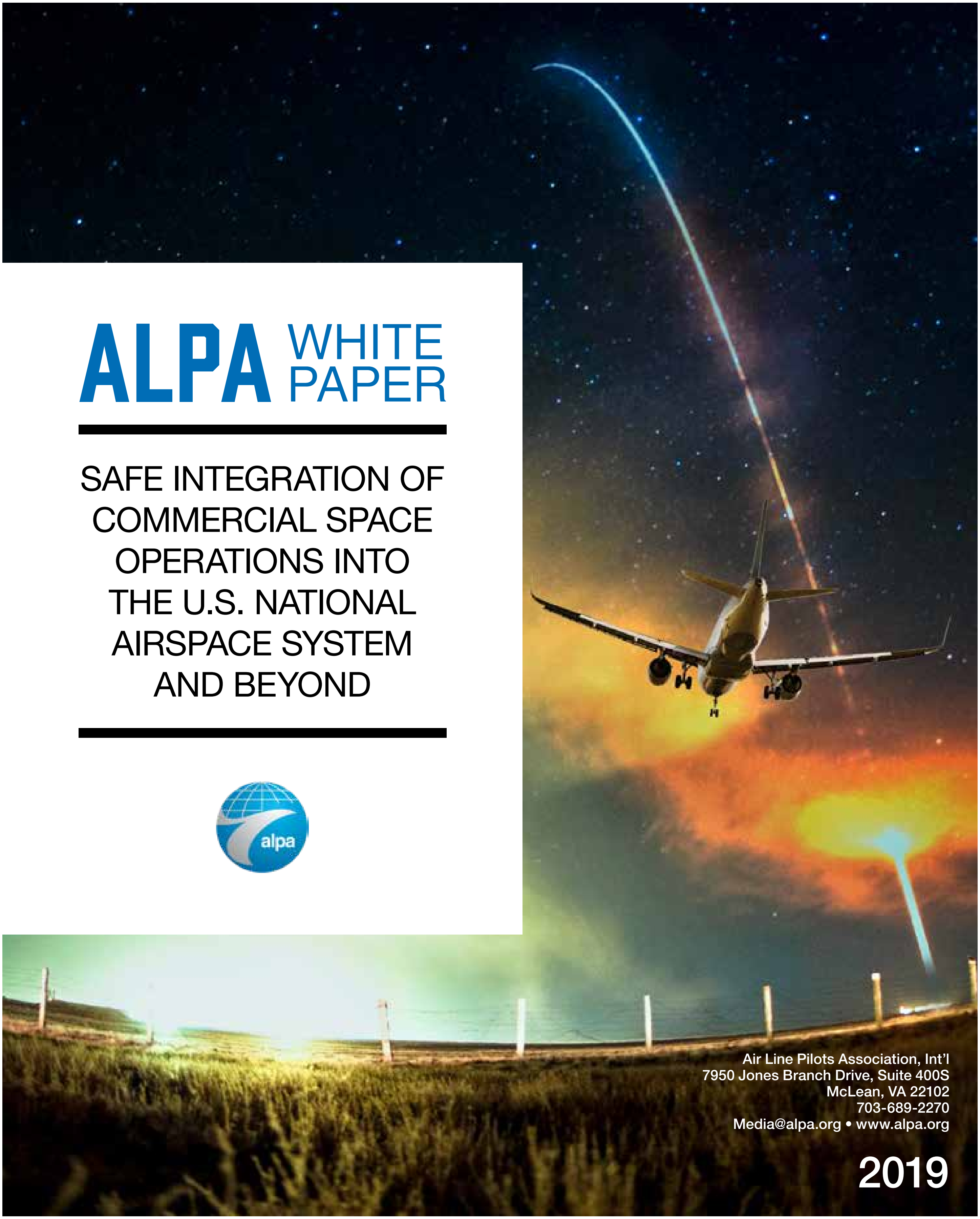
ALPA WHITE PAPER

SAFE INTEGRATION OF COMMERCIAL SPACE OPERATIONS INTO THE U.S. NATIONAL AIRSPACE SYSTEM AND BEYOND



Air Line Pilots Association, Int'l
7950 Jones Branch Drive, Suite 400S
McLean, VA 22102
703-689-2270
Media@alpa.org • www.alpa.org

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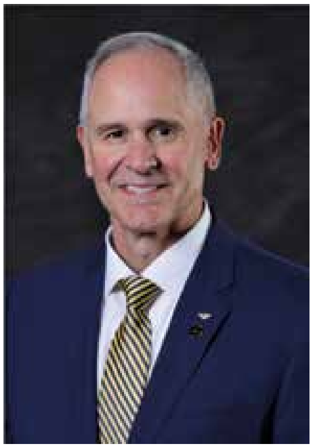

By working together, both the aviation and space communities have the opportunity to benefit from investments in our national airspace infrastructure.

FOREWORD FROM ALPA PRESIDENT JOE DEPETE

The last few years have borne witness to an incredible feat—the coming of age of commercial spaceflight. Launch vehicles regularly and safely depart for low earth orbit to deploy satellites or deliver astronauts and cargo to and from the International Space Station. And for the first time since the heady days of the Apollo program, humankind is looking to step foot on other worlds. As a child of that time, it is again an exciting time to be alive!

But these achievements in space must also take into consideration those of us who are working in the lower parts of the sky. In our 2018 paper, *Addressing the Challenges to Aviation from Evolving Space Transportation*, the Air Line Pilots Association, Int'l (ALPA) highlighted the numerous challenges that the tremendous growth in commercial space operations will present to the nation, including space operator approval, spaceport licensing, regulations for spacecraft crew and participants, spacecraft design standards, and other critical areas. We believe that the number of commercial space launches and recoveries will rapidly escalate in the next 10 years, and that the United States will lead by example in successful commercial space operations that are safely integrated with the mature commercial aviation industry.

We are seeing that growth take place much faster than anticipated.

As a result of these launches, as well as recovery operations, an undue burden has been placed on critical and limited public resources—namely, the national airspace system (NAS), air traffic management, ground infrastructure, and airport services.

In this follow-up paper, ALPA will explore the operational integration of commercial space into the NAS and beyond, particularly in the area of oceanic air traffic management with an eye toward achieving the same level of safety. This paper seeks to highlight the opportunity that exists today for the aviation and commercial space industries to collaborate on and benefit from a joint vision for the future.

This vision will address the evolution from today's manual, segregated operations to a future that is highly integrated—not just with airspace sharing, but also in information sharing, situational awareness, collaborative decision making, and operational procedures. By working together, both the aviation and space communities have the opportunity to benefit from investments in our national airspace infrastructure.

For nearly 90 years, ALPA has been at the forefront of creating the safest form of long-distance transportation in human history. Some of these safety gains carried a high human cost that should not be borne again. The pilots of ALPA, and the aviation industry at large, stand willing and ready to share our experience and expertise with the commercial space industry in the hope of avoiding past mistakes, capitalizing on hard-earned lessons, and building a future we can all be proud of.

Joseph G DePete

Capt. Joe DePete
ALPA President

INTRODUCTION

The ALPA Air Safety Organization (ASO) works on behalf of the safety interests of over 63,000 professional airline pilots who operate around the globe and around the clock. The ALPA ASO formed the Commercial Space Task Group to ensure that Association resources and expertise were focused on issues surrounding the integration of commercial space operations into the airspace where our members fly.

In our 2018 paper, *Addressing the Challenges to Aviation from Evolving Space Transportation*, we highlighted the numerous challenges that the tremendous growth in commercial space operations will present to the nation, including space operator approval, spaceport licensing, regulations for spacecraft crew and participants, spacecraft design standards, and other critical areas. It is ALPA's belief that the number of commercial space launches and recoveries will rapidly escalate in the next 10 years, and that the United States will lead by example in successful commercial space operations that are safely integrated with the mature commercial aviation industry.

In this follow-up paper, ALPA will take a deeper dive into the operational integration of commercial space into the NAS and beyond, particularly in the area of oceanic air traffic management with an eye toward the same level of safety. **The purpose of this paper is to highlight the opportunity that exists today for the aviation and commercial space industries to collaborate on and benefit from a joint vision for the future.** This vision will address evolution from today's manual, segregated operation to one which is highly integrated in terms of not only airspace sharing, but also in information sharing, situational awareness, collaborative decision making, and operational procedures.

By working together toward an integrated future, both the aviation and space communities have the opportunity to benefit from investments in our national airspace infrastructure.

A SpaceX Falcon 9 rocket soars upward after lifting off from Space Launch Complex 40 at Cape Canaveral Air Force Station in Florida. Source: NASA.

CHARACTERIZING THE INTEGRATION CHALLENGE

> The FAA needs a comprehensive plan to integrate commercial space operations and avoid major disruptions for the other users of the NAS as the demand for access to the NAS for commercial space operations increases. As commercial space operations increase, and as the commercial space operations locations continue to expand . . . [there is a need] to reduce NAS impacts while maintaining a high level of safety. At some point, segregation of commercial aviation operations from commercial space operations will not be a viable solution.
>
> —ALPA, *Addressing the Challenges to Aviation from Evolving Space Transportation*, 2018

CURRENT OPERATIONS ARE ACCOMMODATION, NOT INTEGRATION

The current process for managing a space launch has largely remained unchanged since the 1960s: traffic managers create a restricted area that covers the launch area at the time of the launch window, and once the launch activities have ceased, the restricted area is lifted. All other NAS users must stay out of this restricted area and route around the closed airspace. While the analysis tools for creating the restricted areas have improved, and the time buffers and coordination methods have changed, the operational concept is still to segregate regular aviation traffic from the airspace required for the rocket launch. This was a reasonable option when there were only a few launches per year.

The Saturn I (SA-4) flight lifts off from Kennedy Space Center launch Complex 34, March 28, 1963. The overall concept for space launch activities has remained unchanged for decades. Source: NASA.

The prelaunch burden for space operators inherent in this process is significant. Commercial space launch coordination is a lengthy process consisting of three primary stages. The first stage is the preapplication consultation for the proposed commercial space launch. Preapplication consultations can last months or even years, depending upon the readiness of the commercial space operator and mission type. Areas covered include draft environmental documents, letter of agreement requirements between the space operator, FAA Office of Commercial Space Transportation (AST), and FAA Air Traffic Organization, and the application materials required for a policy review package.

Once the preapplication process is complete, the commercial space operator submits a launch license application to AST for formal evaluation. The FAA may take up to 180 days to respond. AST prepares documents describing the operation from the formal application and sends the operational description to various agencies for policy review (Department of Defense, State Department, NASA, Federal Communications Commission, National Oceanic and Atmospheric Administration), requesting formal feedback within 30 days. AST personnel also conduct both a flight safety analysis and a system safety analysis risk assessment and file their results with the formal application. The space vehicle's operational and airspace requirements are evaluated as part of the safety analysis to determine the size of the airspace restrictions that will need to be in place for public safety. A letter of agreement is completed between each air traffic control (ATC) facility having jurisdiction over the required launch airspace and the space operator. AST reviews the application requirements and, once all requirements are met, issues an operating license to the space operator.

After a launch license is issued, the space operator begins operational planning and execution of the actual launch (also referred to as the launch window). This is normally expressed in time (T) from preparing the space vehicle for launch (T minus [T-]) to completion of the space operation. The operational launch window can range from several days (T-48 hrs.) to complete the necessary safety inspections, launch rehearsals and readiness reviews, and space vehicle preflight

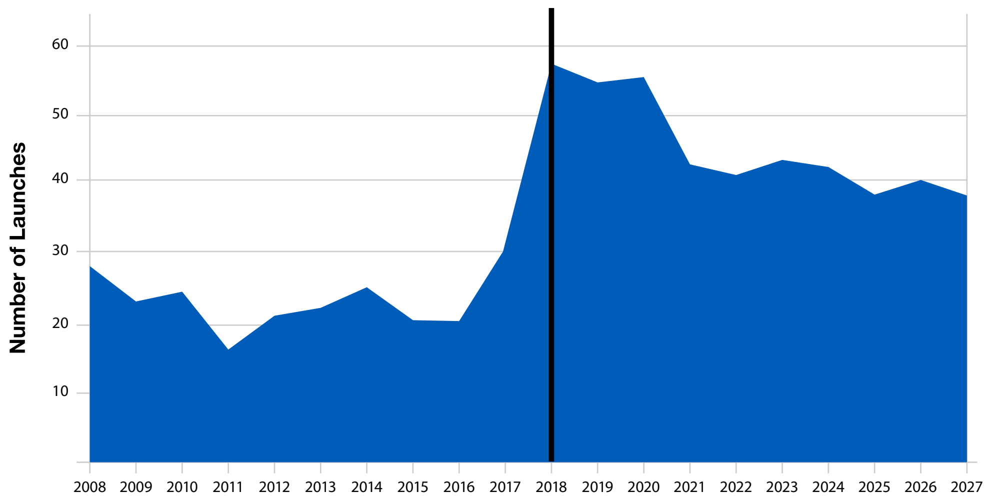

Figure 1: Historical and Projected Commercial Orbital Launches (U.S.)
Source: Federal Aviation Administration, *The Annual Compendium of Commercial Space Transportation: 2018*.

staging. The window for the scheduled launch can open up to 11 hours (T-11 hrs.) from the actual time of launch. Onsite FAA safety inspectors monitor launch parameters to include weather, vehicle system health, and operator compliance with the approved license requirements.

Meanwhile, the FAA air traffic organization is also taking steps to prepare for the launch. Once the space operator has completed its launch plans, the information on required airspace is sent to the FAA's Air Traffic Control System Command Center (ATCSCC). At the ATCSCC, FAA traffic managers identify the impacted airspace, issue notices to airmen (NOTAMs) and coordinate with affected Air Route Traffic Control Centers (ARTCCs). If necessary, traffic management initiatives (e.g., ground delay programs, ground stops, etc.) are put in place to reduce the volume of traffic in order to prevent unsafe congestion. While airlines usually receive some advance notice of the planned launch, dispatchers learn the specifics of the planned launch when the NOTAMs are issued. The airline dispatchers then identify flights that will be impacted, and file flight plans that route the aircraft around the closed airspace accordingly.

Approximately 30 minutes before launch, air traffic controllers are instructed to clear the airspace required to ensure safety. ARTCC controllers begin rerouting traffic around the airspace required for the launch operation until the launch is complete or the launch window is canceled.

During the launch itself, FAA traffic managers may not have any direct feed of launch status, and there is no real-time depiction or status of the launch activities available on ATC automation. Once launch activities are concluded, ATC is notified by e-mail or telephone by the spacecraft operator, which removes the restricted area and in coordination with flight operators assesses whether and how to put flights back onto more efficient paths.

The procedures described above, which halt aviation activities in the affected airspace, are an *accommodation* of space activities. In contrast, the long-term objective should be to fully *integrate* space operations. This has the potential to offer space operators a significantly reduced burden for coordination and approval, with the far-term objective for filing-and-flying like other aviation users of the airspace. Space operators would then have the flexibility to perform launch planning with similar lead times as commercial aviation operators; for example, launch plan filing a few hours ahead of time rather than beginning to coordinate weeks in advance. Similarly for ATC, the move away from closing airspace on the assumption of a launch failure to an assumption of success, with management of off-nominal events by exception, would be much more in line with how the rest of aviation operates today.

COASTAL SPACE LAUNCH ACTIVITIES ARE PROJECTED TO INCREASE

In *The Annual Compendium of Commercial Space Transportation: 2018*, the FAA projects U.S. orbital launches to increase over the next several years, with a near-term spike of about 55 launches a year, then averaging out to about 40 launches per year thereafter, which is about twice the average number of launches experienced from 2010 to 2016 (Figure 1). However, this forecast does not take into consideration the *speculative* growth of space operations for novel applications of satellites, such as constellations of thousands of satellites for mobile Internet services.[1]

1 Cao, Sissi, "Jeff Bezos Poaches SpaceX's Satellite Team to Build a Very Similar Project for Amazon." *Observer.com*. **https://observer.com/2019/04/jeff-bezos-hires-rajeev-badyal-spacex-starlink-head-amazon-kuiper.** April 8, 2019. Retrieved April 10, 2019.

SPACE TOURISM AND SUBORBITAL LAUNCHES

In addition, reusable suborbital vehicles (e.g., Virgin Galactic SpaceShipTwo) are also omitted from Figure 1. While the uncertainty of the forecasts are high, FAA-funded studies suggest that hundreds or even thousands of launches of suborbital vehicles may occur within a few years of the commencement of routine operations.[2] If the volume of space launches does materialize, then without integration these could become another source of significant disruption to the NAS.

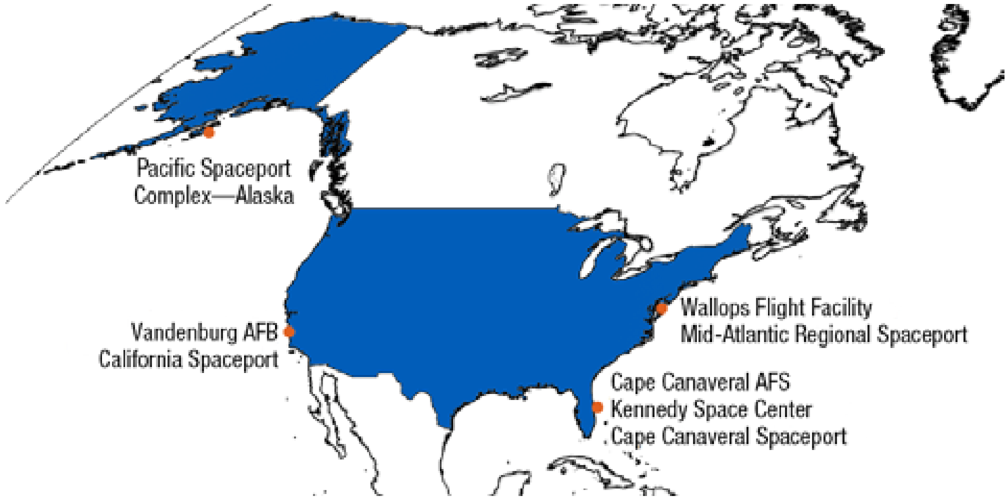

Figure 2: U.S. Orbital Launch Facilities (a launch facility in the Central Pacific Ocean in the Marshall Islands is not shown). Source: FAA.

However, for the purposes of this white paper, orbital launches will be the focus because they generally require a larger airspace restriction area and currently launch into the oceanic airspace regime. It is for these reasons that orbital launches may present a more difficult integration challenge. Figure 2 shows orbital space launch sites that are either government owned or commercially licensed by the FAA.

When calculating the airspace to be closed for a launch, the specifics of the launch such as performance of the launch vehicle, operational history, orbital trajectory, planned reentry trajectories for any booster stages, potential debris from catastrophic vehicle failures, and other factors are taken into account, and a geographic hazard area is defined for the specific spaceflight. Figure 3 shows an example of the closed airspace for a spacecraft launch in 2013.[3]

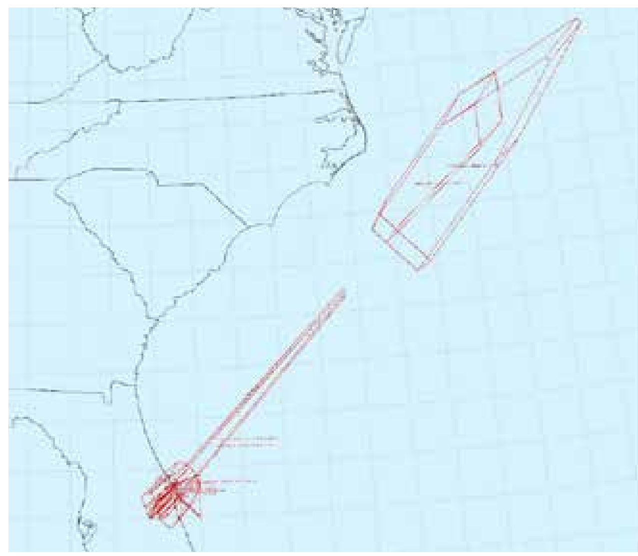

Figure 3: Closed Airspace for a 2013 Space Launch. Source: DOT/FAA.

When looking at the airspace that could be impacted at each launch site, all of the current orbital launch facilities have an effect on major air traffic routes:

- Launching eastward, the Florida facilities affect major offshore routes from Cape Fear, N.C., to south Florida (Atlantic High Offshore Airspace), as well the West Atlantic Route System (WATRS) oceanic routes from the northeast United States to the Caribbean.
- Also launching eastward, the Virginia facilities affect the WATRS oceanic routes.
- The California facilities launch southward, which affect routes from Southern California to the Central Pacific. Note that the affected area may include airspace operated by Mazatlán Center in Mexico.
- The Alaska facilities also launch southward but largely avoid any major routes.

Figures 4 and 5 show the East Coast and West Coast launch impacts to airspace.

2 Tauri Group, The, *Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand* (Alexandria, VA: 2012), 3.
3 Young, Jessica, and M. Kee, *SpaceX Falcon 9/Dragon Operations NAS Impact and Operational Analysis*, Department of Transportation, Federal Aviation Administration DOT/FAA/TC-TN13/49, (Atlantic City: January 2014), 17–19.

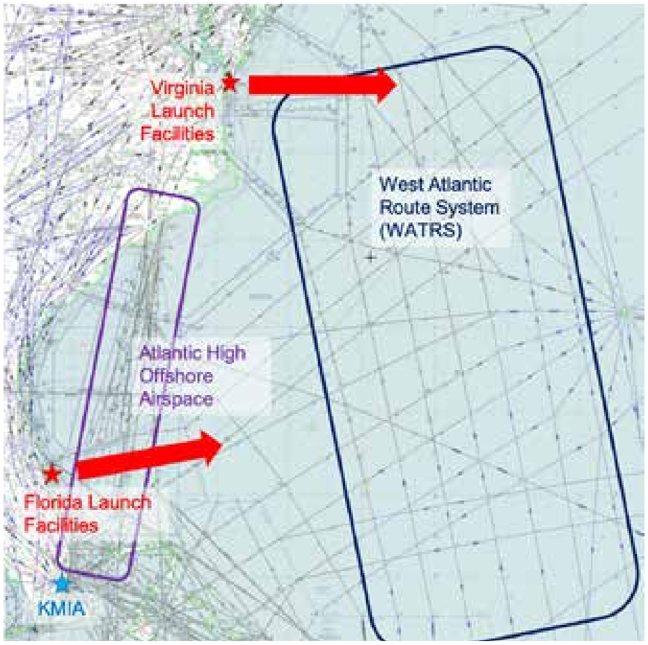

Figure 4: Impacts to Airspace from Florida and Virginia Launch Facilities. Source: ALPA Engineering & Air Safety.

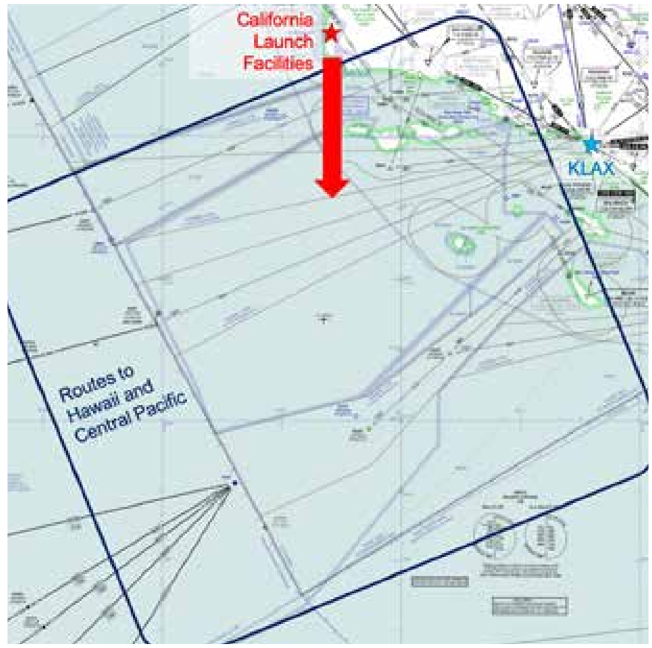

Figure 5: Impacts to Pacific Routes from California Launch Sites. Source: ALPA Engineering & Air Safety.

The East Coast routes affected by both the Virginia and Florida launch sites are heavily traveled by commercial aviation. The Atlantic High Offshore Airspace is an important route for domestic U.S. traffic traveling north-south. These routes, when used in conjunction with inland routes on the East Coast, accommodate high volumes of traffic. When space-launch activities close these routes, all of the traffic must use the inland routes and congestion, especially in the Jacksonville Center airspace, is acute.

Similarly, the WATRS tracks are heavily used by flights traveling between the eastern Caribbean and the northeast United States. When the WATRS tracks are not available, these flights must also fly along the already congested inland routes on the East Coast, which can add a significant amount of distance to the flight (Figure 6).

Figure 6: Comparison of flight routes from New York to San Juan, Puerto Rico. The eastern (right) flight path shows a route using the WATRS tracks, while the western (left) flight path shows the route when WATRS routes are closed. Source: "Gridlock in the Sky," *The Washington Post*, December 12, 2018.

As described in the 2018 ALPA white paper, the impact on these routes from the launch depicted in Figure 6 can be significant:

"ALPA sought to understand the impacts of [this] . . . launch on aviation operations. The launch was at the Kennedy Space Center . . . According to the FAA:

- 563 flights were delayed.
- 34,841 additional nautical miles (nm) were flown.
- An additional 62 nm were flown on average per flight.
- 4,645 total minutes delayed.

- There was an average eight-minute delay per flight.
- 5,000 square nm impacted.
- Orlando International Airport experienced 62 departure and 59 arrival delays.

" . . . FAA's analysis of the impacts of launches at Cape Canaveral indicates that the continued use of segregated airspace on an increasingly frequent basis could become a prohibitively expensive method of supporting space operations."[4]

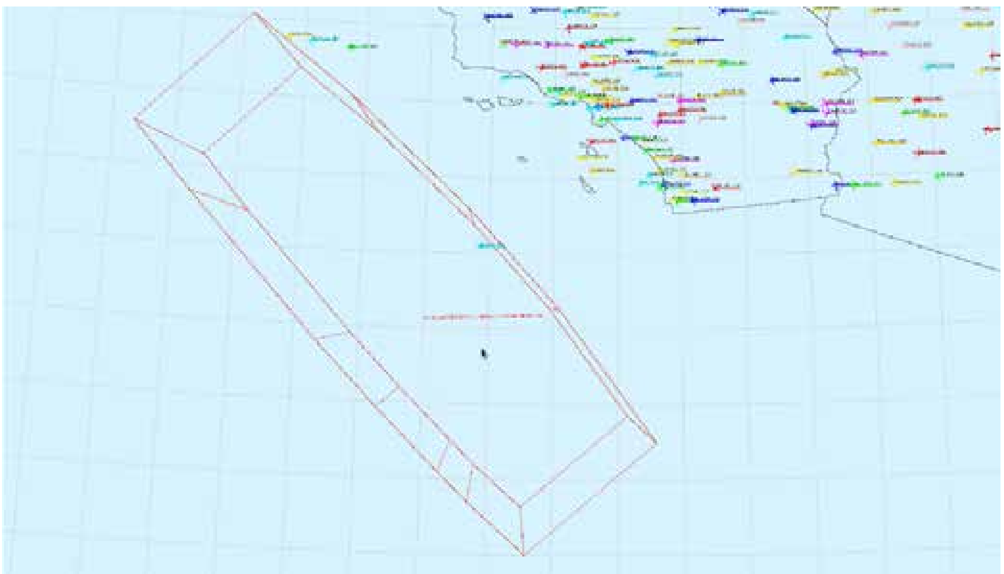

Figure 7: Example Airspace Closure for Reentry Operation. Source: *SpaceX Falcon 9/Dragon Operations NAS Impact and Operational Analysis*, Department of Transportation, Federal Aviation Administration.

Similarly, there have been reports of the increasing impact on the Pacific routes for launches out of California, and for spacecraft reentry operations. Most orbital recoveries take place over the North Pacific; Figure 7 shows an example airspace closure off the coast of southern California (note: Mexican airspace is also affected but is not depicted in this figure).

As summarized by the International Federation of Air Line Pilots' Associations (IFALPA) representative at a recent Informal South Pacific Planning and Coordination Group meeting:

> "Commercial space is becoming a real issue for Oakland [Oceanic Center], because there are more and more missions occurring out in the airspace and they are struggling to keep up with the pace of missions in the Pacific. One example is a mission . . . that will essentially close half of the [Central Pacific] route structure between [Hawaii] and [California]. [We] will see more and more of these missions and there is not a lot [FAA] can do about some of it. They are working to keep relationships/communications positive with the operators."[5]

The large volume of airspace currently required for space launches, coupled with the historically experienced variability in launch time, yield a considerable amount of airline dispatch uncertainty. Given the number of airline flights operating at any given time and tightly connecting schedules at hubs, changes in timing or routing particularly with short notice can lead to rolling delays. These can easily ripple through an entire day's schedule or beyond. Such changes result in increased fuel costs and potentially in missed connections or cancellations that adversely impact customers.

From a safety standpoint, these also increase risk: delays can lead to crew fatigue, changes can lead to errors, and so on. Fortunately, while there are multiple safeguards in place to mitigate these risks, the goal for integrating commercial space operations would be to reduce or eliminate the risks for the benefit of safe operation.

At present, the bulk of the impact is in coastal/oceanic areas and is mitigated to an extent by relatively infrequent space launches. However, advances in ATC technology such as space-based Automatic Dependent Surveillance-Broadcast (ADS-B) for reduced separation will allow for greater air business and commercial airline traffic density in these areas, so the impact of even a single orbital launch will increase.

4 Air Line Pilots Association, Int'l, *Addressing the Challenges to Aviation from Evolving Space Transportation*, (Herndon, Va.: June 2018), 10.

5 IFALPA, *33rd Meeting Informal South Pacific Air Traffic Services Co-ordinating Group and FANS Interoperability Team*, 19REG121, (Queenstown NZ: March 2019), 7.

LAUNCH FACILITIES ACROSS THE GLOBE

RUSSIA: 17 LAUNCHES IN 2018

Russia has several launch facilities including Baikonur Cosmodrome in Kazakhstan, and the Plesetsk and Vostochny Cosmodromes in the interior of the country.

CHINA: 39 LAUNCHES IN 2018

China has three primary launch facilities including Wenchang on Hainan Island, and Jiuquan and Taiyuan, which are located in the interior of the country. China has taken steps to move launches to less-populated areas after a past launch failure resulted in injuries and deaths of nearby residents on the ground.

UNITED STATES: 34 LAUNCHES IN 2018

In 2018, the United States' launches spread among four launch locations (note: one U.S. company, Rocket Lab, launches from New Zealand). The Virginia, California, and Florida launch facilities are located near major cities and launch toward major air traffic routes.

INDIA: 7 LAUNCHES IN 2018

India's primary launch facility is Satish Dhawan, located on the southeast coast near Chennai. While the launch facility is relatively close to Chennai, launch trajectories appear to avoid many of the major domestic routes within India.

EUROPEAN SPACE AGENCY (ESA): 11 LAUNCHES IN 2018

The ESA has its primary launch facility in French Guiana, located on the coast of South America north of Brazil. The facility is located away from any major population centers and directs launches away from the main routes between North and South America.

AMERICA'S ORBITAL COMMERCIAL SPACE INTEGRATION CHALLENGE PRESENTS AN OPPORTUNITY

When looking at the challenge presented by the orbital launch facilities in the United States, they are all located on the coast and launch with trajectories over the ocean. Ironically, it is the oceanic areas which currently have the least air traffic management infrastructure (e.g., communications, surveillance, and ATC automation), and therefore have the least ability to tactically manage airspace.

The FAA's Office of Commercial Space Transportation and NextGen recognize the criticality of developing the means to safely and efficiently integrate the ever-increasing number and variety of space operations with an already-crowded airspace system, both domestically and internationally. **However, at this time, there is no detailed, comprehensive long-term plan for true integration of commercial space operations into the NAS, nor is there a long-term plan for oceanic air traffic management evolution beyond near-term enhancements.** This is a significant shortfall.

ALPA proposes that this shortfall presents an opportunity for the commercial aviation and commercial space communities to jointly advocate for investments in oceanic airspace capabilities which can return benefits to both.

BEGINNING TO EVOLVE FROM ACCOMMODATION TOWARD SAFE INTEGRATION

As a key stakeholder, ALPA has been actively involved in technical and steering committees involving commercial space and air traffic management. These groups include RTCA technical groups, the NextGen Advisory Committee, and the Access to Airspace Aviation Rulemaking Committee, to name a few. Similarly, ALPA's involvement in such programs as ADS-B, DataComm, RNAV/RNP, and other groups has given us a detailed understanding of the level of effort required to realize the safety and efficiency benefits made possible through these programs. The commercial space industry as well as FAA AST is in the midst of an ongoing, exhaustive effort of testing and evaluating vehicles and launch processes that must eventually lead to safe, reliable, repeatable operations. The efforts needed to develop the necessary comprehensive plan to integrate commercial space operations with commercial aircraft operations will be complex and require a similar level of effort, and therefore should be started sooner rather than later.

The FAA has recognized that the current method of segregation, whereby ATC closes large volumes of airspace for extended periods, while safe, is not efficient or sustainable as a long-term solution. Further, the FAA clearly understands that moving away from today's model will require infrastructure investments in hardware, software, procedures, and training for air traffic management. A 2014 FAA Commercial Space Concept of Operations document notes that:

> "This approach was adopted due to current planning and real-time shortfalls, which include manual interfaces, lack of integrated safety and capacity/efficiency evaluation processes, lack of standardized planning and real-time processes, lack of surveillance, and the inability of existing automation systems to process and display space vehicle data."[6]

COMMUNICATIONS, NAVIGATION, SURVEILLANCE (CNS)/AIR TRAFFIC MANAGEMENT IMPROVEMENTS WOULD BENEFIT ALL

To a large extent, the same capabilities that would safely improve the efficiency of airplane oceanic operations would be beneficial in reducing the impact of orbital space operations from the coasts on civil airspace. Airline pilots and dispatchers, air traffic controllers, air traffic management facilities, and spacecraft operations centers would all benefit from having improved ATC services as well as a common set of real-time data on which to base both strategic and tactical operational decisions.

In the broadest sense, spaceflights will need to be planned and flown using similar conceptual processes and safeguards as airliners. There needs to be a filed launch plan (similar to a flight plan); the plan needs to describe in detail the mission parameters (route, altitude, time), be communicated to other airspace users and traffic management functions in real time to create shared situational awareness, and provisions must be made to accommodate irregularities. A controlling entity will need to take all that information and apply procedures that ensure all users of the airspace remain clear of each other

6 *Management of Space Vehicle Operations in the National Airspace System Concept of Operations*, Federal Aviation Administration, August 2014, pg. iii.

by the current safety protocol for safe separation standard, as well as avoid weather and other hazards, etc. The procedures will have to take into account the performance characteristics of all vehicles being controlled, and any ATC instructions will need to be communicated to airline pilots and to space operators simultaneously in real time.

The FAA also recognizes that many of the advancements needed to achieve full integration can be provided by tools under development by NextGen for more efficient management of traditional aircraft traffic. Many of these tools already have significant applicability in oceanic airspace.

For example, compared to domestic operations, oceanic communication between aircraft and controllers is slow and cumbersome, surveillance information is received more sporadically and with latency, and automated tools for controllers necessarily operate on a more strategic level as tactical control is not possible. Aircraft are routed on parallel tracks with much larger separations than are used domestically (e.g., dozens of miles instead of the three to five miles when in domestic airspace).

Thus, we see a strong connection between the technology that can be employed to safely improve efficiency in oceanic airspace and the use of that technology to reduce the impact of spaceflight on commercial air traffic. More accurate and frequent data exchange, ATC automation improvements, surveillance, and real-time voice and data communications will aid pilots in safely conducting operations. These tools will allow more precise, timely identification of closed airspace with an ancillary benefit of providing information on weather hazards.

DATA EXCHANGE AND ATC AUTOMATION

Currently, space operators have very detailed information about the status of their launches via data telemetry—much more than an airline has on a typical flight. The challenge to date has been to develop a data-exchange mechanism to pass this information along to other parties. The FAA's space data integrator (SDI) under development is a move in this direction. SDI will provide controllers and traffic managers with situational awareness of a spaceflight mission through real-time data on vehicle state and operational status, calculate the location and extent of potential hazard areas, and provide visibility into mission progress. SDI will afford the capability for FAA and, by extension, other airspace users to benefit from a detailed level of knowledge of a space mission as it progresses through shared airspace. In addition, the real-time, detailed view provided by SDI allows alert and execution of contingencies if off-nominal events occur.

Satellite-based ADS-B is a key component to tracking aircraft as they fly over the oceans, where there are no ground-based ADS-B receivers. The improved surveillance in the ocean allows air traffic control to improve safety and efficiency. Source: Aireon

SURVEILLANCE

Another example is ADS-B. Currently deployed using ground receivers, ADS-B represents a major advance in efficient air traffic management and pilot situational awareness, with the potential to safely increase the capacity of the NAS. However, application in oceanic airspace lagged due to the difficulty of deploying ground stations on the water. The solution that was developed is space-based ADS-B. Simply put, this is the same capability (and therefore advantage) as the current ground-based ADS-B, but information is received by a satellite constellation instead of ground stations and relayed to air traffic controllers in real time. Space-based ADS-B has the potential to provide surveillance information equivalent to en route radar surveillance for global airspace, including over the ocean.

Figure 8: Soyuz MS-10 Trajectory. Source: ALPA Engineering & Air Safety.

A similar capability, if employed by commercial space operators on orbital/suborbital and boosters during the launch or recovery phases, could give all airspace users timely information on each other, thus improving all airspace users' ability to operate safely and efficiently.

VOICE AND DATA COMMUNICATIONS (DATACOMM)

Advances in communications are similarly possible. DataComm is in use internationally to supplement voice communications with digital messaging. This reduces the likelihood of missing or misunderstanding instructions in the flight deck and on the ground. While DataComm is currently used over the ocean, it is limited to more strategic communications, because it is not as immediate as, for example, direct controller-pilot voice communication via VHF radio used in domestic airspace. More timely performance-based voice and data communications via satellite and possibly by next-generation HF radio to both airborne aircraft and space operators can help reduce the separation buffers among the two, both physically and in time. More timely communications will also provide the capability for better dissemination of weather and similar data that directly impact both aircraft and space operations.

ATC PROCEDURES AND SEPARATION STANDARDS

In the near and mid-term, higher-fidelity CNS data and the ability to exchange this data in real time would allow better definition, geographically and temporally, of the protected airspace needed for space operations (both commercial and government-sponsored), and to disseminate this information to ATC and other airspace users.

As an example of the opportunity space, consider the booster separation failure during the October 11, 2018, manned Soyuz MS-10 launch (Figure 8). The failure occurred approximately 122 seconds after liftoff.[7] At the time of the booster failure and separation of the crew capsule, the spacecraft was at an altitude of about 50 km (164,000'),[8] well above the altitudes used by commercial aviation. Because of the altitude and speed of the spacecraft, the various spacecraft elements took several minutes to fall back to lower altitudes and the ground, with the crew capsule landing about 17 minutes 39 seconds after the booster failure and capsule separation, after reaching a peak altitude of 93 km (300,000').[9]

7 Harwood, William, "Rocket Failure Forces Emergency Landing for U.S. and Russian Astronauts," cbsnews.com, October 11, 2018, **www.cbsnews.com/news/soyuz-rocket-launch-abort-mission-iss-nasa-astronaut-russians-ballistic-descent**, retrieved April 11, 2019.

8 RussianSpaceWeb.com, "Soyuz MS-10 Makes Emergency Landing After a Launch Failure," October 11, 2018, **http://russianspaceweb.com/soyuz-ms-10.html**, retrieved April 11, 2019.

9 Burghardt, Thomas, "NASA and Roscosmos Trying to Avoid an Empty Space Station," October 18, 2018, **www.nasaspaceflight.com/2018/10/nasa-roscosmos-trying-avoid-empty-space-station**, retrieved April 11, 2019.

Given the timeline above, which is typical for an orbital flight, a few things are apparent: first, during a normal launch, the actual time period when airspace is impacted during the launch phase is quite short (e.g., less than two minutes to get well above FL600). Events such as booster separation and return (ballistic or otherwise) are also predictable in both time and location. Finally, with accurate knowledge of the spacecraft state at the time of an anomaly, even off-nominal events can potentially be managed in a more real-time fashion with fewer effects on airspace.

From these characteristics of spacecraft trajectories, with better real-time surveillance of the various spacecraft components during launch it becomes feasible to imagine that an air traffic management capability with full access to real-time information would allow for much more tactical control of the launch operation with surrounding air traffic, including management by exception.

At first, the opportunities are more temporal in nature. With data exchange and ATC integration, controllers and traffic managers will have the opportunity to see launch status in real time, and therefore can potentially expedite the reopening of restricted airspace associated with the launch. Aircraft operators would have real-time information on precisely when the airspace was no longer needed and potentially resume more efficient routing more quickly, all while maintaining necessary safety margins.

Next, development of safe national and international separation standards between aircraft and the airspace required for space operations will be enabled by the availability of high-fidelity data to all participants. Air traffic management system improvements will enhance air traffic control and traffic flow management procedures, which will allow more tactical management of restricted airspace for improved efficiency and inform international standards development. The amount of airspace closed for a launch can then potentially start to shrink while maintaining the level of safety, further reducing the number of flights and amount of impact.

Implementation of a common set of tools, procedures, and capabilities in the near and mid-term would serve to safely reduce airline delays and move toward smoother integration as a far-term goal. A number of commercial enterprises have already begun the process of upgrading CNS capabilities. Hardware is in orbit and testing is in progress. The challenge is to meld these efforts into a cohesive integration plan that will take maximum advantage of these considerable technological advances to improve efficiency and safety of both aircraft and space operations internationally.

LONG-TERM VISION

Looking into the future, the vision for commercial space operations is that they become just another operator in the airspace. To recap ALPA's 2018 white paper, creation of spacecraft design assurance standards and crew and operator certification will be critical to integrated space operations. This in turn will help with operational reliability and predictability. A safety system standard as well as design standards for aircraft, operator certification, and high crew-training standards will help ensure that spacecraft reliability achieves the target level of safety.

Once spacecraft (including components such as boosters) and crew training achieve a high level of safety, combined with the CNS/air traffic management improvements, it will be possible to consider a future where airspace is no longer closed, and instead separation of all vehicles in the NAS is achieved via a separation standard. This would provide a clear reduction in the necessary preflight coordination required by space operators for access to airspace and make file-and-fly operations a possibility.

ALPA believes that these enhancements could ultimately allow for a harmonized safety perspective across civil aviation and spaceflight, where spacecraft operations fully meet the U.S. and international standards for a target level of safety of 10^{-9}. The possibility is open to operate without large volumes of closed airspace for those operations which have high enough reliability from operational and design safety standards, and to use closed airspace for uncertified operations as dictated by the target level of safety, but with less frequency and impact than today.

Commercial aviation (including ALPA) and commercial space should continue detailed discussions of an integration strategy with FAA AST and other authorities and find opportunities for collaborative solutions. One has only to look at the history of nearly every technological improvement in commercial air travel to fully appreciate the considerable but necessary testing and development required to safely implement any new technology. The "crawl-walk-run" approach has been proven effective in ensuring that new technology and the procedures that go with it are thoroughly understood, hazards are identified, and mitigations developed, all to ensure the highest levels of safety are maintained. It is vital to integration efforts that the aviation and space communities work together to avoid misaligned development or duplication of effort, and to make maximum use of existing modernization initiatives in CNS improvements, data exchange, controller displays, and decision-support tools.

CONCLUSION

Investments in an integrated oceanic airspace could lead to significant "wins" for all industry stakeholders. Airlines would see reduced dispatch uncertainty during launches and more efficient routes at other times. Commercial space operators would see far less administrative burden and much more flexibility on when they can operate. Pilots and the flying public would enjoy the same level of safety they have today with fewer delays, more reliable arrival times, and less uncertainty. Investment in our oceanic communications, navigation, and surveillance are foundational to achieving this integration.

An immediate task for FAA AST and all the other NAS stakeholders is to define what full safe integration should look like so we can work toward it. We need to ensure that both airplane and space interests have a full understanding of how each operation impacts other airspace users, and what the capabilities and limitations of airline operations are in the context of accommodating space operations. In particular, the impacts to stakeholders that must be fully understood are not the single launch event we see today, but rather the operational environment in which multiple, simultaneous launches and associated recoveries occur weekly. ALPA is encouraged that the FAA is updating its concept of operations for commercial space travel, and we look forward to seeing that product soon.

Once collaborative solutions to the issues discussed above have been identified, rapid technical improvements in CNS capabilities and the adoption of standards and practices by all airspace users to take maximum advantage of those capabilities can occur. Such development will likely require the same long-term dedicated funding and efforts that ALPA has urged for air traffic management improvements in NextGen.

As the strategic integration effort takes shape, it will be important to look at the various modernization initiatives, especially those in oceanic airspace, through an international lens. A coalition of FAA and industry stakeholders has an opportunity to set the foundation for the development of a harmonized, integrated international standards for air traffic management and commercial space operations globally. As with any successful airplane or spaceflight, effective planning is the key to success. The time to begin planning is now.

To recap:

- Current space launches are *accommodated* by closing large volumes of airspace. This places large administrative burdens on commercial space operators, and also causes significant disruption to aviation. Coordination is manual, and electronic data exchange is very limited. ALPA recommends that the aviation and space industries collaborate on a future vision where space launches are an ordinary operation in the NAS. This process is enabled by investments in communications, navigation, surveillance, and air traffic management capabilities.

- Efficiency shortfalls exist in today's oceanic airspace when just considering civil aviation needs—for example, much larger separation standards and the inability to tactically manage oceanic air traffic. This is due to the lack of communications and surveillance technology and requires increased buffers around aircraft to safely manage separation. ALPA recognizes that the improvements that would help with space integration can also be leveraged to improve the efficiency and safety of aviation traffic, with the possibility of oceanic airspace being managed similarly to domestic airspace.

- ALPA sees an opportunity for the aviation and space communities to work together to advocate for modernized oceanic airspace including improved data exchange, communications, aircraft and spacecraft surveillance, and air traffic control capabilities and procedures. These will have the effect of reducing the impact of space launches by reducing the time and distance buffers needed to safely separate launch activities from aircraft in flight.

- In the area of data exchange and ATC automation, ALPA endorses the continued development of the Space Data Integrator (SDI) program and encourages the FAA AST and space community to continue working together to make this capability a reality. The initial benefit will be for improved situational awareness among all aviation and space stakeholders, which will have immediate benefits in the coordination of space-launch activities. The SDI program also enables more tactical management of space launch that may potentially allow for smaller airspace volumes and shorter launch-time windows needed for closed airspace. This will eventually lead to long-term full integration of space operations.

- For communications, ALPA recommends that FAA pursue means to enable more tactical pilot-controller communication. For example, satellite voice services and next-generation digital HF radio may lead to direct controller-pilot communications that are similar to VHF voice radio in domestic airspace. This enables much more tactical management of air traffic, as the controller now has a greater ability to intervene.

- Improved surveillance capabilities are the second prerequisite for improving controller ability to tactically intervene. Space-based ADS-B is already a reality and is being used to separate traffic today, with the same performance as domestic en route radars. ALPA recommends that the FAA incorporate space-based ADS-B in their infrastructure plans for oceanic airspace, and that similar methods of surveillance be developed for installation on spacecraft components, including boosters and payload elements.

- In the area of air traffic procedures, once the above data exchange, communication, and surveillance capabilities are available, ALPA sees the potential for more tactical management of space activities. Data exchange with ATC automation allows for real-time situational awareness of space activities, while improved communications and surveillance enable much quicker intervention. With appropriate safety analysis, it becomes feasible to imagine that an air traffic management capability with full access to real-time information would enable much more tactical control of the launch operation with surrounding air traffic, including management by exception, meeting one level of safety for aviation and space operations.

A display at the FAA's Potomac TRACON center. Source: ALPA.

- ALPA believes in an evolutionary approach to integration. As with the introduction any other new aviation operation, this will require a crawl-walk-run approach with lessons learned along the way.

Passenger aviation has 105 years of experience, which has resulted in the safest form of long-distance transportation in human history. These safety gains were achieved by learning from many accidents and incidents resulting in loss of life of pilots, passengers, and people on the ground. ALPA and the aviation industry stand willing and ready to share its experience with the commercial space industry with the hopes of avoiding some of our past mistakes and capitalizing on some hard-earned lessons.

ALPA's vision for the integration of commercial space moves from accommodation of space activities, which we have today, to better interoperability via data exchange, improved coordination, and situational awareness in the near to mid-term. With additional investment in communications, surveillance, ATC automation, and development of new procedures and separation standards, along with achievement of spacecraft design-assurance standards and operator and crew certification, ALPA sees a long-term future where space operators are able to file-and-fly like any other operator in the airspace, with separation standards and a harmonized safety approach.

Air Line Pilots Association, Int'l
7950 Jones Branch Drive, Suite 400S | McLean, VA 22102 | 703-689-2270
Media@alpa.org | www.alpa.org
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