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"Research Challenges for Air Traffic Management"
AIAA New Horizons in Aviation Forum
Plenary Panel
Virginia Beach, VA
September 22, 2011

[Remarks as prepared for delivery.]

Good afternoon. Bruce [Holmes] has laid out a fascinating vision of aviation in the future—and I fully concur that aviation has a future. We have already heard the perspectives of the military and the airlines about this future. My talk will provide you with an air traffic management perspective.

I will bring us a little closer to today than Bruce's vision—say, to 2025 and perhaps the decade beyond. Many of you may know this future as the mid- and long-term NextGen initiative.

Understand that this is my look into the crystal ball. It's fuzzy at best. 2025 is only 14 years away, but predictions this far into the future are notoriously poor. We know things will change. As Yogi Berra once said, "The future ain't what it used to be."

Let's begin by going back to the basics. The basics will set the stage to help us understand the challenges with achieving NextGen. In 2005, bold goals and objectives were laid out in the NextGen Integrated Plan:

- We must accommodate, as best we can, all user business models and user preferences.
- We must accommodate whatever mix of old and new aircraft want to fly.
- We must ensure that the system is safe and resilient.
- We must protect the environment.
- We must ensure national and homeland defense.

One real change from today will be that this is a system that serves the users, rather than today's system where users must live within the constraints placed on them by the antiquated, procedural air traffic management system.

The challenge, of course, is making sure the NextGen system we are starting to build today will be sufficiently robust to achieve these objectives, no matter how the future looks. You may remember just six years ago, when the NextGen goals were defined, the future seemed to have fleets of very light jets flying point-to-point and blackening the skies overhead. Today, the future bodes of Unmanned Aircraft Systems (UAS), large and small, mixing in corridors with air transports, general aviation, and commercial space launches. And some folks are already talking about on-demand mobility and "zip planes" for the new

generation. In a nutshell, the basics of flying amount to three things:

- Not getting lost
- Not hitting other planes
- Using scarce resources efficiently

This requires:

- Navigation
- Aircraft separation
- Traffic flow management

In the very early days, barnstormers navigated by following roads and railways. Flyers have navigated across the country using bonfires, lighted beacons, and a series of navigation aids (such as VORS, ILS, etc.) This evolved into the air route system that still exists today. With the advent of GPS—especially once the issue of a back-up system for GPS is resolved—and with modern navigation capabilities onboard aircraft, the old route system may not be an issue.

Today, air traffic controllers use radars, displays, and some decision-support tools to separate aircraft. An airspace system of sectors was designed to accommodate human limitations, making the task manageable. Controllers know the current position and

estimate where an aircraft is going. Greater use of automation, and perhaps by putting more capability and responsibility in the cockpit, is expected to reduce inefficiencies in safely separating aircraft. In fact, the NextGen vision calls for separation using 4D trajectories, which enable operators to know both current and future aircraft positions (intent).

In the very early days of flying, scarcity of resources was not an issue. When airports became congested, holding patterns were created. Today, flow control institutes ground holds and miles-in-trail restrictions. Optimizing use of resources has been a fertile field for operations researchers. But, it is still based on the old route systems and methods that rarely deal with individual aircraft—their performance characteristics or their preferences.

At a recent aviation forum, I told a short story—one that continues to unfold today. A story about aviation and the power of research and innovation. I'd like to share that same story with you. It's about an air traffic jam in the skies over New York City.

In January 1956, an article in Popular Mechanics magazine stated: "Planes were stacked up in every holding pattern around the city, with more roaring in from every direction. They were backed up halfway across the country. Disgruntled passengers in Miami and Chicago grumbled about delays while tense traffic

controllers in New York guided all those planes onto cleared runways."

Does this story sound all too familiar? Remember, this article was written in 1956! Let's continue with the story for a moment.

The writer looked to research and technology as solutions for safe air travel in the future and a better means of using a limited resource—the crowded space above our heads. Long-range radars would allow controllers to know where the plane is and to follow it from far outside the landing area. Transponders, if installed on commercial planes, were expected to extend the usefulness of radar, easily identifying the plane. And simulations would be used to design new flight procedures. The advent of computers could perhaps quickly and constantly calculate the path that a plane would fly to land safely, at a rate of two aircraft per minute.

So flying boils down to navigating, separating aircraft, and effective use of resources. Further, technologies, such as computers, have advanced significantly. Why then are we still stuck in air traffic jams?

When I look at the technology we use and the way the system is operated, I can't help but conclude we are stuck in the 20th century. Today, research remains critically important to the

full realization of NextGen. Research and technology must push our air transportation system to the next level, keeping travelers safe, providing more airspace capacity where it is needed, and allowing growth while being mindful of the environment. In much the same way as years ago, a set of new technologies is on the horizon and will enable the NextGen vision:

- Satellite-based navigation
- Automatic Dependent Surveillance-Broadcast (ADS-B) Out for improved surveillance and ADS-B In for putting more operational responsibility in the cockpit
- A net-centric information system and underlying communication infrastructure to enable advancements, such as UAS operations, and everyone having a common current picture of the weather
- Computing and data storage capabilities that will enable aircraft separation and Trajectory-based Operations (TBO)

Beginning in 2004, hundreds of subject matter experts came together at the Joint Planning and Development Office (JPDO) to set the broad vision for NextGen. It is a vision predicated on the concept of TBO, where aircraft have 4D trajectory contracts with the service provider. TBO represents a merger of traditional

strategic flow planning with tactical trajectory management. The concept, which is still under investigation, is intended to:

- Deal with individual aircraft
- Plan to eliminate complex airspace
- Enhance flight plan negotiations and improve situational awareness
- Consider weather information, airspace constraints, and environment when planning flight trajectories
- Dynamically balance capacity and demand
- Maximize operators' opportunities to use the system rather than constrain flight demand

The rate of technology change in our daily lives is exponential. It's only a short time ago that the iPad and cloud computing began transforming our daily lives, providing us with new services and new ways of connecting to the world. There is tremendous potential for innovation. I have a few thoughts to share regarding research to modernize air traffic management.

First, innovation fuels growth. Big infrastructural investments often tend to overshadow the research contribution, particularly when budgets get tight. We can't afford to let it deter us from research! But we must be creative and make very smart choices.

For this reason, I asked the JPDO to take a hard look at the implementation path and the priorities for NextGen in 2025. This will help the JPDO prioritize those capabilities where the most mature development and demonstrations are needed. And, more importantly, it will let us balance our research investments—keeping an eye on where innovation is needed for the longer term. I really believe it's time for the research community to step up to setting the foundation for what's next. I think we're a little too comfortable refining what we know.

Using risk-based analysis methods, the JPDO made a prediction for 2025. The prediction systematically considered aircraft, airspace, and airports. Analyses assumed a progression of capabilities, beginning by leveraging avionics on many aircraft today, adding advanced avionics capabilities and, ultimately, moving to higher levels of automation in ground-based and airborne systems. One possible "sweet spot" for the 2025 system was identified and described in a gate-to-gate flight profile. Subject matter experts, some of the same people who helped create the NextGen vision, recently reviewed the system description, providing over 200 substantive comments that the JPDO will use to improve it.

Next, one likely driver for the path to 2025 is the emergence of UAS. UAS already play a unique role in the safety and security

of many U.S. military and civil missions, such as border surveillance, oil pipeline monitoring, and local law enforcement. They have evolved from simple drones to large, sophisticated aircraft. They are here and they want into the system.

Industry forecasts predict exponential growth for UAS applications.

From an operational, infrastructure, and safety perspective, this presents many challenges due to the diversity of aircraft, control stations, autonomous systems, and communications methods. UAS span a wide spectrum of size, endurance, and performance characteristics, often different from manned aircraft, with slower cruise speeds and climb rates.

During the past year, the JPDO led an assessment of the government's research portfolio for integration of UAS into NextGen. Is it sufficient? Our study engaged researchers, operators, and regulators from across the Federal Aviation Administration, National Aeronautics and Space Administration, and the Departments of Commerce, Defense and Homeland Security. Challenges and opportunities were identified in four areas: Communication, Airspace, Airframes, and Human Systems Integration. Research challenges, based on assessments by performers, must now be cross-walked with the expectations of

regulators. This linkage is the key to finding a true integration path.

In the longer term, perhaps the 2025-2035 timeframe without major breakthroughs, NextGen will be characterized by potential new roles for humans and greater automation. Prior JPDO work showed that current Validation and Verification (V&V) tools and techniques will not be adequate to deal with such a complex socio-technical system. Today's tools make assumptions about the independence of different parts of the system—an assumption that falls apart when you consider the many interdependencies of NextGen components. The tools we have now are also insufficient in dealing with people as an integral part of the "system of systems"—again a fundamental characteristic of NextGen. Finally, the V&V tools for NextGen must be able to validate the resilience of the system design.

The JPDO sees V&V as a major risk to long-term transformation. Therefore, our Safety Working Group, a team made up of public- and private-sector experts, has started planning for a NextGen TBO safety case. Validation, throughout the research, development, implementation, and operations lifecycle is needed to ensure safety, and that the system of systems—including people—works. Another related challenge comes from avionics certification: 21st century technology will

require new efficient means of certifying systems to show it is safe and to get aircraft equipped.

One final safety challenge I want to leave with you has to do with the fact that we will no longer be able to depend on the traditional redundancies that made the air traffic management system robust. Think about this as the independence of the communications, navigation, and surveillance systems, and the controller's ability to keep traffic moving safely when automation failed. As NextGen considers more automation, the system design must overcome this.

Before I leave the subject of new horizons for air traffic management, I must mention an overarching challenge for the enterprise that was pointed out in the National Plan for Aeronautics R&D. The air transportation system is a complex system of systems that involves multiple technologies, organizational structures, behaviors and cultures, and competing economic entities. Solving the technology problem is not enough. Systems will not work together if we don't begin with people talking together.

The transition from the current to the future air transportation system is expected to involve changes in all of these areas. Better understanding of enterprise-level issues (e.g., environmental, political, institutional, and managerial) is

critical to the successful transformation of the air transportation system. Designing a system that meets the (often conflicting) objectives of all stakeholders is difficult, if not impossible.

Along these lines, interoperability is a topic that is not often covered in technical papers. Nonetheless, it is of critical importance as concepts and technologies are developed for NextGen and similar initiatives, such as Single European Sky Air Traffic Management Research (SESAR), Comprehensive Assessment and Restructure of the Air Traffic Services (CARATS), and others in the world. The JPDO's Global Harmonization Working Group is developing an interactive roadmap, based on the interagency plan. This will allow collaboration with international stakeholders to support effective NextGen interoperability and to identify capabilities that will require global standards.

To close, just like the computers and technology that were envisioned in the 1956 Popular Mechanics article, the NextGen vision that I've presented to you represents a major air traffic management improvement for 2025 and beyond. The implementation of NextGen is the largest global human undertaking to date. The number of systems, vehicles, operations, agencies, research areas, industries, and governments that will need to coordinate on standards,

procedures, equipage, and policies is unprecedented. It will incorporate complexities that out rivals any past large scale effort and requires that all of us work together.