designated a Commercial Space Point of Contact (POC) to improve the coordination required among affected parties for a space launch or reentry operation. The Commercial Space POC works closely with the experts in AST to gather and distribute mission-related information required for timely notification of ATC facilities and other NAS users and for effective planning. Likewise, AST has stationed representatives at the Air Traffic Control System Command Center to gain insight into the constraints imposed by the air traffic environment, to inform the process regarding the constraints faced by the space operator, and to assist the Commercial Space POC in identifying strategies to address those constraints. Indeed, the FAA has recognized that an interdisciplinary approach and close collaboration across its lines of business is essential to the success of its efforts to integrate commercial space launch and reentry operations into the NAS.

PLANNING PROCESS OVERVIEW

Presently, the FAA's integration work for space launch and reentry operations focuses primarily on planning. Effective planning, supported by the timely and efficient distribution of required information, currently provides the FAA with its best opportunity to safely and efficiently accommodate space launch and reentry operations in the NAS.

The planning process consists of the following five steps: input data gathering, plan development and constraint identification, assessment, decision making, and final planning.

Input Data Gathering

The process begins when a launch or reentry vehicle operator or amateur rocket operator approaches the FAA to conduct an operation. At this time, the operator provides the FAA with its proposed trajectory, the timing and duration of its operational window, a list of alternate dates and times during which the operation can be completed successfully, and a list of applicable constraints. These constraints may be meteorological, such as wind or visibility limits. They also may be related to orbital dynamics, mission success requirements, or safety requirements. For example, a launch with a scientific payload may require specific atmospheric or lighting conditions.

The FAA encourages space launch and reentry vehicle operators to provide the necessary information as early as possible, so as to provide the operator with initial feedback on the mission proposal and to capitalize on the flexibility that is often present early on in mission design. Options for making small adjustments to the mission proposal to improve the effect of a mission on the airspace system's efficiency and capacity generally become more limited and more cost prohibitive as the launch or reentry date gets closer.

Plan Development and Constraint Identification

The FAA team checks the input dates and times against the schedule of other known activities to identify potential conflicts. These other activities can include military exercises, other aviation events such as airshows, or even large sporting events like the Super Bowl or the Daytona 500 that require special airspace management. The Commercial Space POC identifies the ATC facilities responsible for the airspace where the launch originates or the reentry terminates and works with them to identify potential location-specific issues or constraints. The POC also coordinates with representatives from AST, who work directly with the launch or reentry vehicle operator to identify additional issues or constraints. At this time, AST analysts also develop predicted aircraft hazard areas or evaluate hazard areas provided by the vehicle operator.

Assessment

In the assessment step, the Commercial Space POC uses available tools and datasets to characterize the effect of the operation as planned on the efficiency and capacity of the NAS. This work can vary in terms of complexity and scope, depending upon on the type of mission being considered (e.g., launch to orbit, reentry from orbit, or suborbital), the time or day of the operation, and the location. A typical assessment begins with a specialist overlaying the predicted aircraft hazard areas onto airspace maps to identify additional affected ATC facilities, special use airspace, and airports. The specialist then evaluates the aircraft hazard areas against a set of data describing historical air traffic patterns and volume within the area of interest, identifying the affected routes, estimating the number of aircraft affected, and

calculating the reroute mileage or delay time required for each flight to avoid the hazard areas during the times when they could be active.

Using this data as a baseline, the FAA team evaluates the launch or reentry mission constraints against the available airspace management strategies. Using its experience and lessons learned from previous missions, it weighs the potential benefits to NAS efficiency and capacity that may be realized through exercising one or more of the available strategies against the effect these strategies could have on the operator's opportunity for mission success. Once all of the available strategies have been considered, the team documents its efforts and its recommended strategy and supporting rationale for review by the appropriate decision makers.

Decision Making

Decision making occurs at the lowest appropriate organizational level. In many instances, the decision to exercise a particular strategy is made by the affected ATC facility, based on local constraints and available resources. However, in cases where multiple ATC facilities are affected or the facility has limited experience with the type or scope of the operation being considered, the decision can be elevated and additional resources can be applied as necessary.

Final Planning

In the final planning step, the Commercial Space POC coordinates the selected strategy among the necessary ATC facilities and provides updated notification to the other airspace users. Multiple methods for disseminating information are often exercised, including the issuing of system impact reports, briefings to representatives of other stakeholders, discussions on operational planning teleconferences, and the issuing of Notices to Airmen (NOTAMs). The FAA team continues to monitor variations in conditions surrounding the operation, including weather and the effects of other concurrent activities, and AST coordinates with the launch or reentry operator as necessary to address any needed changes.

OPERATIONAL MONITORING AND RESPONSE

Some options exist for a tactical or realtime monitoring and response of space launch and reentry operations. In response to the *Columbia* accident, the FAA and NASA developed processes and tools to distribute tactical information in realtime and to use that information to maintain situational awareness and to respond to contingencies that could affect the safety of the airspace system. The FAA has since adapted and tailored those processes to commercial space launches and reentries, including the reentries of the SpaceX *Dragon*.

The FAA's realtime monitoring capability is led by the Air Traffic Control System Command Center. The FAA team of ATO and AST experts uses a dedicated operations area in the Command Center during launch and reentry preparations and operations to centralize data flow and communications. A hotline between the Command Center, other affected ATC

facilities, and the vehicle operator is established and used to share mission preparation and status information. Through agreements with the vehicle operator, the FAA receives pertinent vehicle data that allows the FAA team to monitor mission events against pre-defined timelines.

With this information, the FAA maintains an increased level of situational awareness that allows for the most efficient execution of airspace management plans. Airspace restrictions that must be implemented in advance of the operation are initiated as late as possible to in order to reduce their effect on the system while maintaining the required level of safety. Likewise the FAA removes these restrictions as quickly as possible as it receives information indicating that a hazard to the airspace is no longer present.

Much of this work is conducted manually, using existing tools that were not designed for this purpose. As such, opportunities to increase the efficiency and timeliness of the process, as well as reduce the potential for error, could be realized with a more specific definition of interfaces and the automation of data and information distribution.

In the event of a vehicle failure that could pose a hazard to the airspace, the FAA would use the vehicle data provided by the operator, both over the hotline and through negotiated data connections, to compute a best estimate of the location and extent of the hazarded airspace. Depending upon the scenario, this airspace may coincide with airspace restrictions that are already in place. However, particularly for failures occurring during a reentry from orbit, this may not be the case. Once the FAA identifies the hazarded airspace, the ATC facilities would identify any aircraft within the area and any aircraft approaching the area and use traffic management initiatives, as necessary, to manage the situation.

POST-MISSION ASSESSMENT

Once a mission is completed, the FAA team reviews the plans it implemented and evaluates the outcome of the mission against those plans to verify their effectiveness and identify any shortcomings. As necessary, the team works with the ATC facilities and vehicle operator to resolve any issues. It gathers and documents lessons learned so that it can develop and apply process adjustments to future missions.

NEXT STEPS

Over time, the FAA expects to identify best practices across the variety of missions. It can then use these best practices to develop standardized processes and procedures. Currently, the variety of vehicle and mission concepts prevents developing such guidance. Further, technical limitations and a lack of automation prevent a broader application of the operational monitoring and response techniques described above.

However, the FAA continues to work toward a shift in paradigm from "protecting from failure" to "operating for success." In this manner, the airspace required to contain space vehicle hazards would only be closed in response to a vehicle failure, and airspace would remain open to all traffic otherwise. Such an approach would require the following:

- Vehicle designers must invest in and develop technological innovations to increase vehicle reliability while keeping their costs down,
- Vehicle operators must conduct high frequency operations and develop techniques that increase operational predictability, and
- The FAA must invest in and develop technologies that broaden and improve ATC capabilities.

With regard to its role in this transition, the FAA must work to automate receiving, processing, and disseminating data and information in realtime. To compliment this work, the FAA must develop automated decision support tools for monitoring operations and responding to contingencies.

To that end, the FAA has conducted initial testing of ADS-B technologies as candidate systems for providing communication, navigation, and surveillance capabilities for commercial space. Some of this work has been conducted through the Commercial Space Transportation Center of Excellence (CST COE). The FAA provides grants to the CST COE to promote research and development of commercial space transportation in partnership with academia and industry. In addition, the FAA has conducted an initial exploration of data distribution concepts, including transmission of graphical data to the cockpit[5]. However, a considerable amount of work remains to be accomplished.

CONCLUSION

The FAA has developed an approach to integrating commercial space launch and reentry operations into the National Airspace System. This approach seeks to capitalize on upfront planning in order to minimize the effect of a launch or reentry operation on the system's performance without jeopardizing the vehicle operator's opportunity for mission success. The FAA has successfully applied this approach to a number of launch, reentry, and amateur rocket activities. As enabling technologies are developed and implemented, tactical options will become more broadly applicable and effective. Over time, the FAA seeks to transition from an approach that protects from failure using preemptive airspace restrictions to an approach that operates for success through limited airspace restrictions, increased mission monitoring capabilities, and the ability to effectively respond to contingencies.

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