
Office of Inspector General

Audit Report

FAA HAS NOT EFFECTIVELY DEPLOYED CONTROLLER AUTOMATION TOOLS THAT OPTIMIZE BENEFITS OF PERFORMANCE- BASED NAVIGATION

Federal Aviation Administration

Report Number: AV-2015-081

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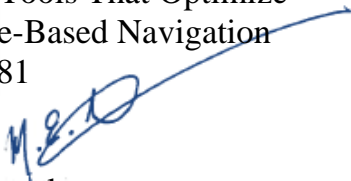
Memorandum

U.S. Department of
Transportation

Office of the Secretary
of Transportation
Office of Inspector General

Subject: **ACTION:** FAA Has Not Effectively Deployed
Controller Automation Tools That Optimize
Benefits of Performance-Based Navigation
Report No. AV-2015-081

Date: August 20, 2015

From: Matthew E. Hampton 
Assistant Inspector General
for Aviation Audits

Reply to
Attn. of: JA-10

To: Federal Aviation Administrator

A cornerstone of the Federal Aviation Administration's (FAA) Next Generation Air Transportation System (NextGen) is its initiative to enhance efficiency and capacity at airports through the use of performance-based navigation (PBN). PBN delivers new routes and flight procedures that primarily use satellite-based navigation aids and on-board aircraft equipment to navigate with greater precision and accuracy. As such, PBN can provide significant benefits, such as more direct flight paths, improved on-time airport arrival rates, greater fuel savings, and reduced emissions and noise. According to a September 2013 Government/industry report on NextGen priorities,¹ optimizing the use of PBN procedures should be FAA's top NextGen priority. Although over 50 percent of major airlines' aircraft are equipped and approved to use advanced PBN procedures, use of these procedures remains low.

A key barrier to increasing PBN use and achieving benefits is FAA's lack of automated tools that would allow air traffic controllers to effectively merge and sequence airport landings for arriving aircraft with differing equipment and capabilities. FAA has determined that using automated decision support tools to help space and sequence aircraft based on time rather than the traditional miles-based method increases traffic flow efficiency and can optimize benefits from PBN.

¹ NextGen Advisory Committee, *NextGen Prioritization: A Report of the NextGen Advisory Committee in Response to Tasking from the Federal Aviation Administration*, September 2013.

Concerned with FAA's long history of delays in deploying new systems for NextGen, the Chairmen and Ranking Members of the House Committee on Transportation and Infrastructure and the Subcommittee on Aviation requested that we assess the Agency's progress in developing and deploying these tools. Accordingly, our audit objectives were to assess (1) FAA's progress in developing and deploying new air traffic controller automation tools for managing PBN operations, and (2) the degree to which these tools meet air traffic controllers' needs to improve PBN use.

We conducted this review in accordance with generally accepted Government auditing standards. Exhibit A details our scope and methodology, and exhibit B lists the specific organizations we visited or contacted.

RESULTS IN BRIEF

FAA has deployed an automation tool—Time Based Flow Management (TBFM)—which can help controllers optimize PBN operations at high altitude facilities;² however, FAA has not effectively implemented it, nor deployed a key tool to help optimize PBN operations close to airports. When FAA deployed TBFM, the Agency did not resolve longstanding problems that plagued the previous system. These problems included a lack of clear guidance for facilities on its use, standardized operating procedures, and metrics for measuring program success and whether benefits are being realized. As a result, controllers' use of the tool was fragmented and inconsistent among the air traffic facilities we visited. FAA has begun taking actions to address these problems, but it is unclear when the Agency will fully resolve them given the magnitude of the problems with the tool. Also, without a sequencing tool for managing traffic close to busy airports, controllers will have difficulty increasing PBN use, and efficiencies gained in high altitude airspace could be lost.

The automation tool FAA has deployed that can improve PBN use—TBFM—is not adequately meeting air traffic controllers' needs. According to FAA, our interviews with controllers, and industry experts, controllers require a tool to provide reliable, predictable, and accurate information; work during all weather conditions; and be tailored to the local air traffic operating environment. Despite identifying these requirements in multiple internal and external³ reports as early as 2001, FAA has yet to fully address them. In addition, using time-based capabilities

² TBFM is a decision support tool that helps optimize the flow of traffic to busy airports by using time to sequence and separate aircraft rather than miles, the traditional method controllers have used for years. TBFM has evolved from the previous time-based sequencing tool, the Traffic Management Advisor (TMA), that had been in development and use for over 15 years.

³ *Free Flight Tools Show Promise, but Implementation Challenges Remain* (GAO Report No. GAO-01-932), August 2001; and *Free Flight Phase 1 Technologies: Progress to Date and Future Challenges* (OIG Report No. AV-2002-067), December 14, 2001.

to help space and sequence aircraft is a significant cultural change from how controllers have traditionally managed aircraft. Yet, FAA has not provided adequate training and technical support to encourage controllers' use of the tool.⁴ Further, for the TBFM tool to work effectively, facilities must coordinate with neighboring facilities to provide the most efficient traffic flows. However, managers at three of the seven en route centers we reviewed expressed concern that multi-center operations were not working effectively, in part because FAA had not established local facility agreements. As a result of these unresolved issues, controllers have experienced significant operational problems in using the tool that hinder its use system-wide.

We are making recommendations to improve FAA's implementation of controller automation tools and help optimize PBN operations.

BACKGROUND

To enhance capacity and reduce delays at congested airports, FAA is implementing PBN flight procedures, such as Area Navigation (RNAV)⁵ and Required Navigation Performance (RNP).⁶ As part of the RNAV implementation strategy, FAA is implementing optimized profile descents for smoother flight paths that use less fuel than conventional "step-down" approaches, which require aircraft to fly a long series of progressive descents to get closer to the runway.

In 1996, due to anticipated future National Airspace System (NAS) capacity constraints, FAA began transitioning from traditional methods of air traffic separation using distance (i.e., miles) to time-based sequencing through the development of the Traffic Management Advisor (TMA),⁷ a controller automation decision support tool originally pioneered by the National Aeronautics and Space Administration (NASA). Unlike the traditional method of separating aircraft based on distance (referred to as "miles-in-trail"), time-based sequencing dynamically spaces aircraft based on several factors, including aircraft size and capabilities, to deliver aircraft to a specific place at a specific time, thus allowing air traffic controllers and managers to manage aircraft in congested airspace more efficiently (see figure 1).

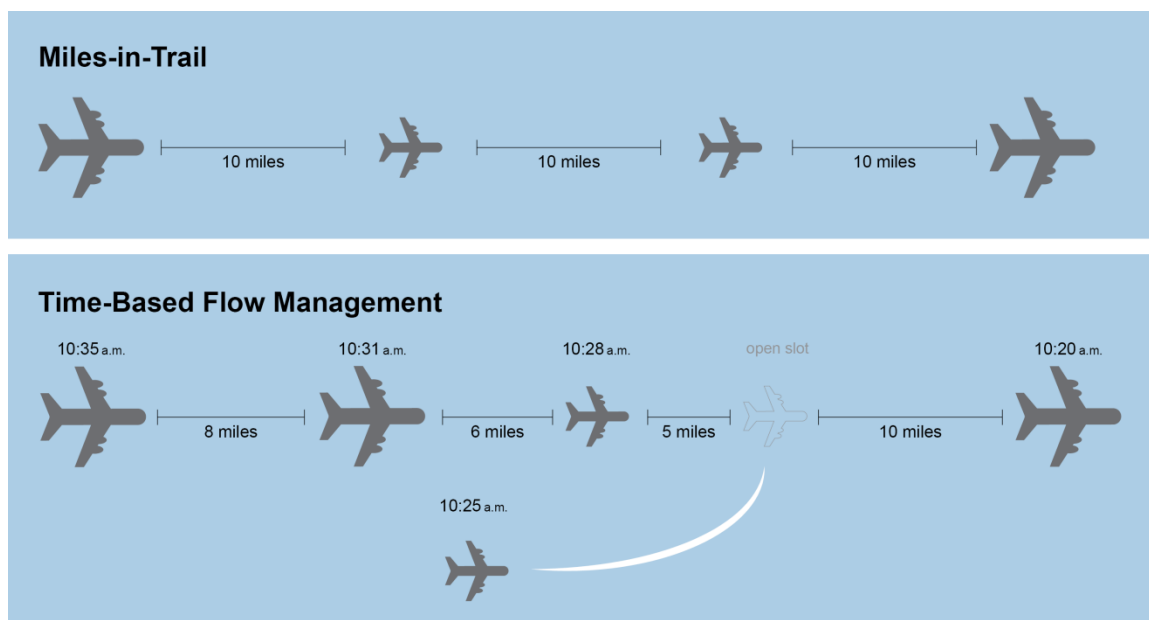
⁴ In fiscal year 2015 FAA began deploying a new advanced adaptation course for facility automation specialists.

⁵ RNAV is a method of navigation in which aircraft use satellite signals to fly any desired flight path without the limitations imposed by ground-based navigation systems.

⁶ RNP is a form of RNAV that adds monitoring and alerting capabilities for pilots, thereby allowing aircraft to fly more precise flight paths.

⁷ TMA is a time-based controller automation tool that was deployed to Air Route Traffic Control Centers (ARTCC), Terminal Radar Approach Control Facilities (TRACON), and Airport Towers. FAA completed deployment in 2008.

Figure 1. Difference Between Miles-in-Trail and Time-Based Flow Management for Separating Aircraft at High Altitudes



Source: OIG analysis.

FAA has determined that sequencing aircraft based on time rather than the traditional miles-based method is a key element of NextGen that increases the capacity and efficiency of the NAS, while also allowing aircraft to use more precise PBN procedures.

FAA HAS NOT EFFECTIVELY IMPLEMENTED CONTROLLER AUTOMATION TOOLS THAT OPTIMIZE PBN OPERATIONS

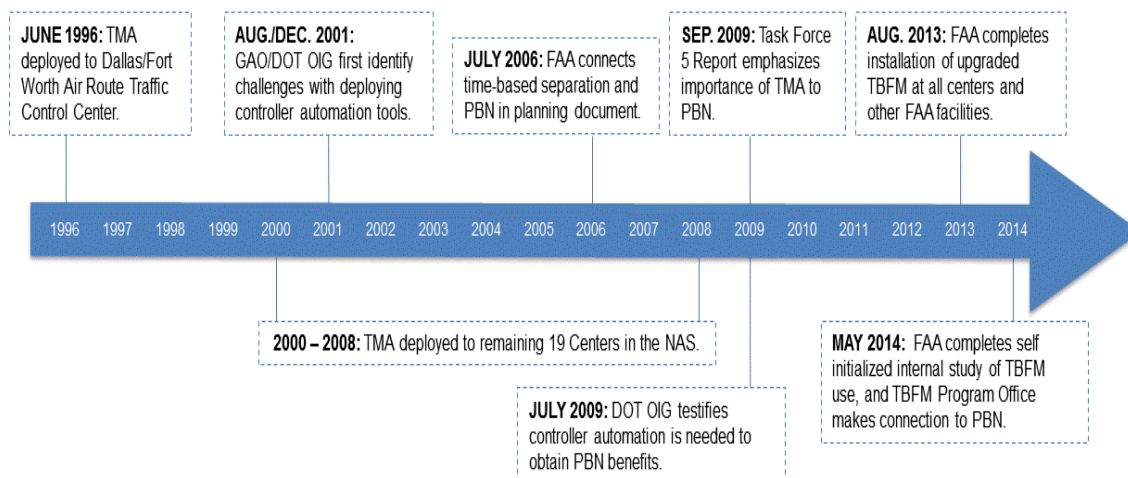
FAA has deployed an automated tool called TBFM, which can help controllers optimize PBN operations at high altitude. However, the Agency has not effectively implemented it, nor deployed a tool for managing air traffic close to the busiest airports, which is essential to realizing all the benefits of PBN from high-altitude down to the runway.

FAA Has Not Effectively Implemented Its Automation Tool That Can Help Optimize PBN Use at High Altitude

FAA has taken over 15 years and spent over \$675 million testing and deploying automated decision support tools⁸ to help controllers space and sequence aircraft based on time—an important component of FAA's vision for NextGen (see figure 2).

⁸ Length of time and cost calculated using FAA documents.

Figure 2. Timeline of Air Traffic Controller Automation Tools



Source: OIG analysis.

FAA's initial efforts to deploy controller automation tools were plagued with implementation issues and inconsistent use by controllers. Specifically, between 1996 and 2008, the Agency deployed its first time-based decision support tool, TMA. According to FAA officials, TMA was originally designed for use to help improve the flow of traffic due to airport capacity constraints, not as a PBN tool, and its use was optional even though the Agency deployed the system at all 20 en-route Centers responsible for managing high-altitude traffic. During that same period, our office⁹ highlighted the need for policies, procedures, and expectations for use, among other things, to mitigate risks and increase the tools' use and acceptance by the controller workforce. However, controllers and managers at six facilities indicated that FAA provided insufficient policies and procedures. As we reported in June 2014,¹⁰ inconsistent use of TMA, due to a lack of controller training and insufficient procedures, was a key barrier to increasing PBN use.

To address shortfalls in the system and meet current and future NextGen needs, FAA upgraded TMA to TBFM¹¹ at all 20 en route centers between 2010 and 2013. FAA also deployed elements of the system to 30 Terminal Radar Approach Control (TRACON) facilities and 37 airport towers for situational awareness and scheduling purposes. Like TMA, the TBFM system enables the use of time-based

⁹ *Free Flight Phase 1 Technologies: Progress To Date and Future Challenges* (OIG Report No. AV-2002-067), December 14, 2001.

¹⁰ *FAA Faces Significant Obstacles in Advancing the Implementation and Use of Performance-Based Navigation Procedures* (OIG Report No. AV-2014-057), June 17, 2014.

¹¹ TBFM is an evolutionary enhancement of the Traffic Management Advisor. TBFM is a tool intended to streamline traffic flows by scheduling aircraft to arrive at a specific place at a specific time. FAA plans to introduce new TBFM capabilities, such as sequencing aircraft further out from the airport to optimize PBN benefits with smoother descents and efficiently rerouting aircraft in flight to avoid inclement weather.

sequencing to optimize the flow of flights as they approach and depart congested airspace and airports in the NAS.

However, like with TMA, FAA's TBFM deployment has been plagued with significant problems and has not effectively optimized PBN use. According to FAA program officials, the Agency only recently recognized the importance of consistently using TBFM to optimize PBN use. However, several previous FAA planning documents, such as the 2006 PBN Roadmap and the 2008 and 2009 NextGen Implementation Plans, as well as numerous Government/industry reports¹² have noted the importance of using time-based automation in conjunction with PBN.

Our current work and a FAA TBFM program review in 2014 determined that the implementation and use of TBFM has been inadequate due to several factors, including lack of:

- a national program vision stating a unified direction and connectivity to PBN,
- standardized operating policies and procedures,
- clear guidance regarding when to use the system, and
- metrics or tracking tools to gather data for measuring potential system benefits.

As a result, controllers' use of TBFM has been fragmented and inconsistent among air traffic facilities. FAA facility representatives we interviewed indicated other contributing factors, including their airspace complexity, lack of neighboring center participation, and lack of specialized staffing. For example, although the TBFM system was operational at three facilities we visited, the facilities had not assigned anyone to manage it.

FAA is taking steps to improve TBFM implementation. In 2014, FAA performed a study¹³ at the request of the Air Traffic Organization's leadership to identify gaps associated with operational use of TBFM. The study identified 45 needed improvements, and in June 2014, FAA established a draft action plan to implement them. The Agency has already begun to help facilities understand the importance of using TBFM by establishing a national program vision statement. According to FAA officials, the Agency is also continuing work on developing

¹² RTCA, "NextGen Mid-Term Implementation Task Force Report," Sept. 9, 2009; FAA, "Obstacles to Performance Based Navigation Implementation," March 1, 2012; NextGen Advisory Committee (NAC), "Recommendation for Increased Utilization of Performance Based Navigation (PBN) in the National Airspace System (NAS)," June 2013; NAC, "NextGen Prioritization," September 2013.

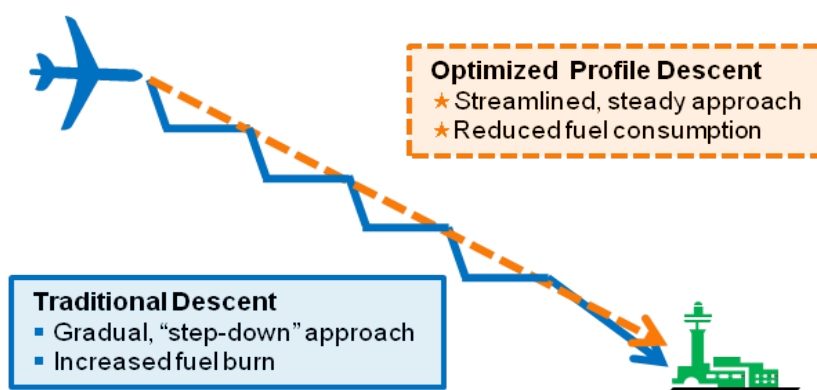
¹³ TBFM Study Report, April 17, 2014.

new standardized policies and procedures, including clear guidance on using the system.

However, while the Agency is in the early stages of implementing its draft action plan, milestone dates have already slipped and it does not yet have a final plan with dates for all proposed actions. For example, FAA has delayed the publication of a usage policy originally planned for June 2015 until December 2015. Also, FAA prioritized outstanding system problem reports but has not committed to a timeline to resolve them.

Additionally, as recommended by a 2009 Government-industry task force,¹⁴ FAA is coordinating TBFM improvements with FAA's metroplex program, which aims to improve the efficiency near large metropolitan areas by implementing high value PBN procedures and making airspace changes. For example, Houston facility representatives stated they received increased support from the FAA William J. Hughes Technical Center,¹⁵ MITRE, and a private contractor in tailoring TBFM to its airspace and use of new PBN procedures with smoother descents (see figure 3).¹⁶ According to MITRE's post-implementation analysis, the Houston Metroplex is expected to save \$6.1 million annually in reduced fuel costs for airlines, which is at the lower end of MITRE's initial expected savings range of \$5.8 to \$16.7 million. The fuel savings are primarily due to the improved descents, which are facilitated by TBFM.

Figure 3. Comparison of a Conventional “Step-Down” Approach Versus an Optimized Profile Descent



Source: OIG analysis.

¹⁴ RTCA, “NextGen Mid-Term Implementation Task Force Report,” Sept. 9, 2009 recommended that FAA implement quality PBN procedures at key metroplex sites in an integrated manner with airspace redesign and use of automation tools to increase benefits.

¹⁵ The William J. Hughes Technical Center provides system testing and help desk support for FAA automation systems.

¹⁶ Optimized Profile Descents (OPD) are more efficient procedures by which aircraft approach airports prior to landing. They are designed to reduce level offs during descent, thus reducing fuel consumption and noise.

Although MITRE analysts found that TBFM allows for more fuel-efficient flights, they also found it may be contributing to additional delays and did not include those costs in the benefit calculation.

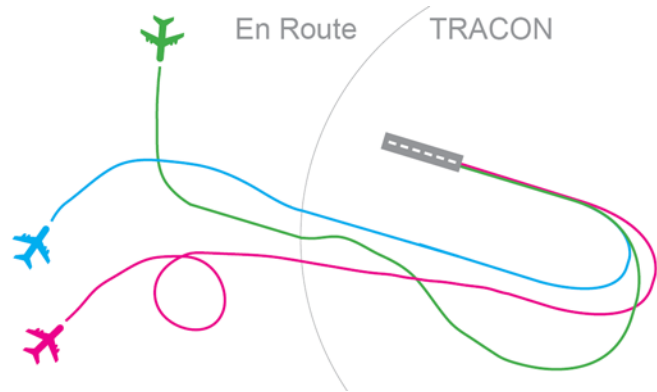
FAA Is Several Years Away From Deploying a New Controller Automated Tool for Managing Airport Arrivals

FAA has not yet deployed a much needed tool to help controllers manage aircraft arrivals in the airspace closest to the busiest airports. Advanced PBN procedures, such as RNP, allow more efficient approaches to runways, including curved paths. However, without an automated decision support tool for use in terminal airspace,¹⁷ controllers cannot effectively manage some aircraft arriving on straight-in approaches and others on curved PBN procedures. In addition, any efficiencies gained for PBN smoother descents at high altitude can be lost once aircraft enter the terminal airspace, as they will be forced to use costly level-offs (i.e., a “step-down” descent that requires more fuel). As figure 4 below illustrates, using a time-based tool for aircraft arrivals allows aircraft to fly shorter, more direct paths as they land.

Figure 4. Differences in Aircraft Arrivals With and Without TBFM

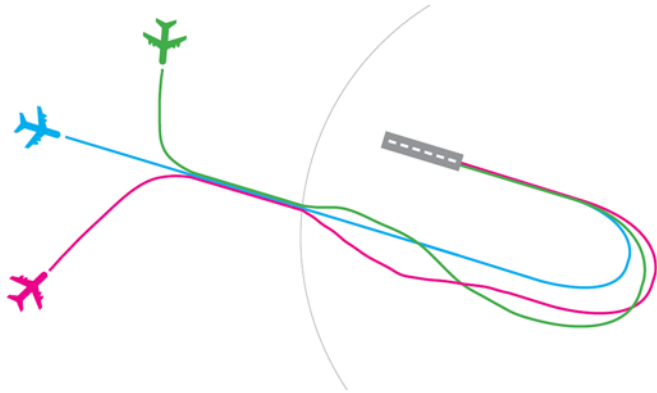
TBFM NOT USED

- No automation tools to help controllers sequence and space aircraft
- Inconsistent flow of aircraft to airport
- Controllers more likely to direct aircraft off procedures and into holding to maintain safe spacing
- Results in more level offs (Step-down type descent)



TIME-BASED SEQUENCING (TBFM)

- TBFM for high altitude, but no automation for area closest to airport
- More consistent flow of traffic
- Able to use RNAVs with OPDs (optimized profile descent) instead of level offs more often
- RNP's very difficult for air traffic controllers to manage



Source: OIG analysis.

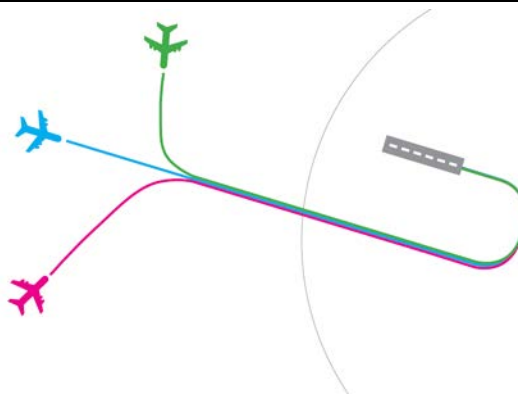
¹⁷ Terminal Airspace is an area roughly 60 miles around the arrival airport.

To address this problem, FAA is currently working on a new tool to help controllers merge and sequence aircraft in terminal airspace called Terminal Spacing and Sequencing (TSS). It extends the capabilities of TBFM into the airspace closest to the airport, potentially resulting in even further efficiency gains (see figure 5 below).

Figure 5. Expected Efficiency Gains With Both TBFM and TSS

WITH TBFM and TSS

- Maximum use and benefit of PBN (use of RNAV and RNP)
- Increased use of OPDs (optimized profile descent) instead of level offs
- Minimal changes required by air traffic controllers
- Facilitates use of RNPs with curved final approaches



Source: OIG analysis.

However, FAA may face challenges in deploying TSS, especially since two previous efforts to implement similar capabilities have failed. First, FAA had originally deployed a system similar to TSS along with TMA, called passive Final Approach Spacing Tool, in 1999. However, FAA never fully deployed it. As our office reported in 2001,¹⁸ the tool suffered technical problems, including lack of technological maturity and complex site-specific adaptation issues. Both our office and the General Accountability Office (GAO) concluded that achieving controller acceptance and use of the tool was a key barrier. The National Air Traffic Controllers Association's (NATCA) TBFM representative also stated FAA may face a similar challenge deploying TSS.

Second, in 2013,¹⁹ FAA stopped work on a decision support tool for use in managing airport arrivals, the Relative Position Indicator (RPI), after 11 years of development in collaboration with MITRE and other contractors. According to FAA, RPI did not meet the needs of controllers at busy airports even though it was specifically designed to do so. FAA also stated that it did not deploy RPI nationally because it lacked needed technology, such as features that would account for weather. Before abandoning it, according to FAA officials, the Agency had invested \$7.5 million in developing and testing RPI.

¹⁸ *Free Flight Phase 1 Technologies: Progress to Date and Future Challenges* (OIG Report No. AV-2002-067), December 14, 2001.

¹⁹ FAA did not have documentation on when it made the decision to abandon RPI, but a contractor last performed work on RPI in 2013.

FAA's decision to halt its efforts on RPI has impacted use of advanced procedures at key airports. FAA used Seattle as a demonstration site for RPI and planned to begin implementing the tool at other sites in 2012. However, due to FAA's decision to abandon RPI, FAA launched new PBN procedures in Seattle without this critical element. Although pilots can still fly the PBN procedures, Seattle TRACON officials told us that they will only be able to use advanced RNP approaches about 15 percent of the time for Seattle-Tacoma International arrivals. According to FAA data, less than 1 percent of eligible aircraft arriving into Seattle-Tacoma International Airport are actually using an RNP approach.²⁰

Although FAA's new effort, TSS, has potential to increase PBN use in metroplex and non-metroplex areas, FAA is still testing and developing the tool in collaboration with NASA. In 2014, MITRE cautioned that FAA's aggressive timeline for TSS will not allow for needed concept engineering work and operational evaluations. In fact, FAA has delayed a key step in the acquisition process—the final investment decision—for TSS several times. It was originally scheduled for September 2014, but was delayed three times and was not held until April 2015. FAA now plans to deploy TSS beginning in 2019 rather than originally planned in 2018. According to FAA, these delays are the result of budget uncertainties. Given the complexity and the Agency's past experiences with automation tools, it is uncertain when TSS will be fully deployed.

FAA'S CURRENT AUTOMATION TOOL FOR IMPROVING PBN USE DOES NOT FULLY MEET CONTROLLERS' NEEDS

TBFM, the automated decision support tool currently deployed to help improve PBN use, is not fully meeting air traffic controllers' needs. First, FAA's deployed tool is experiencing significant performance and reliability issues that have remained unresolved for years. Second, FAA has provided limited training for instructing controllers on how to use the tool. Third, FAA has not provided controllers sufficient technical support with TBFM to address and resolve problems. As a result, controllers have experienced significant problems with using the tool, such as increased air traffic management complexity.

FAA's Deployed Tool Continues To Experience Performance and Reliability Issues

FAA's controller automation tools suffer from longstanding problems that prevent the tools from meeting controllers' needs, especially the need for a tool that can provide reliable, predictable, and accurate arrival times. While FAA has identified and provided specific actions intended to correct these shortfalls in multiple

²⁰ FAA publishes PBN usage data on its public Web site, <http://www.faa.gov/nextgen/pbn/dashboard/>. The data are provided by MITRE and validated by FAA.

reports since 2009, to date none of FAA's attempts to deploy or implement changes to TBFM have produced a reliable tool for controllers. Additionally, many challenges and issues have been repeated through several of our, FAA, and industry reports, but FAA has yet to fully address them. (See table 1 for a list of these unresolved issues.)

Table 1. Unresolved TMA/TBFM Issues Cited in Prior Reports

	Vision/ Direction/ Expectations of Use	Policy & Procedures	Controller Training	System Management Software & Adaptation	Missing Terminal Tool	Coordination Across Facilities
FAA report, <i>TMA Shortfall Analysis</i> (Apr. 2009)	●	●	●		●	●
RTCA <i>NextGen Mid-Term Implementation Task Force Report</i> (Sept. 2009)			●			●
FAA report, <i>TBFM FID Program Baseline ROD</i> (Apr. 2010)			●	●		●
FAA report, <i>Obstacles to Performance Based Navigation Implementation</i> (Mar. 2012)		●	●	●		
NextGen Advisory Committee (NAC), <i>Recommendations for Increased Utilization of PBN in NAS</i> (June 2013); and <i>Addendum</i> (Feb. 2014)	●				●	
FAA report, <i>TBFM Study Report</i> (Apr. 2014)	●	●	●	●	●	●
OIG report, <i>FAA Faces Significant Obstacles in Advancing the Implementation and Use of PBN</i> (June 2014)		●	●			

Source: OIG analysis.

For example, to allow pilots to use PBN procedures during peak traffic times, controllers require a tool that can help them merge aircraft onto PBN routes while maintaining safe spacing without directing the pilot to change course. TBFM is intended to accomplish this by scheduling aircraft to arrive at the airport at specific times while also accounting for the needed spacing. However, controllers, managers, and automation support staff in each of the seven en route facilities we

visited—as well as FAA’s 2014 program review—identified continued technical problems. These include:

- **Unreliability of TBFM’s generated delay times.** Controllers stated that the “delay countdown timer,” which is used to provide guidance to controllers on how much delay an aircraft must absorb in order to meet the scheduled arrival time, can be erratic and often fluctuates. As a result, many controllers are reluctant to rely on TBFM. Controllers stated that trying to work with the delay timer actually added to their workload and increased the amount of communication between the controller and pilot.
- **Inability to use TBFM during adverse weather.** According to representatives at facilities we visited, weather is a key factor in determining if TBFM will be used at all. Controllers and FAA managers we interviewed stated that the automation is either turned off during adverse weather conditions or the times generated by TBFM are ignored because they lack accuracy.

While FAA has TBFM enhancements under way and planned, which could help resolve these performance and reliability issues, it is uncertain when they will be fully implemented to provide widespread benefits. These enhancements include:

- **Ground-based Interval Management-Spacing.** FAA’s newest TBFM enhancement includes two separate capabilities that work together to help improve the flow of traffic further away from the airport.²¹ Streamlining the traffic earlier in the flight path helps facilitate PBN procedures by reducing the need to direct pilots off of the procedure closer to airports where PBN routes are established. FAA has reported that at Albuquerque Center, the test site for this new enhancement, some of the predicted benefits are being achieved, including controllers keeping aircraft on PBN routes longer. However, during our visit, facility managers and controllers explained that the enhancement will only provide limited benefits until neighboring air traffic centers begin using it sometime in 2015.
- **Path Stretch.** According to FAA, in 2014 the Agency removed a capability called Path Stretch²² from a proposed final decision to invest funds due to shifting funding priorities and some unresolved operational issues, even though

²¹ GIM-S adds two capabilities to TBFM: 1) Speed Advisory provides air traffic controllers a required aircraft speed needed to arrive at a specific location at a scheduled time. 2) Extended Metering provides more accurate delay times to controllers. GIM-S was developed primarily to advance Automatic Dependent Surveillance-Broadcast and achieve benefits for the program.

²² This capability is intended to help controllers make decisions on directing aircraft to meet scheduled times while also allowing PBN use.

an FAA report concluded this capability was needed to improve TBFM's accuracy and facilitate PBN use.

- **Metering During Reroute Operations.** This capability adds additional reference points for pilots that may be aligned with published flight paths to enhance the ability to continue time-based sequencing in the presence of adverse weather. According to NATCA's TBFM representative, this capability is needed to help optimize PBN use but the concept is not technically mature.

FAA originally planned to deploy Path Stretch and Metering During Reroute Operations between 2017 and 2020, but the Agency now states they are delayed indefinitely due to shifting budget priorities. However, MITRE concluded in its 2014 report that these enhancements lacked technical maturity, which may be the larger issue.

FAA Has Provided Limited Training on TBFM

Another longstanding, unmet need for controllers has been the lack of sufficient training on how to use time-based automation tools. Time-based sequencing and spacing represents a significant cultural change for the way air traffic controllers manage aircraft operations. Yet, during the over 15 years that FAA was testing and deploying TMA and TBFM, it did not provide a national training program for air traffic controllers on how to use the tools to sequence aircraft based on time. Instead, facilities have had to develop their own training, consisting primarily of on the job training, leading to disparate use among air traffic facilities. FAA's TBFM Study Report also identified that the current training situation has led to a disparity in understanding of the capabilities and use of TBFM. In the absence of national training, training is very localized and non-standardized.

Traffic Management Coordinators,²³ controllers, and automation support staff told us that they received little to no training, or that the original training they received was inadequate for what they are required to do with TBFM. The traffic coordinators and controllers at the facilities we visited said that they received on-the-job training through observation of the subject matter experts or were self-taught. The traffic coordinators stated that facilities need more classroom training, computer based instruction, and replay capability to learn from past situations.

To its credit, FAA has begun taking steps to improve its training, although it may be years before all users are trained. According to FAA, the Agency has recently

²³ The Traffic Management Coordinator (TMC) position is an air traffic management position in the Traffic Management Unit at an ARTCC and other air traffic facilities. The TMCs often work between centers, sharing plans for moving aircraft around weather, including devising alternative routes. At the centers, they work with controllers to schedule departures to meet the flow patterns that have been set.

developed a 90-minute online course for air traffic controllers and expects to train all controllers by the end of this year. FAA officials stated this 90-minute course will cover operational issues reported by controllers, such as how to address aircraft holding protocols and delay issues. Additionally, FAA states that it began to roll out a 7-day course for traffic management coordinators in April 2015, but does not expect to train all traffic coordinators until December 2017.

FAA Has Provided Insufficient Technical Support for TBFM

FAA has not provided facilities with sufficient technical and related support to enable and encourage widespread use of TBFM. In addition, FAA lacks a process to capture and share subject matter expertise from individual facilities across the NAS. Areas where support has been limited include:

- **Implementing software releases.** Facilities use their own discretion on when or if they implement new software releases. Field Automation Support and William J. Hughes Technical Center staff told us that air traffic facilities are using several different methods/systems for implementing and tracking new TBFM software releases due to a lack of guidance from FAA. In addition, FAA's 2014 TBFM study team concluded that the TBFM program office has processes in place for testing new software prior to deployment in the field, but its aggressive schedule does not allow adequate time for resolving and addressing issues identified during testing. According to the study, the Agency did not have an adequate tracking system in place for communicating and determining the impact on operations of new software releases to the field.
- **Performing adaptation work and validation testing.** For TBFM to be effective, each facility must perform adaptation (i.e., customization)²⁴ work to ensure that the system is tailored to its local operating environment and airport layout, resulting in more accurate scheduling predictions. However, FAA has provided only minimum guidance, leading facilities to develop their own processes. According to FAA, the Agency recently developed an adaptation course and began training facility automation specialists in October 2014. FAA also does not perform validation testing to ensure implemented changes are performing as intended, which has resulted in continued performance issues at individual facilities. For example, Oakland Center has struggled to properly customize its TBFM system to perform arrival sequencing to San Francisco International Airport. Despite requests for technical support received from several sources, FAA has not yet developed a solution.

²⁴ Adaptation is the depiction of local airspace and air traffic control routing structure designed to provide a frame of reference for TBFM to conduct calculations and predictions. Adaptations are a critical component of the TBFM system and must be maintained properly in order for TBFM to function correctly.

- **Managing traffic flow between adjacent facilities.** TBFM was designed to allow neighboring facilities to support each other by sequencing aircraft earlier in the arrival stream. However, system settings are inconsistent across facilities, limiting the ability of some centers to work together. For example, Oakland Center cannot rely on Los Angeles, Salt Lake City, or Seattle centers to help manage arriving traffic. Lack of technical standardization of settings among facilities limits TBFM's ability to facilitate PBN procedures.
- **Encouraging collaboration and knowledge sharing.** Managers we interviewed indicated a lack of collaboration between facility subject matter experts, inadequate system documentation, and the lack of an effective way to capture and retain the knowledge they have gained through experience when senior controllers retire. According to FAA's internal study, the Agency lacks a clear process for capturing lessons learned during TBFM implementation and use. Furthermore, FAA's technical support system is complex. Instead of having a centralized database to share and track issues, FAA requires technicians to submit trouble tickets to three different databases, each with different reporting organizations. None of these databases have a way to track tickets once submitted, usually requiring contracted support to correct issues that might otherwise be resolved locally if the knowledge was available. In 2010, FAA identified the lack of adequate documentation as a high risk for the program.

Controllers Have Experienced Significant Problems Using the System

From January 2012 to December 2013, controllers filed at least 54 reports related to TMA/TBFM-related problems as part of FAA's Air Traffic Safety Action Program (ATSAP).²⁵ Controllers reported issues including a lack of national guidelines, a lack of accountability, facilities opting out of using the system, a lack of standards as it relates to TBFM settings, lack of coordination between facilities, and greater complexity during increased traffic demand when time-based sequencing was used as a traffic management initiative. For example, controllers indicated in two separate instances that shifting from traditional distance-based separation methods to time-based methods during periods of increased traffic demand added to air traffic management complexity, resulting in distraction and a reported loss of separation between aircraft.

Air traffic controllers at six of the seven facilities managing high-altitude traffic indicated that TBFM actually increased their workload. Because most facilities only use the tool during peak arrival periods to maintain a capacity demand balance, controllers who manage traffic flows to several facilities simultaneously

²⁵ The Air Traffic Safety Action Program is a voluntary safety reporting program for air traffic personnel that enable them to report air traffic safety events and retain confidentiality.

under these conditions indicated they experienced an increased workload. For example, controllers may deliver aircraft to multiple facilities using different methods (e.g., time-based sequencing to one and miles-based to others) due to several factors, including airspace complexity and adverse weather events. According to ATSAP reports and controllers we interviewed, splitting the controller's concentration between different methods impacts their workload.

Air traffic controllers have also experienced difficulties as aircraft transition from high altitude (cruise) to approach and landing on the airport runway (e.g., from en route to terminal airspace). Controllers at four of the seven TRACONs we visited that do not have automation tools expressed frustrations with aircraft moving too close together, referred to as "compression," as they are approaching the airport runway on new PBN routes with smoother descents. These controllers attributed the compression to insufficient spacing being provided by en route center controllers using TBFM. Controllers who do not have sequencing tools must then direct pilots to change course to maintain separation, diverting them off of PBN procedures, which results in the loss of expected benefits. According to FAA, this highlights the need for better coordination between en route and terminal traffic management coordinators to adjust TBFM settings.

Another operational problem relates to a key TBFM enhancement that allows neighboring facilities to work together to create smoother flows of aircraft further from the airport,²⁶ thus facilitating PBN use. Managers at three of the seven centers we visited and multiple ATSAP reports we reviewed disclosed concern that multi-center operations were not working effectively, in part because FAA had not established local facility agreements. Local facility agreements are important because they allow facilities to allocate and share certain PBN responsibilities between facilities to manage workloads. For example, a 2007 Safety Risk Management Document for one facility highlighted risks due to a lack of training, operating procedures, and implementation of multi-facility agreements, including excessive workload for controllers and traffic coordinators. Despite FAA's knowledge of these risks, the Agency did not fully mitigate them. Moreover, based on documents we reviewed, this facility experienced increased airspace management complexity, which may have contributed to a 2010 event in which a pilot was alerted to take action in the cockpit to maintain safe separation.²⁷

²⁶ Adjacent Center Metering (ACM).

²⁷ The system that provided the reported alert is the Traffic Alert and Collision Avoidance System (TCAS), which is an onboard collision avoidance system that alerts pilots to maintain minimum separation standards.

CONCLUSION

Performance-based navigation is a powerful tool that can enhance efficiency, reduce fuel costs, and provide many other benefits to airspace users. TBFM is a critical decision support tool for NextGen and to facilitate PBN operations. However, FAA has not provided basic support to encourage its use, and additional enhancements are still required to further optimize PBN. FAA has identified most of the issues and has a plan to address them, but they have identified these issues in the past without resolution. Given the importance of TBFM and the significant cultural shift it represents to air traffic controllers, the Agency must make implementing TBFM a top management priority, establish firm action plan deadlines, follow through on the action items, and fully implement the needed enhancements. Additionally, to help accelerate implementation and create consistency, FAA facilities must share knowledge and lessons learned between facilities and work together to effectively manage traffic flow. Otherwise, the promised benefits of NextGen, including from PBN, will not be realized.

RECOMMENDATIONS

To improve FAA's implementation of controller automation tools and help optimize PBN procedures, we recommend that FAA:

1. Establish firm milestones and follow through with all action items required to address TBFM Study Team report recommendations and a process to account for their completion.
2. Prioritize actions needed to complete the implementation of enhancements, including Ground Interval Management-Spacing, Terminal Sequencing and Spacing, and Path Stretch which further facilitate PBN use.
3. Establish a NAS-wide TBFM user collaboration and information sharing database or tracking system to capture lessons learned by facilities and subject matter experts during TBFM implementation and use.
4. Establish a process for creating agreements (e.g., Letters of Agreement), including corresponding procedures, between facilities to accommodate wider use of automation tools and establish a target date for implementing them.

AGENCY COMMENTS AND OFFICE OF INSPECTOR GENERAL RESPONSE

We provided FAA a copy of our draft report on July 7, 2015, and received its response on August 7, 2015, which is included in full in the appendix. FAA

concurred with recommendations 1, 3, and 4, agreed to implement them as written, and provided appropriate target action dates. FAA partially concurred with recommendation 2 because the Agency believes it has processes for prioritization in place, but agrees that additional collaboration is needed with the user community to expedite PBN use. FAA stated that it will provide an update on this collaboration by December 31, 2015. In addition, FAA stated that it would provide a detailed response to all our recommendations at a later date. Accordingly, we consider recommendations 1, 3, and 4 resolved but open pending completion of the planned actions. We consider recommendation 2 open and unresolved pending our receipt of FAA's December 2015 update.

ACTIONS REQUIRED

We consider recommendations 1, 3, and 4 resolved but open pending FAA's detailed response and completion of all planned actions and recommendation 2 unresolved pending FAA's December 2015 update as stated above. In accordance with DOT Order 8000.1C, we request that FAA provide its detailed response to our recommendations within 30 days of this report.

We appreciate the courtesies and cooperation of FAA representatives during this audit. If you have any questions concerning this report, please call me at (202) 366-0500 or Robin P. Koch, Program Director, at (404) 562-3770.

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cc: DOT Audit Liaison, M-1
FAA Audit Liaison, AAE-100

EXHIBIT A. SCOPE AND METHODOLOGY

We conducted this audit between July 2014 and July 2015 in accordance with generally accepted Government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. Our audit objectives were to assess (1) FAA's progress in developing and deploying new air traffic controller automation tools for managing PBN operations, and (2) the degree to which these tools meet air traffic controllers' needs to improve PBN use.

To assess FAA's progress in developing and deploying new air traffic controller automation tools for managing PBN operations, we first identified the tools that were available by reviewing previous DOT OIG and GAO audit reports to gain the historical perspective of FAA's modernization efforts. We reviewed FAA's 2013 and 2014 NextGen Implementation Plans. We also interviewed FAA program officials for PBN and automation tools. We determined and FAA confirmed that TBFM is the only tactical decision support tool available to controllers to help optimize PBN operations. To determine FAA's progress in developing and deploying TBFM and TSS, we interviewed NASA air traffic system developers, FAA officials at the William J. Hughes Technical Center, and MITRE representatives to understand the technology development process and obstacles. We also reviewed NASA, FAA, and MITRE reports, including TBFM program briefings, concept of operations, shortfall analysis reports, and post-implementation review reports. We used FAA documents to calculate the development time and cost for TBFM, TSS, and their predecessors.

To assess the degree to which TBFM is meeting controllers' needs to improve PBN use, we performed work at 15 air traffic facilities—7 of the 20 en route centers, 7 of the 34 TRACONs that have TBFM, and the FAA National Air Traffic Control System Command Center. We selected facilities based on the degree of PBN implementation, where FAA was deploying new TBFM capabilities, and locations with unique TBFM operations. We conducted interviews with controllers, traffic management coordinators, and automation personnel and reviewed available documentation to determine how and under what conditions TBFM is used, and its effectiveness. We reviewed FAA's April 2014 TBFM Study Report and Recommendations, which found similar problems with TBFM. We also reviewed key source documents used by FAA for its analysis, such as ATSAP reports.

The scope of work on internal controls was limited to understanding FAA's process for how systems or technologies such as TBFM are approved and funded

through the Agency's formal investment processes. Through the documentation we reviewed, we determined that FAA followed its acquisition policies and procedures to approve TBFM and its enhancements. Although FAA followed the acquisition process, FAA lacked program management controls to ensure implementation as included in this report.

EXHIBIT B. ORGANIZATIONS VISITED OR CONTACTED

FAA Headquarters, Washington, D.C.

- Air Traffic Organization
 - Air Traffic Procedures
 - Mission Support Services
 - Operational Concepts, Validation and Requirements
 - TBFM Program Management Office
- MITRE Corporation, McLean, VA
- NextGen Advanced Concepts and Technology Development Office

FAA Field Facilities

- Albuquerque Air Route Traffic Control Center, Albuquerque, NM
- Dallas Terminal Radar Approach Control, Dallas, TX
- Denver Air Route Traffic Control Center, Longmont, CO
- Denver Terminal Radar Approach Control, Denver, CO
- FAA National Air Traffic Control System Command Center, Warrenton, VA
- FAA Western Service Center, Renton, WA
- FAA William J. Hughes Technical Center, Egg Harbor Township, NJ
 - En Route Automation Modernization Laboratory
 - Standard Terminal Automation Replacement System Laboratory
 - Time Based Flow Management Laboratory
- Fort Worth Air Route Traffic Control Center, Fort Worth, TX
- Houston Air Route Traffic Control Center, Houston, TX
- Houston Terminal Radar Approach Control, Houston, TX
- New York Air Route Traffic Control Center, Ronkonkoma, NY
- New York Terminal Radar Approach Control, East Garden City, NY
- Oakland Air Route Traffic Control Center, Oakland, CA
- Philadelphia Terminal Radar Approach Control, Philadelphia, PA

- Phoenix Terminal Radar Approach Control, Phoenix, AZ
- Seattle Air Route Traffic Control Center, Auburn, WA
- Seattle Terminal Radar Approach Control, Burien, WA

NASA Headquarters, Washington, D.C.

- NASA Headquarters, Washington, D.C.
 - Airspace Systems Program
- NASA AMES Research Center, Moffet Field, CA
 - Future Flight Central – Airport Tower Simulator
 - NextGen Concepts and Technology Development
 - Terminal Sequencing and Spacing Laboratory
 - Dynamic Weather Routes Demonstration

Aviation Stakeholders

- National Air Traffic Controllers Association, Washington, D.C.
- NextGen Advisory Committee (NAC)
- RTCA Inc., Washington, D.C.
- Southwest Airlines, Dallas, TX
- United Airlines, Houston, TX

EXHIBIT C. MAJOR CONTRIBUTORS TO THIS REPORT

Name	Title
Robin Koch	Program Director
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Audre Azuolas	Writer/Editor
Petra Swartzlander	Senior Statistician



Federal Aviation Administration

Memorandum

Date: August 7, 2015

To: Matthew E. Hampton, Assistant Inspector General for Aviation Audits

From: H. Clayton Foushee, Director, Office of Audit and Evaluation, AAE-1

Subject: Federal Aviation Administration's (FAA) Response to Office of Inspector General (OIG) Draft Report: Deployed Controller Automation Tools that Optimize Benefits of Performance-Based Navigation

The FAA is dedicated to enhancing efficiency and capacity in the National Airspace System (NAS) through the use of Performance-Based Navigation (PBN). As early as January 2014, Air Traffic Organization (ATO) leadership recognized the need to quickly provide controller automation tools to optimize the benefits of PBN and deployed the Time Based Flow Management (TBFM) automation tool. TBFM allows for Optimized Profile Descents (OPD) into terminal areas. Without the TBFM tool, controllers would more often sequence traffic using miles in trail procedures and create more delays by using holding patterns.

The FAA offers the following observations in response to the OIG's draft report findings:

- During the course of this audit, the FAA deployed new training for controllers on the Agency's plans for TBFM along with a video emphasizing both management and National Air Traffic Controller Association (NATCA) support of TBFM and increasing PBN usage as top priorities. To date, over 4,300 controllers have received the training. More than 80 traffic management coordinators have received a new comprehensive seven-day training course for the daily operation of the system.
- It is important to understand that OPDs can still be flown in the En Route environment and at airports, when the volume of traffic permits, thus an automation tool is not always necessary when utilizing PBN.
- The FAA is addressing issues associated with the performance and reliability of the TBFM automation tool on several fronts and both continue to improve. Metroplex team assurances that adaptations reflect current operations and improvements in problem report processing have had positive impacts.
- The FAA is developing a set of national procedures including roles and responsibilities, coordination between facilities and a strong policy for the use of the tool to support PBN with a target publication date of December 10, 2015.

The FAA partially concurs with OIG recommendation 2 and fully concurs with the remaining three recommendations, as written. The FAA expects to implement recommendations 3 and 4 by January 31, 2016, and recommendation 1 July 31, 2016. With regard to recommendation 2, the Agency believes that it already has the appropriate processes for prioritization in place but agrees that additional collaboration is needed with the user community in order to expedite PBN usage. The FAA commits to increasing its community outreach efforts in this area and will provide the OIG with an update by December 31, 2015.

The FAA will provide a detailed response to the recommendations within 30 days after the publication of the final report. Please contact H. Clayton Foushee at (202) 267-9000, if you have any questions or require additional information about these comments.