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COMMITTEE ON TRANSPORTATION AND
INFRASTRUCTURE, SUBCOMMITTEE ON AVIATION
U.S. HOUSE OF PREPRESENTATIVES
NEXTGEN: AREA NAVIGATION (RNAV) AND REQUIRED NAVIGATION PERFORMANCE (RNP)

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Good morning, Chairman Costello, Ranking member Petri, and Members of the Subcommittee. Thank you for inviting me to participate in today's hearing on NextGen: Area Navigation (RNAV) and Required Navigation Performance (RNP). My name is Agam Sinha and I am a Senior Vice President at The MITRE Corporation. I am also the General Manager of MITRE's Center for Advanced Aviation System Development (CAASD), which is the Federal Aviation Administration's (FAA's) Federally Funded Research and Development Center (FFRDC).

My testimony today will address RNAV and RNP, which together form the FAA's Performance-based Navigation (PBN) initiative and constitute a foundational element of NextGen. I will be addressing the following points:

- Over the past few years, RNAV and RNP procedures have been implemented in some of the most complex airspaces in the nation, to include terminal and en route airspace, which have resulted in significant benefits such as increases in capacity, reduction of delays, and reduction of emissions.

- These implementations have been successful due to the close collaboration between the FAA and the aviation community, through forums such as RTCA and the Performance-based Operations Aviation Rulemaking Committee (PARC), as well as the close coordination between the FAA's air traffic and flight standards organizations.

- Additional benefits can be achieved in the near-term through new applications of RNAV and RNP, and through optimized aircraft vertical profiles, especially during the descent phase of the flight. Recent MITRE modeling and analysis have shown potential significant benefits of these optimized profile descents in terms of reduced fuel consumption and reduced emissions. Another potential near-term benefit can be realized by the use of advanced RNP procedures to decoupling flight paths in complex airspace, resulting in improved traffic flows and airspace efficiencies.

- Aircraft equipage for RNAV and RNP operations has increased over the past few years, which enables nation-wide application of these procedures. A recent MITRE analysis of the Part 121 operators shows that overall RNAV equipage exceeds 90 percent, while RNP equipage varies depending on the RNP level. More advanced RNP capabilities that enable more beneficial procedures are about 40 percent of the fleet.

- While there are beneficial near-term opportunities to leverage RNAV and RNP as outlined above, even greater benefits can be realized beyond the near-term by utilizing RNAV and RNP as part of a more comprehensive airspace re-design, by moving away from overlays of historical traffic patterns and designing more efficient flight paths in the airspace. Recent experience in airspace design has shown longer lead time in implementing non-overlay routes, including significant efforts needed to address the environmental requirements that exist today. Streamlining the environmental process can potentially shorten the implementation timelines, resulting in earlier benefits.

- Finally, as we look ahead, RNAV and RNP in combination with other capabilities such as ADS-B, air/ground data communications, and enhanced ground automation can result even in greater benefits.

Area Navigation (RNAV) and Required Navigation Performance (RNP)

In the past, airspace design and utilization were the result of several limiting factors, including the dependence on the location of ground-based navigation aids (NAVAIDs) and conventional navigation methods, i.e., navigating from one NAVAID to another NAVAID. These conventional navigation methods lead to inefficient routes, procedures and airspace usage.

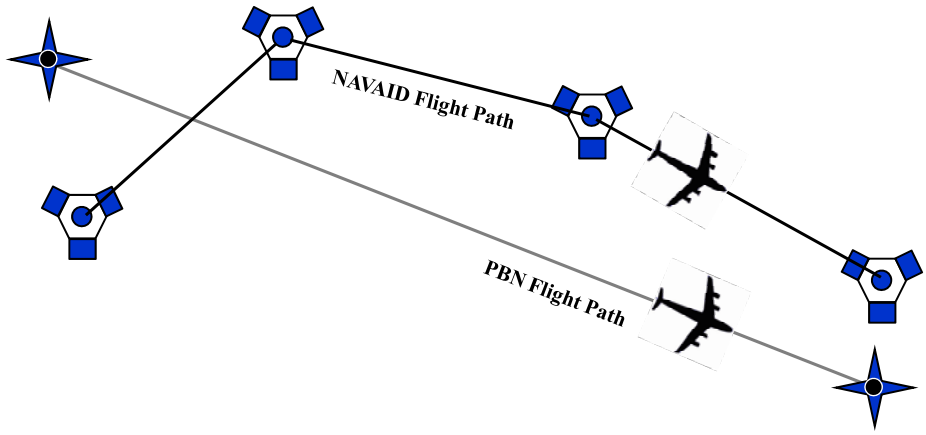

Figure 1: PBN Enables Design of Efficient Routes

The aviation community is moving forward in solving these problems by better utilizing capabilities already available on a vast majority of air transport and regional airline aircraft to perform RNAV and RNP operations, also known as Performance-based Navigation (PBN).

As illustrated in Figure 1, RNAV enables aircraft to fly any desired path rather than flying to or from a fixed ground navigation aid. RNP takes advantage of more advanced on-board avionics that monitor the aircraft's navigation performance and alert pilots when the required performance is not being achieved.

RNAV and RNP Equipage

RNAV and RNP equipage have been steadily increasing over the past several years. MITRE's analysis of the air transport fleet documents high levels of RNAV and growing levels of RNP equipage. Forecasts of new production aircraft indicate acceleration and continued growth in PBN capability. Figure 2 depicts current and future PBN equipage (assumes no retrofit). For air transport aircraft operations in 2009, RNAV equipage exceeds 90 percent. RNP equipage (specifically RNP 0.3 capable aircraft) exceeds 60 percent. Advanced RNP (specifically RNP 0.3 with curved-path capable aircraft) equipage is nearly 40 percent.

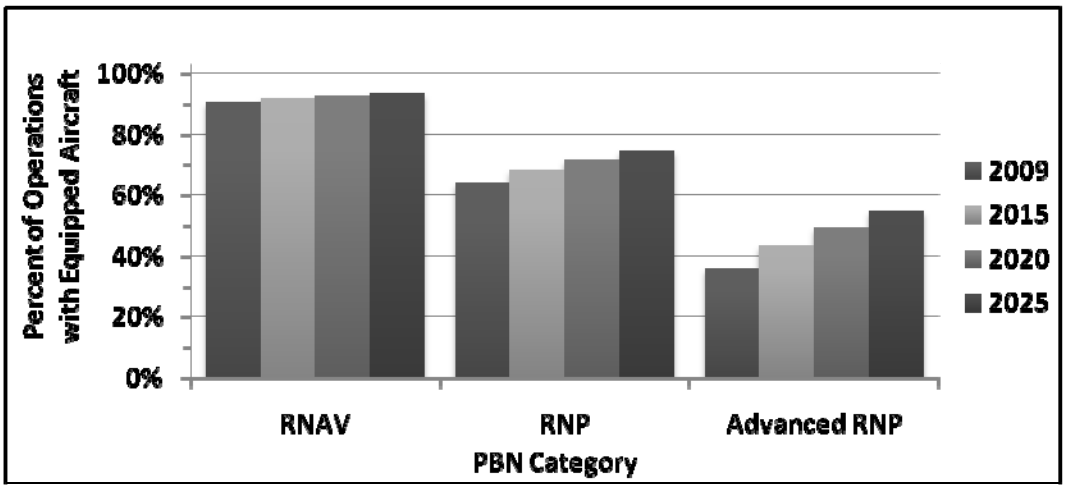

Figure 2: PBN Equipage: Current and Forecast for Air Transport Fleet

RNAV and RNP Procedures

RNAV and RNP procedures are being implemented to achieve repeatable and predictable departure, en route, arrival, and approach paths for aircraft. These procedures improve airport capacity and throughput, reduce the likelihood of aircraft collisions with terrain, improve situational awareness and predictability for pilots and controllers, and achieve more-efficient traffic flows. Using RNAV and RNP also enables the creation of procedures for airports where the limitations due to terrain and other obstacles make it difficult or impossible to safely fly conventional procedures.

RNAV procedures are being used to increase terminal area ingress and egress, as well as increase runway use for departures. For example, Figure 3 illustrates the East and South departure flows from Hartsfield-Jackson Atlanta International Airport; RNAV procedures have enabled additional departure flows in each direction without additional navigational infrastructure costs. In addition, MITRE analyses of the diverging (i.e., fanning out) RNAV departure procedures implemented in Atlanta in 2006 found increased throughput and reduced delays, with a measured capacity gain of 9 to 12 departures per hour. Analysis of these procedures shows $30M in annual benefit (at 2007 demand levels) and a cumulative savings of $105M for the operators who flew these procedures through 2008.

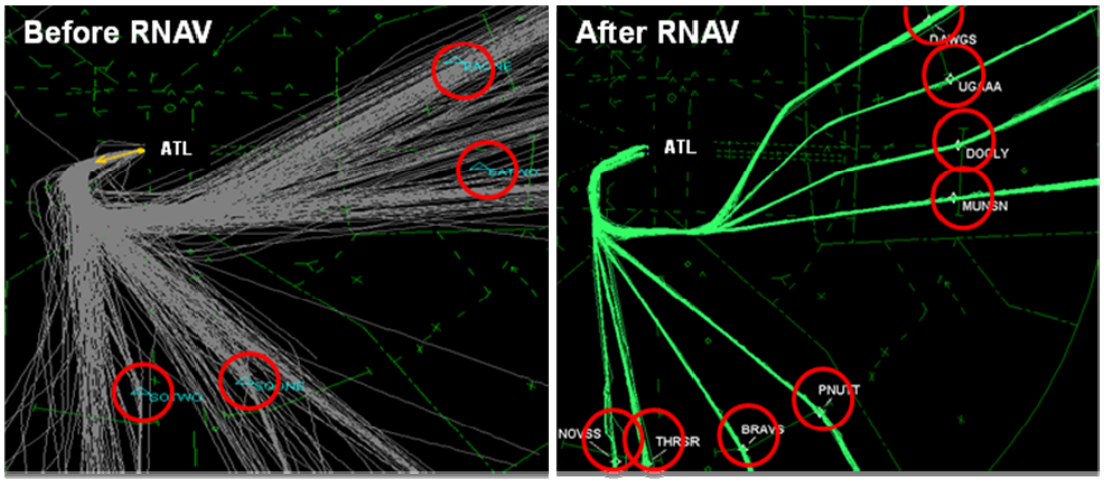

Figure 3: Atlanta Airport West Flow RNAV Departure Procedures

The FAA continues to improve operations in Atlanta with a new runway and with additional implementation of RNAV diverging procedures for flights departing to the East, as those shown in Figure 4. MITRE estimates that implementing these diverging procedures will yield additional benefits to the Atlanta airport operators in the range of $8M to $23M per year.

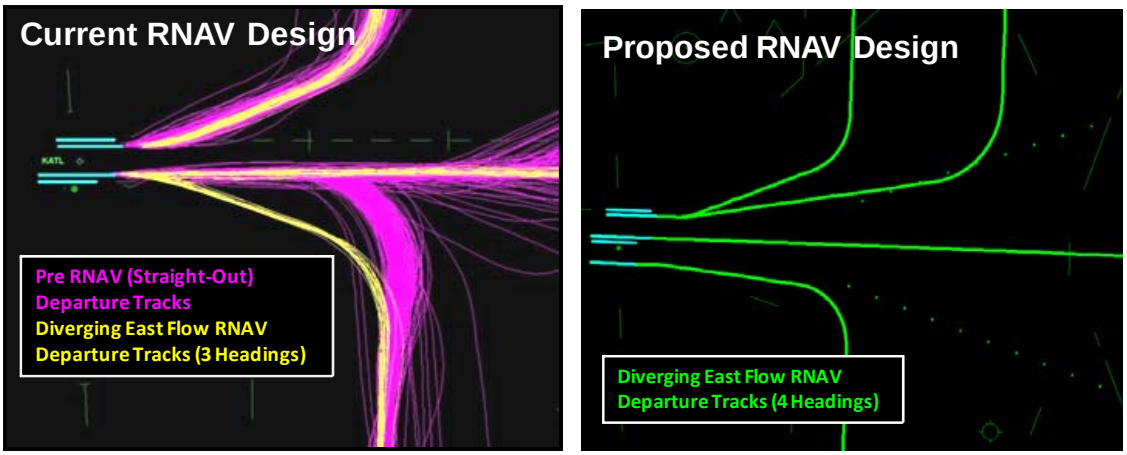

Figure 4: Proposed Diverging East Flow RNAV Departure Procedures at Atlanta

In addition to delay and efficiency benefits, RNAV procedures result in reducing the workload associated with routine voice communications between pilots and air traffic controllers. The reduced level of voice communications decreases the likelihood of "read-

back/hear-back" errors and allows for improved situational awareness. For example, MITRE analysis of the Atlanta RNAV departure procedures shows a decrease of about 50 percent in voice communications and a commensurate decrease in likelihood of communication errors.

Similar RNAV procedures have been implemented at airports such as Dallas-Ft. Worth International Airport (DFW), Las Vegas – McCarran International Airport (LAS) and Phoenix International Airport (PHX), with an annual savings of $45M and a cumulative savings of $130M (2006 through 2008), based on MITRE's post-implementation analyses of these RNAV procedures.

RNP procedures result in a decrease in aircraft path variability and more precise and repeatable flight tracks. RNP systems on the aircraft are designed to monitor the navigation performance of the aircraft. As a result, flight crews have a better understanding of how precisely the aircraft is navigating. The crew is alerted by on-board monitoring systems when the aircraft does not meet the required navigation performance for the procedure. The reduction in variability, increase in path precision and repeatability, coupled with the RNP alerting capability, allow for design of procedures to decouple flight paths in complex airspace leading to more efficient traffic flows and to enable access to runways.

As shown in Figure 5, a MITRE analysis of arrivals at Portland International Airport (PDX) shows a significant reduction in the variability of flight tracks and improved vertical profiles, resulting in both fuel savings and reduced emissions. Additionally, RNP enables the design of precise curved paths through the airspace, adding flexibility to circumnavigate noise-sensitive and obstacle-challenged locations. MITRE researchers have estimated that the RNP procedures at Portland have resulted in fuel savings of 150,000 gallons and a reduction of 7,500 tons of carbon emissions since implementation in 2006.

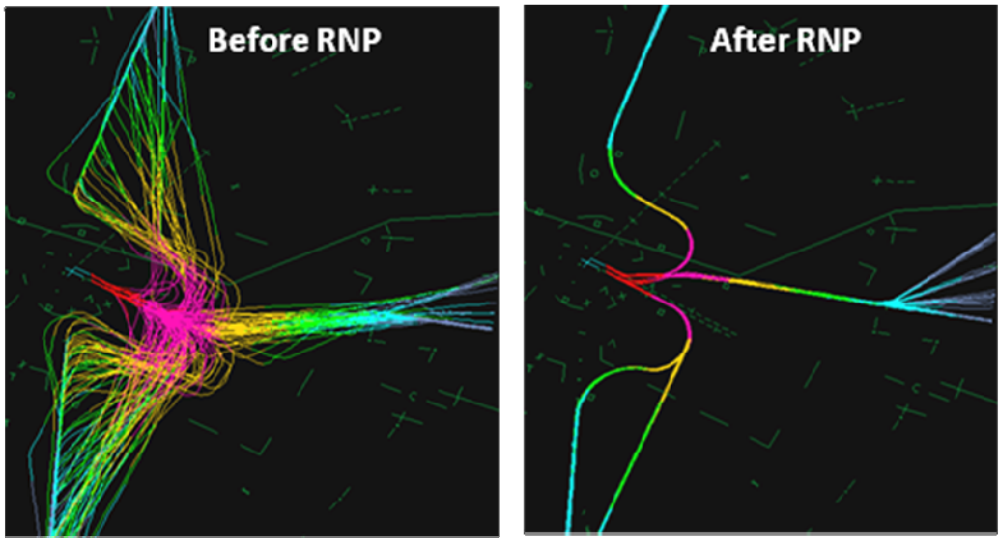

Figure 5: Portland Approach Flight Tracks

In many metropolitan areas, arrival and departure paths at nearby airports can interfere with each other. This means that even in perfect weather conditions, an aircraft at one airport may be delayed on the ground while aircraft at a nearby airport are landing or departing. The greater precision and predictability of aircraft trajectories using RNAV and RNP makes it possible to address this problem by placing more arrival and departure routes in heavily congested airspace than would be possible using traditional navigation procedures. For example, the use of an RNAV departure procedure at Chicago O'Hare International Airport (ORD) in combination with an RNP approach procedure for Chicago Midway Airport (MDW) reduces the amount of interference of the two flows (See Figure 6). A MITRE simulation study of this concept estimates a savings of approximately $4.5M per year in reduced delays under a full PBN equipage scenario.

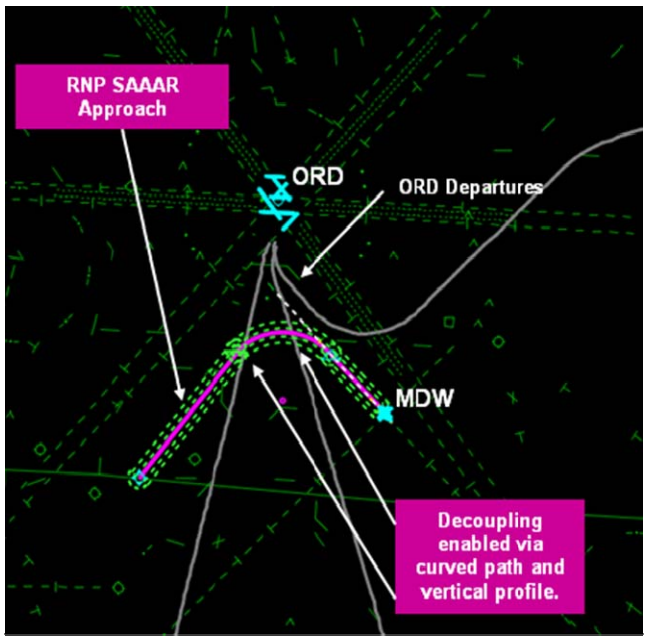

Figure 6: Decoupling of ORD Departures and MDW Arrivals

The FAA and industry have implemented over 300 RNAV arrival and departure procedures, and have implemented more than 130 RNP Special Aircraft and Aircrew Authorization Required (SAAAR) approach procedures. RNP SAAAR approaches can provide an alternative means of access to runway ends that currently cannot support an Instrument Landing System (ILS). For example, at Palm Springs International Airport (PSP), the RNP SAAAR approach enabled increased access by reducing the ceiling and visibility requirements. Since this approach was implemented in 2005, Alaska Airlines has reported over 20 instances where they were able to land utilizing the RNP SAAAR approach to PSP rather than divert, cancel, or incur unnecessary delays. More importantly, during instrument weather conditions, airplanes flying to Palm Springs with RNP SAAAR capability no longer need to make a circuitous circling approach in mountainous terrain. Instead, aircraft fly a safer and shorter path to the runway.

Similarly, at Washington Ronald Reagan National Airport (DCA), RNP approach procedures have enabled aircraft to follow a precise path along the Potomac River, enabling aircraft operators who utilize this approach to more easily avoid prohibited airspace, while landing in low visibility condition to the South (see Figure 7).

Figure 7: RNP SAAAR Procedure at DCA

RNAV and RNP procedures have been implemented across the country. Many of the major arrival/departure flows now have RNAV procedures. These procedures can result in greater savings through the use of more fuel-efficient profiles and flight paths that better address the capacity and throughput needs, and improve airport arrival and departure interactions. These interactions are, in part, responsible for many of the delays that occur today during daily operations at and near every major airport in the country. RNAV and RNP precision can provide the means to "untangle" these interactions for more-efficient operations and greater throughput for airports affected by this competition for airspace use. Taking this step means moving away from overlaying of these procedures along the historical traffic patterns and designing more efficient paths through the airspace.

Figure 8 below shows an example of one of these interactions that increases delays and sequencing requirements between O'Hare and Midway airports. MITRE has analyzed over 600 of these types of interactions across the country and is making recommendations to the FAA on ways to decouple these operations through use of PBN procedures. The challenges in

implementing non-overlay procedures include environmental requirements and airspace design complexities that often require a longer lead time.

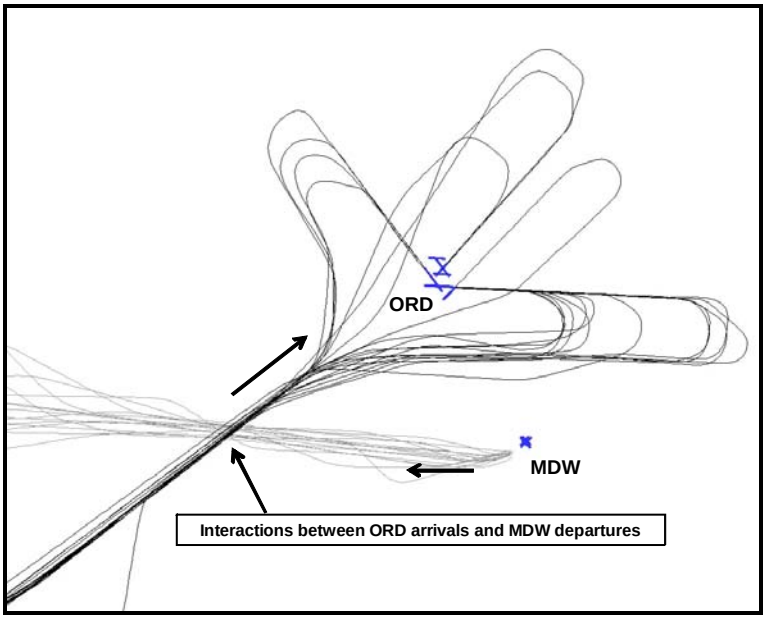

Figure 8: ORD and MDW Path Interactions

To enhance the smooth flow of traffic and realize greater benefits, we also need to better integrate these procedures across airports in a region. When procedures are integrated in a region, the entire airspace system is considered as a shared resource, where trade-offs are made between individual procedures to achieve the most efficient overall traffic flow. An integrated procedure design is expected to improve aircraft arrivals and departures, eliminate conflicting flows among nearby airports, and connect city pairs with new PBN routes for seamless and efficient paths.

The en route airspace faces similar challenges that can be addressed through the use of RNAV and RNP capabilities. RNAV and RNP enable the implementation of published routes in airspace where no ground-based navaids exist, such as over large bodies of water. Additionally, due to the precision inherent in PBN, additional routes can be placed for more efficient use of the airspace, thus increasing capacity and throughput. In October 2005, the FAA implemented the Florida Airspace Optimization (FAO), a series of airspace modifications including:

- New sectors in Washington Center (ZDC) and Miami Center (ZMA) to reduce and balance controller workload.

- New overwater routes to increase north/south capacity (See Figure 9).

- New RNAV and conventional arrivals to eliminate complex airspace merges into Fort Lauderdale (FLL), Miami International (MIA), West Palm Beach International (PBI) and other airports in south Florida (See Figure 10).

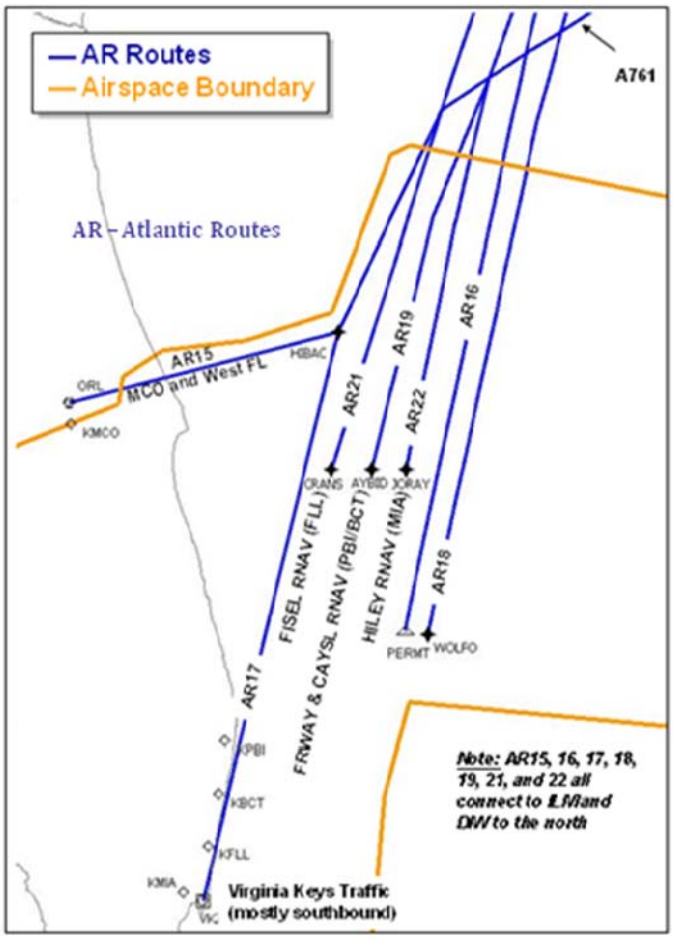

Figure 9: Florida Overwater RNAV Routes

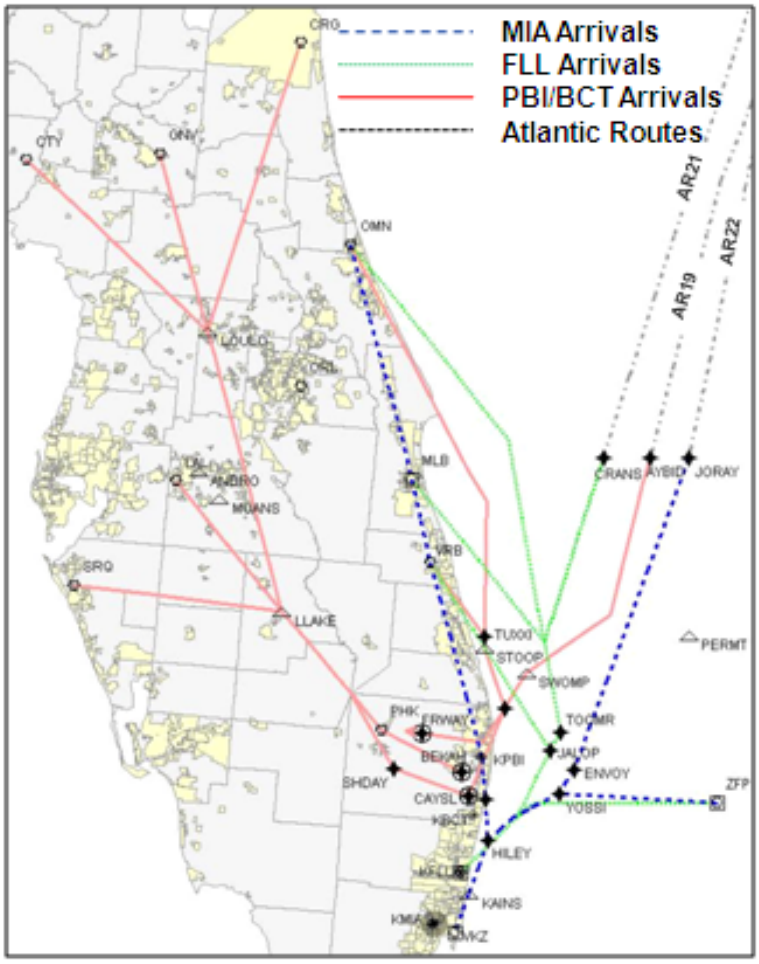

Figure 10: Florida RNAV Departure and Arrival Design

The new overwater procedures added five routes to the existing two. This was accomplished through the design of new RNAV routes that moved flights further east over the Atlantic, creating space for separate Miami, Fort Lauderdale, and West Palm Beach arrival flows. Two other routes also connected traffic to the Florida Keys and Orlando. New south Florida arrival procedures were also added to eliminate complex traffic sequencing and merging. The additional RNAV routes increased north-south flow capacity and efficiency, while providing the means to create direct connections to the RNAV arrival procedures into south Florida. According to MITRE post-implementation analysis of these procedures, airlines operating in this airspace have realized a cumulative savings of over $130 million since implementation in 2005 through 2008.

Optimized Profile Descents (OPDs)

Increased environmental awareness and rising jet fuel prices have stimulated the implementation of methods for reducing air transportation fuel consumption, pollutant emissions and noise, utilizing more advanced features of RNAV and RNP. Within the descent phase of flight, a strategy for reducing these impacts is to minimize the use of level offs. By maintaining idle or near-idle engines during descent, aircraft can minimize the fuel burned, the exhaust gases vented, and the noise generated by the engines. A general term for the broad class of descent routes and procedures which are designed to reduce fuel burn and emissions during descent is Optimized Profile Descents (OPDs).

Two major international partnerships and many independent research programs are currently underway to investigate methods for reducing fuel burn, emissions, and noise in air transportation. These partnerships involve trans-Atlantic and trans-Pacific flights, and include collaboration between industry, government, and academia. Spanning the Atlantic Ocean, the Atlantic Interoperability Initiative to Reduce Emissions (AIRE) was formed with the goal to hasten the development of environmental improvements for all phases of flight. In the Pacific Ocean region, the Asia and South Pacific Initiative to Reduce Emissions (ASPIRE) was formed to extend that goal to flights in Asia and the South Pacific. As part of the initial milestones of the AIRE and ASPIRE programs, field trials of arrival flights utilizing OPDs have been completed, including trans-oceanic flights from Paris to Miami and from Auckland to San Francisco. These trials have demonstrated interoperability and validated the environmental benefits of optimized descents.

In addition to the trial flights of the international AIRE and ASPIRE partnerships, several domestic trial implementations of regularly scheduled flights have clarified the benefits and operational challenges of implementing optimized profile descents. Four such trials, which are notable for their scale, are the United Parcel Service (UPS) nighttime implementation at Louisville, and the arrivals implementations at Los Angeles, Atlanta, and Miami airports. For example, OPD flight trials in Atlanta and Miami airports during 2008 involved twenty flights. MITRE analysis of the data from these flights shows a fuel savings of 50 gallons per flight and a reduction in carbon emissions of approximately 450 kilograms per flight.

MITRE recently conducted a nation-wide analysis of arrival flows at over 100 airports to assess the potential application and benefits of OPD procedures. The analysis considered airports based on level of complexity for design and implementation, and the PBN capability of aircraft that use the airport. MITRE researchers found that OPD procedures can provide significant benefits in terms of reduced fuel consumption and emissions. Figure 11 depicts a sample list of those airports with less complex airspace structures and flows where OPDs can more easily be implemented in the near term. Figure 12 illustrates the range of benefits than can be achieved at those airports. The benefit range represented here is based on actual operational experience and analysis at the airports listed above along with other airports where OPDs are being flown today.

The study also found that the scale of benefits increases at larger airports with more complex airspace structures and flows such as Atlanta, Chicago, Los Angeles, and Philadelphia. For example, OPD implementation on arrival flows at Atlanta could yield benefits of $2.4 to $7.2 million per year in fuel savings. The latter fuel savings is the equivalent to removing 1,400 to 4000 cars from the roads every year. OPD procedure implementation at these more complex airports is likely to require longer lead time.

STL – St. Louis, MO
MHT – Manchester, NH
PIT – Pittsburgh,, PA
CVG – Convington, KY
RDU – Raleigh-Durham, NC
FLL – Fort Lauderdale, FL
PHX – Phoenix, AZ
MCO – Orlando, FL
SAN – San Diego, CA
SLC – Salt Lake City, UT

Figure 11: Selected Airports with Beneficial OPD Procedures

	Range of Fuel Savings: 5 to 15 Gallons Per Flight
Savings (Gallons/Year)	3 Million to 8 Million
Savings (Dollars/Year)	$8 Million to $24 Million
Carbon Reduction (Tons/Year)	27,000 to 80,000
Equivalent Cars off road (Cars /Year)	4,400 to 13,000

Figure 12: Estimated Benefits for Airports in Figure 11

Looking Ahead

Beyond the near-term, there are opportunities to combine different NextGen capabilities to achieve even greater benefits. By combining different NextGen capabilities we can conceptualize new applications and benefits, which cannot be achieved by the use of one capability alone. For example, concepts currently under development for approaches to closely parallel runways combines the use of ADS-B and RNP capabilities. The potential capacity benefit of this procedure is estimated to add approximately 15 to 22 arrivals at airports such as San Francisco, Los Angeles and Seattle. These airports during instrument meteorological conditions lose significant capacity by going to a single-runway operation.

In Summary

As I stated at the outset, the successful RNAV and RNP implementation over the past few years has resulted in significant benefits. As we move forward, we must consider implementation of those RNAV and RNP procedures that result in measurable benefits to the community – not just the number of procedures. Furthermore, we suggest a focus on implementing OPD procedures at airports with less complex airspace structures and flows, which can more easily be achieved in the near term. Recent trials and experience have demonstrated significant benefits, especially in terms of reduced carbon footprint. OPD procedure

implementation at airports with more complex airspace structures and flows should be undertaken as part of a more comprehensive airspace design, which is likely to require a longer lead time. The potential benefits of OPDs at these airports are likely to be even greater. Furthermore, RNAV and RNP procedures result in additional benefits as we consider more comprehensive airspace re-design, where these procedures don't follow the historical flight paths, but rather more-efficient paths through the airspace. I should hasten to add that the latter benefits are likely to be realized beyond the near-term due to significant lead times for addressing the environmental requirements for such comprehensive airspace re-designs. Streamlining the environmental process is likely to shorten the time to achieve these benefits. Finally, as we look ahead, RNAV and RNP, in combination with other capabilities such as ADS-B, data communications, enhanced ground automation capabilities and safe reduction in separation standards can result in even greater benefits.

Mr. Chairman, this concludes my testimony. I would be happy to answer any questions the Committee may have.