Federal Aviation Administration

Roadmap for Performance-Based Navigation

Evolution for Area Navigation (RNAV) and Required Navigation Performance (RNP) Capabilities 2006-2025

July 2006
Version 2.0

U.S. Department
of Transportation

Federal Aviation Administration

Office of the Administrator

800 Independence Ave., S.W.
Washington, D.C. 20591

August 2006

Dear Members of the Aviation Community:

Three years ago, the Federal Aviation Administration published version 1.0 of the *Roadmap for Performance-Based Navigation,* which unveiled our strategy to use performance-based navigation in the United States. The strategy represented a collaborative Government and industry initiative to move forward with applying Area Navigation (RNAV) and Required Navigation Performance (RNP), the two fundamental elements of performance-based navigation. We also set up the FAA's RNAV/RNP Group to ensure that we effectively carried out the commitments described in the *Roadmap*. I congratulate the Government and industry participants for their outstanding accomplishments.

I am delighted to present version 2.0 of the *Roadmap*. This update results from the hard work of our employees and the aviation community. It hasn't been without challenges. I am proud that we worked together to overcome many of those challenges to achieve our goals.

The *Roadmap* describes the road traveled and charts the course ahead. It summarizes the progress made since 2003 and refocuses our strategies, priorities, and milestones for the next objectives using RNAV and RNP. I testified before Congress last year on several of these key implementations. The *Roadmap* describes in more detail the successful implementation of RNAV and RNP procedures at locations such as Dallas/Fort Worth International, Hartsfield-Jackson Atlanta International, and Ronald Reagan Washington National Airports, which are providing real benefits to our aviation community

RNAV and RNP are not only being used in the United States but are also being used around the world. As many of you know, we have worked closely with our international counterparts throughout the past three years to achieve a well-coordinated and harmonized approach to using RNAV and RNP worldwide.

The *Roadmap* implementation is divided into near-, mid-, and far-term objectives. In the near-term, over the next few years, we plan to speed up use of RNAV and RNP around the country, with the added applications of these capabilities in airspace where we need it most. In the midterm, there will be synergies between RNAV and RNP and many other FAA programs that will come online, such as our en route automation capabilities and Automatic Dependent Surveillance-Broadcast (ADS-B). Finally, the far-term strategies to year 2025 in the *Roadmap* are nicely aligned with the Next Generation Air Transportation System goals, being led by the Joint Planning and Development Office.

Thank you for your continued support and active participation in this program.

Sincerely,

Marion

Marion C. Blakey
Administrator

TABLE OF CONTENTS

Purpose and Background

Originally published in July 2003, the *Roadmap for Performance-Based Navigation* is intended to assist aviation stakeholders in understanding operational goals, determining requirements, and considering future investments. The *Roadmap* focuses on addressing future efficiency and capacity needs while maintaining or improving the safety of flight operations by leveraging advances in navigation capabilities on the flight deck. This revision updates the Federal Aviation Administration (FAA) and industry strategy for evolution toward performance-based navigation.

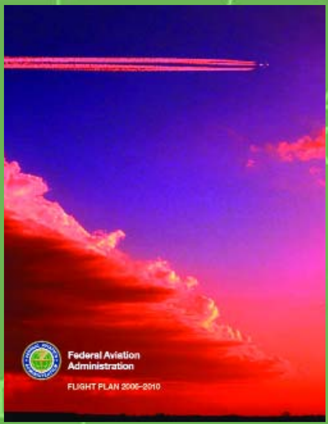
As with the first edition of the *Roadmap*, the FAA has coordinated this update with the aviation community through government-industry forums, including the Performance-Based Operations Aviation Rulemaking Committee (PARC) and RTCA. Since 2003 the FAA and its international partners have collaborated extensively on performance-based navigation standards and issues through various forums such as the International Civil Aviation Organization (ICAO), EUROCONTROL, and the North American Aviation Trilateral (NAAT), as well as through a number of bilateral partnerships. For example, this updated *Roadmap* is intended to be consistent with ICAO's development of a new *Performance-Based Navigation Manual*, and reflects some changes to achieve common international operations.

This *Roadmap* provides a high-level strategy for the evolution of navigation capabilities to be implemented in three timeframes: near term (2006-2010), mid term (2011-2015), and far term (2016-2025). The strategy rests upon two key navigation concepts: Area Navigation (RNAV) and Required Navigation Performance (RNP). It also encompasses instrument approaches, Standard Instrument Departure (SID) and Standard Terminal Arrival (STAR) operations, as well as en route and oceanic operations. The section on far-term initiatives discusses integrated navigation, communication, surveillance and automation strategies.

The *Roadmap* supports other FAA and government-wide planning processes, as the FAA works on several fronts to address the needs of the aviation community. At the forefront is the FAA's *Flight Plan*, the five-year strategy directing FAA budget requests. For the *Flight Plan* time frame and beyond, the FAA's Operational Evolution Plan (OEP) describes the capacity and efficiency initiatives over a rolling 10-year period at the busiest 35 airports in the National Airspace System (NAS). As part of a multi-agency collaboration effort through the Joint Planning and Development Office (JPDO), the FAA is developing a plan for the Next Generation Air Transportation System (NGATS) to meet air transportation needs through the year 2025. These plans have the common goal of adopting satellite-based navigation as a cornerstone for performance-based operations.

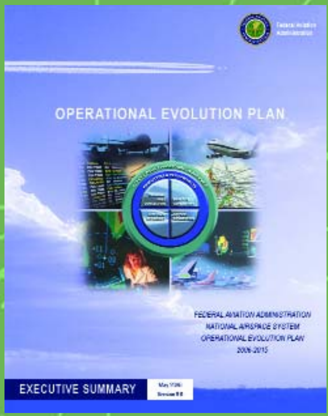
Other emerging performance-based concepts are Required Communications Performance (RCP) and Required Surveillance Performance (RSP). These concepts define specified levels of performance and capability as agreed-upon standards, while leaving the implementation of solutions and technologies to appropriate aviation stakeholders such as avionics manufacturers, aircraft manufacturers, and air traffic service providers.

RNAV and RNP have reached a sufficient level of maturity and definition to be included in key plans and strategies, such as this updated edition of the *Roadmap*. PARC has also made progress in RCP definition since the first edition of the



FAA Flight Plan

- *Five-year strategy plan*
- *Involves all FAA Lines of Business. The FAA Lines of Business in turn have five-year business plans that support the Flight Plan.*



Operational Evolution Plan

- *Critical plan to address effective capacity*
- *Rolling 10-year timeframe*
- *Distills and aligns all commitments needed to deliver critical capacity improvements*

NGATS

- *Long-term view (2025) of the national air transportation system. Has a broad scope with air traffic management as one facet of the plan.*
- *Multi-agency involvement*
- *Aims to transform the system*

Roadmap; the *Roadmap for Performance-Based Communications* is being developed separately. RSP is still in its early developmental stages. As collaborative efforts continue within the FAA and JPDO, the FAA expects to include more complete definitions in the next edition of the *Roadmap*.

The *Roadmap* is intended to help aviation community stakeholders plan their future transition and investment strategies. The stakeholders who will benefit from the concepts in this *Roadmap* include airspace operators, air traffic service providers, regulators and standards organizations, and airframe and avionics manufacturers. As driven by business needs, airlines and operators can use the *Roadmap* to plan future equipage and capability investments. Avionics and aircraft manufacturers can determine the capabilities needed in the future. Similarly, air traffic service providers can determine requirements for future automation systems, and more smoothly modernize ground infrastructure. Finally, regulators and standards organizations can anticipate and develop the key enabling criteria needed for implementation.

Aviation System Context

The nation's air transportation system continues to play an essential role in our economy and security, with the historical growth trend expected to continue steadily over the next 20 years. In 2005, passenger demand grew rapidly, with enplanements up 7 percent from the previous year to 738.6 million and revenue passenger miles increasing 8 percent to 775.3 billion. Both major airlines and regional carriers experienced growth in enplanements in 2005, with the fastest growth at regional carriers. Air transportation between the United States and other nations grew almost twice as fast as domestic markets, led by double-digit increases in both the Latin American and Pacific regions.

Passenger demand for air transportation is projected to increase an average of 3.4 percent each year between 2005 and 2017. By 2017, U.S. commercial air carriers are predicted to transport a total of about one billion passengers, flying over 1.25 trillion passenger miles. Flights already have more passengers, with load factors projected to continue increasing steadily to more than 78 percent by 2017. To support these operational changes, airframe and avionics manufacturers are adding flight deck capabilities that enable advanced navigation and other services.

General aviation (GA) continues to show strength and is expected to grow even stronger in the future. Projections indicate that the piston aircraft fleet will increase at an average annual rate of 1.4 percent, while a broad variety of business jets will grow in number at an average rate of 4 percent per year. The introduction of very light jets (VLJs) into the NAS will create new complexities and spur growth at certain airports in the future. These VLJs are anticipated to increase by as many as 400 to 500 aircraft per year. Adding to airspace and operational complexity, unmanned aircraft systems (UAS) are expected to be used routinely in the NAS.

Growth in scheduled and GA aircraft is expected to increase point-to-point and direct routing, with the need for greater system flexibility to handle peaks in traffic demand, convective weather, military operations and security needs. FAA forecasts indicate that by 2017 traffic will peak at the nation's busiest airports, at a level 30-40 percent higher than today. Thus, stakeholders must make diligent efforts to increase system flexibility, improve strategic management of flights, and control delays while maintaining today's safety levels.

The cost of fuel presents a significant challenge to all segments of the aviation community. For example, higher fuel prices cost air carriers nearly $33 billion in 2005, twice what they spent in 2003. At a consumption rate of nearly 20 billion gallons per year, every penny increase in the price of a gallon of jet fuel raises annual fuel costs for U.S. air carriers by nearly $200 million. This problem can be partially alleviated by efficiencies in airspace and procedures.

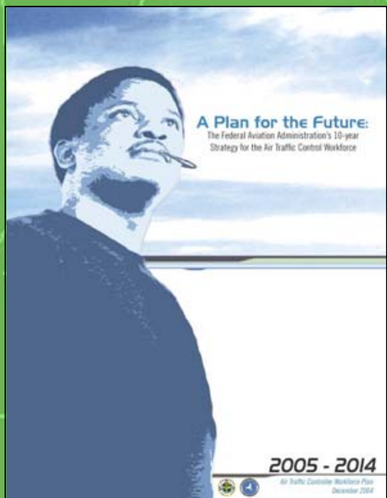
The anticipated growth and higher complexity of the air transportation system are likely to result in increased flight delays, schedule disruptions, choke points, inefficient flight operations, and passenger inconvenience, particularly when

Photo courtesy of Eclipse Aviation

VLJs can takeoff from runways as short as 3000 ft., cruise at speeds of 375 kts, and operate up to 41,000 ft. These aircraft can utilize more than 5,000 runways in the United States.

The FAA is addressing key issues of handling UAS operations in the NAS including where and how frequently these flights will occur, how they will interact with the ATM system, and how these flights will be integrated.

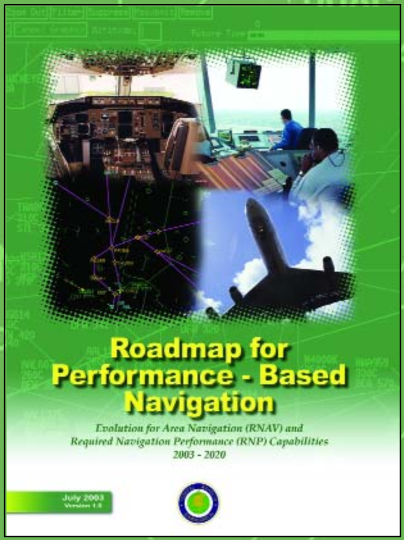
unpredictable weather and other factors constrain airport capacity. Without improvements in system efficiency and workforce productivity, the FAA's cost of operations will continue to increase. Upgrades to the air transportation system must leverage current and evolving capabilities in the near term, while building the foundation to address the future needs of the aviation community stakeholders.



Over the next 10 years, 73 percent of the agency's 15,000 controllers will become eligible to retire. The agency will need to respond by hiring, staffing and training as many as 11,000 new controllers over this time frame. Productivity improvements are needed to reduce the operational costs and enable a reduction in staffing requirements.

Call to Action

Responding to the challenges facing the air transportation industry, the FAA in July 2003 unveiled its commitment to performance-based navigation and outlined its strategy in the *Roadmap for Performance-Based Navigation*. The original *Roadmap* served as a call to action for both the FAA and industry. As a result, the aviation community is instituting performance-based navigation to increase safety, efficiency, and capacity in the NAS.



This new *Roadmap* results from collaborative FAA and industry efforts that establish a joint government/industry strategy for implementing performance-based navigation: critical initiatives to accommodate the expected growth and complexity over the next two decades. The strategy has five key features:

- Expediting the development of performance-based navigation criteria and standards.
- Introducing airspace and procedure improvements in the near term.
- Providing benefits to operators who have invested in existing and upcoming capabilities.
- Establishing target dates for the introduction of navigation mandates for selected procedures and airspace, with an understanding that any mandate must be rationalized on the basis of benefits and costs.
- Defining new concepts and applications of performance-based navigation for the mid term and far term, building synergy and integration among other capabilities toward the realization of NGATS goals.

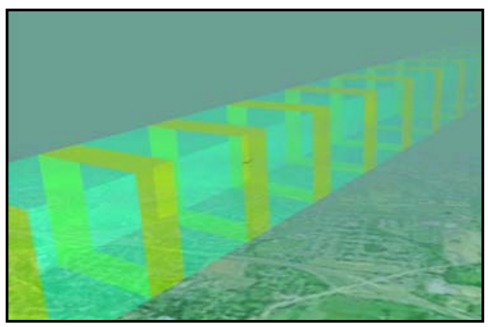
Since 2003, the FAA and the aviation community have made significant progress toward meeting the goals described in the first edition of the *Roadmap*. Achievements have included beneficial RNAV and RNP procedures in the NAS and development of new criteria, standards, and future concepts. This updated *Roadmap* defines new commitments and strategies.

Performance-Based Navigation and its Benefits

Performance-based navigation is a framework for defining a navigation performance specification along a route, during a procedure, or in airspace within which an aircraft must comply with specified operational performance requirements. It provides a simple basis for the design and implementation of automated flight paths and for airspace design, aircraft separation, and obstacle clearance. It also offers a straightforward means to communicate the performance and operational capabilities necessary for the utilization of such paths and airspace. Once the performance level (i.e., the *accuracy value*) is established on the basis of operational needs, the aircraft's own capability determines whether the aircraft can safely achieve the specified performance and thus qualify for the operation. Within the framework of performance-based navigation, the FAA and industry have defined RNAV and RNP specifications that can be satisfied by a range of navigation systems. This *Roadmap* provides an update on these specifications.

Aircraft navigation has long been constrained by the location of ground-based navigation aids (NAVAIDs), which restricted aircraft paths or airspace. **RNAV** operations remove the requirement for a direct link between aircraft navigation and a NAVAID, thereby allowing aircraft better access and permitting flexibility of point-to-point operations.

RNP operations introduce the requirement for onboard performance monitoring and alerting. A critical characteristic of RNP operations is the ability of the aircraft navigation system to monitor the navigation performance it achieves and to inform the crew if the requirement is not met during an operation. This onboard monitoring and alerting capability enhances the pilot's situation awareness and can enable closer route spacing without intervention by air traffic control (ATC).



Certain RNP operations require advanced features of the onboard navigation function and approved training and crew procedures. These operations must receive approvals that are characterized as Special Aircraft and Aircrew Authorization Required (SAAAR), similar to approvals required for operations to conduct instrument landing system (ILS) Category II and III approaches.

Approximately 80 percent of operations at the top 35 OEP airports are estimated to be RNAV-1 capable, with this percentage predicted to increase to over 90 percent by 2010. Approximately 50 percent of transport-category aircraft are capable of basic RNP operations, and 25-30 percent are capable of RNP SAAAR approach operations. Industry-wide forecasts predict that 80-90 percent of transport-category aircraft will be capable of basic RNP operations by 2017.

Many business aviation aircraft are also capable of RNAV and basic RNP operations (approximately 75 percent being Global Positioning System [GPS]-equipped).

RNAV-1 specifications for terminal SIDs and STARs require lateral total system error of not more than 1 NM for 95 percent of the flight time.

RNAV-2 specifications for en route procedures require total system error of not more than 2 NM for 95 percent of the flight time.

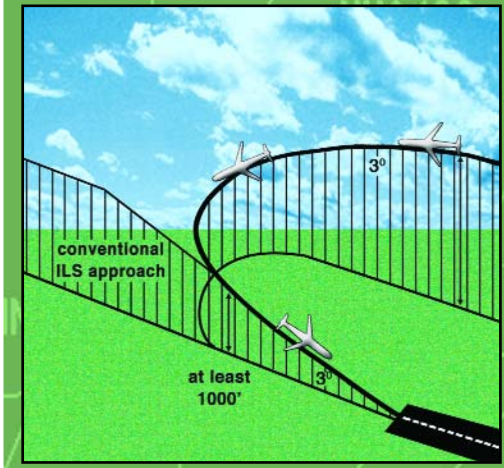
Basic RNP requires onboard navigation performance monitoring and alerting. Basic RNP operations are defined as RNP-2 en route, RNP-1 terminal and RNP-0.3 final approaches. More advanced RNP operations have also been specified as Special Aircraft and Aircrew Authorization Required (SAAAR).

Some piston aircraft are capable of RNAV and basic RNP, with nearly half of all GA instrument flight rules (IFR) aircraft equipped with IFR-certified GPS navigation systems.

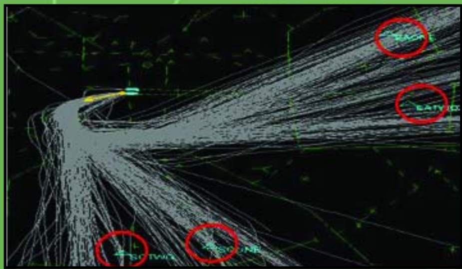
RNAV and RNP specifications facilitate more efficient design of airspace and procedures, which collectively result in improved safety, access, capacity, predictability, operational efficiency, and environmental effects. Specifically, RNAV and RNP may:

- Increase safety by using three-dimensional (3D) approach operations with course guidance to the runway, which reduce the risk of controlled flight into terrain.
- Improve airport and airspace access in all weather conditions, and the ability to meet environmental and obstacle clearance constraints.
- Enhance reliability and reduce delays by defining more precise terminal area procedures that feature parallel routes and environmentally optimized airspace corridors. Flight management systems (FMS) will then be poised to save operators time and money by managing climb, descent, and engine performance profiles more efficiently.
- Improve efficiency and flexibility by increasing use of operator-preferred trajectories NAS-wide, at all altitudes. This will be particularly useful in maintaining schedule integrity when convective weather arises.
- Reduce workload and improve productivity of air traffic controllers.

Performance-based navigation will enable the needed operational improvements by leveraging current and evolving aircraft capabilities in the near term that can be expanded to address the future needs of NAS stakeholders and service providers.



3D operations are defined by a series of points defining latitude, longitude and altitude. The operation may also specify a vertical path angle.

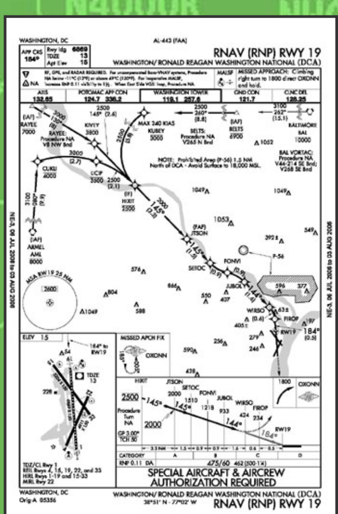


Before RNAV

Departure operations at Hartsfield-Jackson Atlanta International Airport with RNAV SIDs provide an increased number of departure fixes for improved throughput and flexibility.

After RNAV

RNAV SIDs when fully implemented at both Atlanta and Dallas-Ft. Worth are estimated to provide a combined total savings of approximately $50 million annually.



RNP SAAAR approach into Washington, DC's Ronald Reagan National Airport.

Key Accomplishments

The key accomplishments in accordance with the *Roadmap* to date fall into three categories: (a) implementation of new procedures and capabilities, (b) development and publication of enabling criteria and standards, and (c) international harmonization. The FAA and industry collaborated at each step to deliver these improvements despite challenges involving technical, operational, and human factors. The aviation community has collected extensive lessons learned and integrated them into criteria and guidance material.

Particularly noteworthy achievements in 2005 included publication of RNP SAAAR approach criteria and associated guidance for aircraft and operator approval. The procedures currently providing the most significant benefits to operators include the RNAV SIDs at Dallas-Ft. Worth and Atlanta, the RNP SAAAR approaches at Washington, DC's Ronald Reagan National Airport, and Alaska Airlines' special RNP SAAAR approach procedure into Palm Springs.

The FAA also implemented Florida airspace optimization involving new RNAV arrival routes to eliminate complex merges, new sectors to reduce controller workload, and new overwater routes to increase north-south capacity; benefits include fewer traffic management restrictions, reduced delays, and reduced re-routes, expected to produce combined savings of $35 million annually.

Summary of Key Implementations

- 66 RNAV SIDs and STARs at 17 airports in the NAS (18 RNAV STARs, 48 RNAV SIDs, plus helicopter RNAV procedures at four sites)
- 6 RNP SAAAR approaches
- 20 en route RNAV (charted as Q) routes and four RNAV IFR terminal transition (charted as T) routes
- Pacific Oceanic 50 NM lateral separation standard, based on RNP-10 accuracy[1]
- RNAV approaches (LNAV/VNAV) to over 800 runway ends
- 400 new RNAV approaches with LPV minima
- First U.S. operational approvals for RNP SAAAR and aircraft approval for GLS

New Criteria, Standards and Tools

- Order 8260.50, *U.S. Standard for WAAS LPV Approach Procedure Construction Criteria*
- Order 8260.51, *U.S. Standard for Required Navigation Performance (RNP) Instrument Approach Procedure Construction*
- Order 8260.52, *U.S. Standard for Required Navigation Performance (RNP) Approach Procedure with Special Aircraft and Aircrew Authorization Required (SAAAR)*
- Order 8260.53, *United States Standard for Instrument Departures That Use Radar Vectors to Join RNAV Routes*
- Order 7470.1, *DME/DME Evaluation*
- Order 8260.44A, *Civil Utilization of Area Navigation (RNAV) Departure Procedures*

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[1]Oceanic RNP-10 is a 10-NM cross-track accuracy requirement based on ICAO regional supplementary procedures Doc 7030/4 PAC/RAC, Part 1, Chapter 6.

- Notice 8000.326, *Guidelines for Airworthiness and Operational Approval and Procedure Design for Non-14 CFR Part 97 RNP SAAAR Approach Procedures*
- Notice 8000.325, *Special Area Navigation (RNAV) Transition Procedures*
- AC 20-153, *Acceptance of Data Processes and Associated Navigation Databases*
- AC 90-96A, *Approval of U.S. Operators and Aircraft to Operate Under Instrument Flight Rules (IFR) in European Airspace Designated for Basic Area Navigation (B-RNAV) and Precision Area Navigation (P-RNAV)*
- AC 90-100, *U.S. Terminal and En Route Area Navigation (RNAV) Operations*
- AC 90-101, *Approval Guidance for RNP Procedures with SAAAR*
- Terminal Area Route Generation, Evaluation, and Traffic Simulation Tool (TARGETS)
- RNAV-PRO™ DME Screening Tool
- *Aeronautical Information Manual* Revisions for RNAV
- Charting Specifications for RNAV routes and procedures

International Harmonization

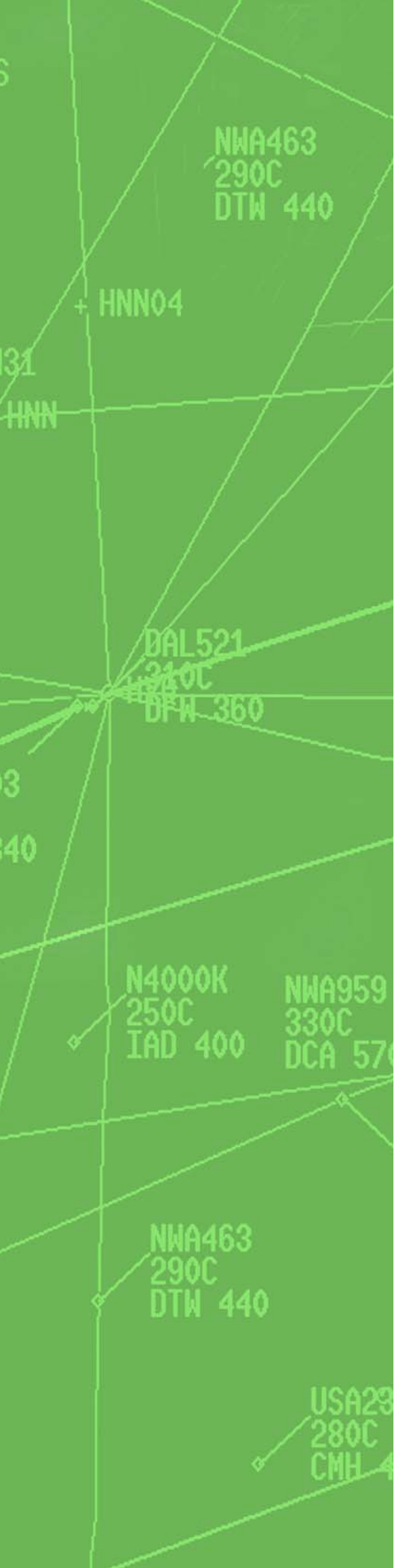
The FAA is currently pursuing harmonization through a series of bilateral and multilateral collaborations:

- A new effort aimed at harmonization of performance-based navigation across North American airspace is underway under the auspices of the North American Aviation Trilateral (NAAT). The NAAT comprises the leaders of the FAA, Transport Canada, and Mexico's Directorate General of Civil Aviation. The NAAT has included NAV CANADA (Canada's air navigation service provider) and SENEAM (Mexico's air navigation services provider) as partners in this endeavor.
- The FAA and EUROCONTROL have completed a project to harmonize their respective requirements for RNAV, as reflected in FAA AC 90-100 and Joint Aviation Authorities (JAA) Temporary Guidance Leaflet (TGL)-10. In June 2005 this harmonization activity resulted in a recommendation to ICAO for ICAO RNAV-1 and RNAV-2 navigation specifications.
- The FAA maintains a regular dialogue with Australia's Civil Aviation Safety Authority as the two nations develop standards and establish RNAV and RNP in their national airspace systems. This dialogue is a valuable adjunct to the formal harmonization activities in which both states engage through ICAO.
- The FAA has extensive efforts underway with General Administration of the Civil Aviation of China (CAAC) to assist in implementation of RNAV and RNP in the People's Republic of China.
- The FAA has worked with the Japan Civil Aviation Bureau (JCAB) on the technical aspects of RNAV implementation. JCAB published an RNAV Roadmap for Japan in April 2005. The FAA participates in informal air traffic groups with Japan in the Informal Pacific ATC Coordination Group; with New Zealand, Australia, Tahiti, and Fiji in the Informal South Pacific ATS Coordinating Group; and with Russia in the Russian-American Coordinating Group for AT to further expand implementation of RNP-10 and RNP-4 in Pacific oceanic airspace.

Pictured here are the NAAT representatives, from left to right, Agustín Arellano (Director General, Los Servicios a la Navegacion en el Espacio Aereo Mexicano (SENEAM)),Gilberto López Meyer (Director General, Civil Aviation, Mexico) Marion Blakey (Administrator, Federal Aviation Administration), Merlin Preuss (Director General, Safety and Security, Transport Canada), Kathy Fox (Vice-President, Operations, NAV CANADA).

North American Aviation Trilateral Statement on Joint Strategy for Implementation of Performance-Based Navigation: Area Navigation (RNAV) and Required Navigation Performance (RNP) in North America

North American Aviation Trilateral Statement on Joint Strategy for Implementation of Performance-Based Navigation: Area Navigation (RNAV) and Required Navigation Performance (RNP) in North America.



The FAA and U.S. industry are engaged in a key harmonization activity through their participation in ICAO's Required Navigation Performance and Special Operational Requirements Study Group (RNPSORSG), which is charged with producing the *Performance-Based Navigation Manual*. Significant ICAO harmonization activities include:

- The FAA and EUROCONTROL coordinated development of a harmonized RNAV standard for terminal area operations. The *Performance-Based Navigation Manual* will incorporate the new standard for RNAV-1 and RNAV-2, which is reflected throughout this update to the *Roadmap*, as the United States transitions to align with the international specification. The transition is expected to be complete with the publication of AC 90-100A.
- The FAA, with the support of industry and numerous nations that are implementing RNP operations, has defined design criteria for U.S. procedures for RNP approaches. These criteria, originally developed with the participation of industry and international experts, use values between RNP-0.3 and RNP-0.1. They have been submitted to the ICAO Obstacle Clearance Panel for adoption in ICAO Document 8168, *Procedures for Air Navigation Services - Aircraft Operations* (PANS OPS). ICAO is expected to adopt RNP Approach (Authorization Required) criteria in 2007.
- The FAA has submitted elements of the U.S. aircraft and operator requirements for RNP Approach (Authorization Required) to the ICAO RNPSORSG for inclusion in the *Performance-Based Navigation Manual*, expected later in 2006.
- ICAO, with support from the FAA, is developing international guidance and specifications for standard RNP-2, RNP-1 and RNP-0.3 operations. These specifications will be published in the *Performance-Based Navigation Manual*.

The FAA will also work through its membership in ICAO regional forums, such as the Planning and Implementation group for the Caribbean and South America Regions and Regional ICAO groups such as North Atlantic Systems Planning Group and Asia Pacific Air Navigation Planning and Implementation Regional Group, to share expertise, lessons learned, and plans for performance-based navigation.

Transition Overview

The transitions described in the *Roadmap* fall into three timeframes: near term (2006-2010), mid term (2011-2015), and far term (2016-2025). Initiatives in the near term focus on realizing the value of investments by operators in current aircraft and new aircraft acquisitions, as well as FAA investments in satellite-based navigation and conventional navigation infrastructure. Key components include wide-scale RNAV implementation and the introduction of RNP for en route, terminal, and approach procedures. Efforts in the mid term center on shifting to predominantly RNP operations for improving flight efficiency and airport access. The mid-term strategy employs RNAV extensively to improve flight operations NAS-wide. Far-term activities concentrate on performance-based operations in the NAS, through integrated RNP, RCP, and RSP; optimized airspace; automation enhancements; and modernization of communications, navigation, and surveillance (CNS) infrastructures. The transition overview is summarized below, with mandates highlighted in the mid term and far term.

Near Term (2006-2010)	Mid Term (2011-2015)	Far Term (2016-2025)
En Route ❒ RNAV Q routes ❒ RNP-2 routes ❒ T routes and lower MEAs ❒ Requirements to incorporate aircraft navigation capabilities into en route automation **Oceanic** ❒ RNP-10 and 50/50 NM lat/long Pacific ❒ RNP-10 and 60 NM lat in WATRS ❒ Expand 30 NM longitudinal/ 30 NM lateral separation (30/30) in the Pacific ❒ Explore RNP-4 in NAT **Terminal** ❒ RNAV SIDs/STARs at OEP airports ❒ RNP-1 SIDs/STARs where beneficial ❒ Automation requirements for merging RNAV arrivals ❒ Concepts for RNAV and RNP with 3D, constant descent arrivals (CDA), and time of arrival control **Approach** ❒ At least 25 RNP SAAAR per year ❒ 300 RNAV (GPS) per year ❒ Standards for closely spaced and converging runway operations based on RNP	**En Route** ❒ RNP-2 routes ❒ T routes and lower MEAs ❒ Enhanced automation incorporating aircraft navigation capabilities ❒ At end of mid term, mandate RNP-2 at and above FL290, and mandate RNAV at and above FL180 **Oceanic** ❒ Limited RNP-4 and 30 NM lat in WATRS ❒ Increase use of operator-preferred routes and dynamic re-routes **Terminal** ❒ RNAV SIDs/STARs at many of the top 100 airports ❒ RNP-1 or lower SIDs/STARs where beneficial ❒ Airspace redesign and procedures for RNAV and RNP with 3D, CDA, and time of arrival control ❒ At the end of mid term, mandate RNAV for arriving/departing at OEP Airports **Approach** ❒ At least 50 RNP per year ❒ 300 RNAV (GPS) per year ❒ Closely spaced parallel and converging runway operations based on RNP ❒ Satellite-based low visibility landing and takeoff procedures (GLS)	**Performance-Based NAS Operations** ❒ RNP Airspace at and above FL290 ❒ Separation assurance through combination of ground and airborne capabilities ❒ Strategic and tactical flow management through system-wide integrated ground and airborne information system ❒ System flexibility and responsiveness through flexible routing and distributed decision-making ❒ Optimized operations through integrated flight planning, automation and surface management capabilities ❒ Mandate RNAV everywhere in CONUS ❒ Mandate RNP in busy en route and terminal airspace

Recent collaboration between FAA and the aviation community on navigation infrastructure sustainment is being accomplished through the Navigation Evolution Working Group, with an expected publication of the Navigation Evolution Roadmap later in 2006

The key tasks involved in the transition to performance-based navigation are:

- Establish navigation service needs through the far term that will guide infrastructure decisions
  - Specify needs for navigation system infrastructure, and ensure funding for managing and transitioning these systems
- Define and adopt a national policy enabling additional benefits based on RNP and RNAV
- Identify operational and integration issues between navigation and surveillance, air-ground communications, and automation tools that maximize the benefits of RNP
- Support mixed operations throughout the term of this *Roadmap*, in particular considering navigation system variations during the near term until appropriate standards are developed and implemented
- Initiate rulemaking for mandates 7-10 years in advance
  - To support Department of Defense requirements, the FAA will develop the policies needed to accommodate the unique missions and capabilities of military aircraft operating in civil airspace
- Harmonize the evolution of capabilities for interoperability across airspace operations
- Increase emphasis on human factors, especially on training and procedures as operations increase reliance on appropriate use of flight deck systems
- Facilitate and advance environmental analysis efforts required to support the development of RNAV and RNP procedures
- Maintain consistent and harmonized global standards for RNAV and RNP operations.

Near Term (2006-2010) Priorities

The near-term strategy will focus on expediting the implementation and proliferation of RNAV and RNP procedures in the NAS by using the increasing navigation capabilities in the inventory. As demand for air travel continues at healthy levels, choke points will develop and delays at the OEP 35 airports will continue to climb. RNAV and RNP procedures will help alleviate those problems. The fleet at the OEP airports reflects an average of 80 percent RNAV-1 capability and this is expected to reach over 90 percent by the end of the near term. Continued introduction of RNAV and RNP procedures in the NAS will not only provide benefits and savings to the operators but also encourage further equipage. Additionally, key FAA and industry initiatives in this time frame will pave the road for mid-term and far-term capabilities.

En Route Operational Capabilities and Milestones

For airspace and corridors requiring structured routes for flow management, the FAA will establish RNAV routes (charted as Q routes). Q routes provide efficient flows between busy airports and feature limited entry and exit points, like "express lanes" on the highway. Parallel Q routes will be established where necessary to meet increasing traffic levels. In 2006 the FAA will publish 23 new Q routes, primarily in the western and southwestern United States.

During the near term, airspace redesign will extend into the southeastern United States. Non-restrictive routing (NRR) operations will be based on the National Reference System (NRS).[2] The NRS, a grid of waypoints overlying the United States, will be used to provide a basis for non-restrictive routing operations. In the NRR service environment, if the aircraft is RNAV capable the user can plan the most advantageous path for portions of a proposed route of flight.

The FAA will implement RNP-2 routes to enable reduced route spacing (e.g., in non-radar areas) and increased capacity, flexibility, and weather avoidance. RNP-2 routes will potentially permit 8 NM en route track spacing in both radar and non-radar airspace where RNP-2 aircraft capability exists and where procedures and automation tools support these operations. For readiness in the mid term, the FAA will establish requirements for new automation to improve traffic flow management, dynamic rerouting, and conflict probe of RNP-2 routes.

To benefit GA operators, the FAA is creating low-altitude RNAV routes (published as Tango [or T] routes) in selected terminal areas. T routes allow aircraft to transit Class B and C airspace more efficiently than the existing paths that rely on ground-based NAVAIDs and radar vectoring. In 2006, the FAA will implement 10 new T routes. T routes are also being established in some areas where NAVAID decommissioning has limited conventional IFR service between key airports. The FAA will evaluate T routes for use along coastlines and other areas; for example, to avoid military use airspace. Where structured routes are unnecessary, RNAV-capable GA operators will continue to request and fly direct.

GPS makes it possible to lower minimum en route altitudes (MEAs). Lowering MEAs improves flight safety by avoiding icing and turbulence at higher altitudes,

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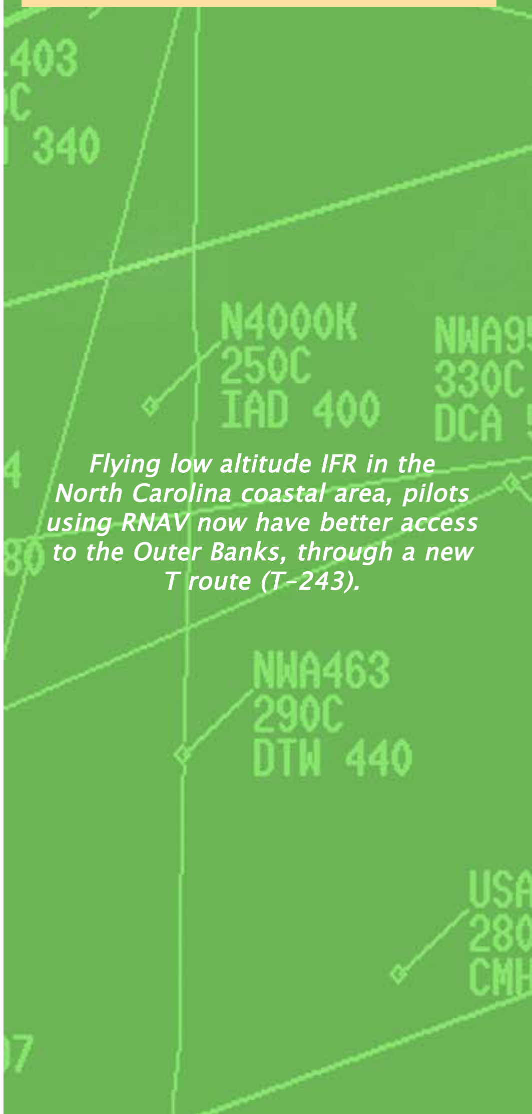
[2]The NRS is the basis for flight plan filing and operations in the redesigned high altitude environment. The NRS provides increased flexibility to en route flight operations and controllers by allowing more efficient tactical route changes that ensure aircraft separation.

OEP 35 Airports	
Atlanta Hartsfield-Jackson International	ATL
Baltimore-Washington International	BWI
Boston Logan International	BOS
Charlotte/Douglas International	CLT
Chicago Midway	MDW
Chicago O'Hare International	ORD
Cincinnati-Northern Kentucky	CVG
Cleveland-Hopkins International	CLE
Dallas-Fort Worth International	DFW
Denver International	DEN
Detroit Metro Wayne County	DTW
Fort Lauderdale-Hollywood International	FLL
George Bush Intercontinental	IAH
Greater Pittsburgh International	PIT
Honolulu International	HNL
Lambert St. Louis International	STL
Las Vegas McCarran International	LAS
Los Angeles International	LAX
Memphis International	MEM
Miami International	MIA
Minneapolis-St Paul International	MSP
New York John F. Kennedy International	JFK
New York LaGuardia	LGA
Newark International	EWR
Orlando International	MCO
Philadelphia International	PHL
Phoenix Sky Harbor International	PHX
Portland International	PDX
Ronald Reagan National	DCA
Salt Lake City International	SLC
San Diego International Lindbergh	SAN
San Francisco International	SFO
Seattle-Tacoma International	SEA
Tampa International	TPA
Washington Dulles International	IAD



Flying low altitude IFR in the North Carolina coastal area, pilots using RNAV now have better access to the Outer Banks, through a new T route (T-243).

and allows maximum use of available airspace. Alaska has already established lower MEAs, and this has yielded safety benefits. In 2006, the FAA will establish lower MEAs on five existing IFR airways in CONUS, which will require changes to automation.

Oceanic Operational Capabilities and Milestones

To promote global harmonization, the FAA continues to work closely with its international partners in promulgating reduced oceanic longitudinal/lateral separation minima between aircraft approved for RNP-10 and RNP-4 operations. During the near term, the current RNP-10 routes in the Pacific Region will continue, with the Oakland Air Route Traffic Control Center (ARTCC) using the Advanced Technologies and Oceanic Procedures (ATOP) Ocean21 system. Ocean21 supports the Future Air Navigation System (FANS) 1/A automatic dependent surveillance-contract (ADS-C) functionality necessary for the automated application of 50 NM longitudinal separation. The Ocean 21 automation sytsem now in use at New York and Oakland ARTCCs has enhanced ATC capability to support RNP operations by reducing separation standards for RNP-approved aircraft. Anchorage ARTCC is expected to convert fully to Ocean21 for portions of its oceanic airspace in 2007-2008.

ATOP has been implemented in New York and Oakland Air Route Traffic Control Centers (ARTCC). ATOP Ocean21 system (pictured here) supports reduced separation standards for RNP-approved aircraft.

In December 2005 the United States began using 30 NM horizontal separation between RNP-4 approved aircraft flying between California and the South Pacific region. With lessons learned from these trials, the FAA plans to expand operational implementation to other oceanic airspace, beginning in the Pacific. This reduced horizontal separation for aircraft that demonstrate more stringent RNP capability and other CNS features is part of a worldwide ICAO-coordinated effort to improve air traffic and air navigation services.

The North Atlantic (NAT) ICAO Region has implemented Minimum Navigation Performance Specifications (MNPS), and the FAA is heading an initiative involving both the ICAO NAT and Caribbean Regions to redesign the airspace and reduce separation in the West Atlantic Route System (WATRS) and surrounding areas. The goal of this program is to implement RNP-10 by the end of 2008. Using RNP-10 in this complex airspace area will permit lateral separation to be reduced from 90 NM to 60 or 50 NM. Both ICAO Regions support the introduction of RNP-4 in the NAT in the near term provided analyses demonstrate this would produce benefits.

Terminal Operational Capabilities and Milestones

RNAV in the terminal domain is improving airspace design at many of the busiest airports in the United States through better use of arrival and departure corridors. RNAV also helps to reduce conflict between traffic flows by consolidating flight tracks. RNAV SIDs and STARs improve safety, capacity, and flight efficiency. For example, these procedures are already reducing controller-pilot communications in Atlanta and Dallas-Ft. Worth by up to 50 percent and in the process also lowering communication errors.

In 2006, the FAA will publish 90 RNAV SIDs and STARs and make associated changes in airspace design. The FAA will implement RNAV SIDs and STARs at the OEP airports by the end of the near term. In addition, the FAA will implement RNP SIDs and STARs, in certain cases applying advanced functionality such as radius-to-fix (RF) path terminators to ensure repeatable turns where beneficial and to permit more efficient design of limited airspace.

The FAA is establishing the following strategies for RNAV and RNP SIDs:

1. Introduce RNAV-1 SIDs to ensure maximum reduction in controller-pilot communications and to meet environmental or obstacle clearance requirements.
2. Establish diverging RNAV-1 departure paths where feasible to take advantage of available airspace for maximum runway throughput.
3. Where operationally feasible, apply seamless procedures from RNAV-1 SIDs to en route entry points to achieve smooth transition between terminal and en route RNAV operations.
4. Sequence departures to maximize benefits of RNAV; identify automation requirements for traffic flow management, sequencing tools, flight plan processing, and tower data entry activities.
5. Apply RNP-1 SIDs where RNAV-1 SIDs do not maximize benefits.

The FAA is establishing the following implementation strategies for RNAV and RNP STARs:

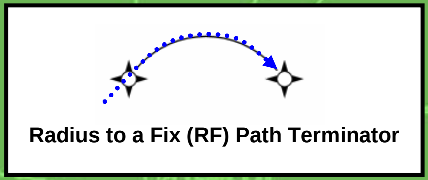
1. For maximum benefit, apply RNAV-1 STAR runway transitions that connect RNAV STARs to a standard instrument approach procedure (SIAP).
2. In moderate to heavy traffic areas with merging RNAV arrival streams, identify requirements for tactical controller tools that maximize efficiency and throughput for RNAV arrival operations.
3. Develop operational concepts and requirements for constant descent arrivals (CDAs) and for applying time of arrival control based on RNAV and RNP procedures.
4. Implement RNP-1 STARs where RNAV-1 STARs do not maximize benefits.

Approach Operational Capabilities and Milestones

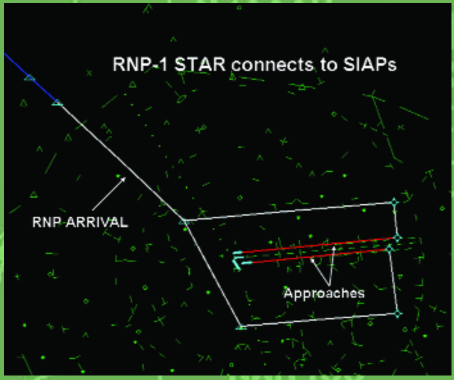
Operational changes, especially in the approach domain, are required in order to retain capacity in adverse weather conditions. One means for enabling such changes is to provide instrument approaches to nearly all runways. Instrument operations, in turn, can be improved by de-conflicting traffic flows or removing dependencies between flows, thus increasing capacity. Enabling approaches to airports with closely spaced parallel runways, even during reduced visibility conditions, has proven particularly useful.

To achieve optimum runway capacity in low visibility conditions, the FAA is introducing new RNAV approaches to runways without existing instrument procedures. RNAV approaches include: (a) minima for Wide Area Augmentation System (WAAS)-enabled localizer performance with vertical guidance (LPV), (b) minima for vertically guided approach services based on lateral navigation/vertical navigation (LNAV/VNAV), and (c) minima for non-precision approaches based on LNAV.[3] RNAV approaches with LPV minima provide services equivalent to ILS Category I. To avoid expenditures for new ILS, the FAA is developing RNAV approaches at a rate of 300 per year.

Terminal automation requirements are being identified that would provide merging tools for controllers.



Advanced features such as RF path terminators allow for the design of procedures that deliver measurable benefits to those operators equipped to execute them.



RNAV-1 STAR connecting to SIAP

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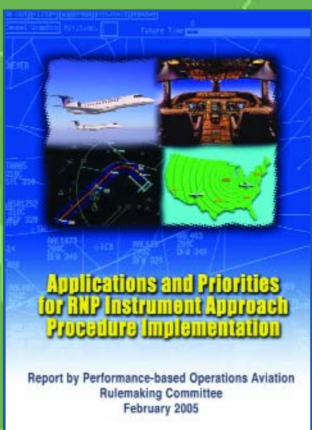
[3] Specifications for construction of LNAV/VNAV and LNAV approaches will soon be defined based on new and improved standards for RNP-0.3.

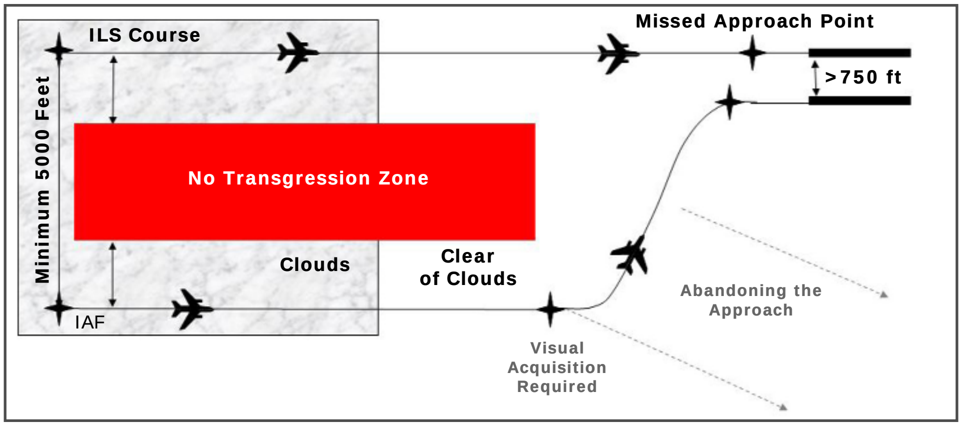
In response to industry interest in achieving a higher pace of implementation, the FAA is developing policy for delegating procedure development to the private sector.



A benefits-driven strategy for RNP SAAAR approach implementation

Photos Courtesy of the Boeing Company.

GLS will allow for Category II and III precision approaches to non-ILS runways where a suitable GBAS is available.



RPAT (Parallel Approach Transition) RNP will improve access to airports with parallel runways (separated by less than 4300 feet). RPAT applies during marginal VMC, when the airport acceptance rate is reduced due to discontinued use of parallel visual approaches.

RNP SAAAR instrument approaches permit de-confliction of operations between adjacent airports and allow better runway access. Busy terminal areas and airports with challenging terrain have the greatest need for this capability. The FAA is developing RNP SAAAR approaches to runways that require features such as RNP less than 0.3, RF legs, and precise, guided turns on the missed approach. For 2006, the FAA will publish at least 15 RNP SAAAR approaches, with another 15 in development. Starting in 2007, the FAA will publish at least 25 per year. Close collaboration between the FAA and industry will determine the priority of implementation sites. In addition, operators will retain the option of developing proprietary special procedures tailored to their own needs.

The FAA will also continue the evolution of the Ground-Based Augmentation System (GBAS)[4] for use in GNSS (Global Navigation Satellite System) Landing System (GLS)[5] approach operations to improve access in low-visibility conditions. GLS will allow Category I, II and III precision approaches to non-ILS runways where a suitable GBAS is installed. GLS will enhance efficiency and capacity by mitigating the need for critical area protection as is the case during ILS operations. It will also reduce the reliance on the aging ILS infrastructure. Non-federal GBAS installations and GLS approaches are expected in the near term.

Operators and manufacturers are pursuing the use of enhanced flight visibility systems (EFVS) to further improve runway access and evolve to “equivalent visual operations” in IMC. EFVS uses advanced sensor technology and head-up guidance systems to provide flight crews the performance necessary for approval to fly straight-in approaches from existing decision altitudes down to 100’ height above touchdown.

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[4]GBAS is a ground-based facility that provides local GPS corrections to onboard receivers. GBAS is currently an FAA research and development project. The FAA continues to make progress by resolving the integrity risks that pose the largest implementation challenges. By September 2006, the FAA's GBAS Office expects to complete the integrity analysis and embed improved integrity monitoring algorithms in a prototype system that will be used to enable industry compliance with ICAO Standards and Recommended Practices.

[5]GLS is a precision landing operation using GPS signals augmented by a GBAS. The system is intended to provide landing and taxi guidance capability for air carrier operations in low-visibility conditions.

Summary of Near-Term (2006-2010) Commitments

Implementation of Procedures

- Completion of RNAV SID and STAR procedures at the OEP 35 airports
- Approaches - at least 25 RNP SAAAR, 300 RNAV (GPS) with LNAV, LNAV/VNAV and LPV lines of minima per year
- 23 Q routes in 2006
- RNP-2 routes in en route
- Oceanic RNP combined with other capabilities for reduced separation minima
- T routes and lower MEAs
- RNP-1 SIDs and STARs
- Non-federal GBAS installations and GLS approaches

New Enabling Criteria and Standards

- Approval guidance and obstacle clearance criteria for basic RNP and advanced functionality
- RNP-1 SIDs and STARs
- RNP track separation for radar and non radar
- Parallel runway operations based on RNAV and RNP

Policy

- By 2008, issue rulemaking for RNAV and RNP mandates for the mid term
- Policy for delegation of authority to private sector for development of public procedures
- Policy for beneficial access and service to RNAV- and RNP-capable aircraft
- Policy for cancellation of conventional procedures

Requirements Analysis and Concept Development

- RNP operations in mixed environments
- Airspace and procedures supporting 3D, CDAs, and time of arrival control
- Flight plan filing and processing for RNP operations
- Terminal arrival merging tools enabling maximum benefits of RNAV and RNP
- Converging runway and closely-spaced parallel runway operations based on RNP
- Requirements for traffic flow management, dynamic rerouting, conflict probe of RNP routes, and enhanced surveillance
- Operational needs for lower RNP values
  - RNP<2 en route, RNP<1 terminal, RNP<0.3 approach

Mid Term (2011-2015) Priorities

In the mid term, increasing demand for air travel will continue to challenge the efficiencies of the air traffic management system. Nearly 900 million passenger enplanements are projected for 2011, increasing to one billion enplanements by the end of the mid term.

While the hub-and-spoke system will remain largely the same as today for major airline operations, the demand for more point-to-point service will create new markets and spur increases in low-cost carriers, air taxi operations, and on-demand services. Additionally, the emergence of VLJs is expected to create new markets in the general and business aviation sectors for personal, air taxi, and point-to-point passenger operations. As many as 2,500 VLJs are projected to be operating in the NAS by the beginning of the mid term. Many airports will thus experience significant increases in unscheduled traffic. In addition, many destination airports that support scheduled air carrier traffic are forecast to grow (e.g., Tucson and Palm Beach), and to experience congestion or delays if efforts to increase their capacity fall short. As a result, additional airspace flexibility will be necessary to accommodate not only the increasing growth, but also the increasing air traffic complexity.

The mid term time frame will benefit from opportunities resulting from modernized infrastructure. The En Route Automation Modernization (ERAM) program will be in place beginning in 2011, providing a platform for new capabilities. Flight planning and flight data processing will be improved to account for navigation capabilities such as RNP-2 and RNP-1 (or lower). Upgrades to the Center-TRACON Automation System Traffic Management Advisor and installation of the Standard Terminal Automation Replacement System will improve arrivals and departures at many airports. Traffic flow management modernization capabilities will facilitate the smooth flow of traffic even when resources are constrained. Airspace redesign will be based on procedures and standards using RNAV and RNP. Additionally, as a result of an increasingly well-equipped fleet in the inventory, capability to meet RNAV operations will reach nearly 90 percent.

The mid term will leverage these increasing flight capabilities based on RNAV and RNP, with a commensurate increase in benefits such as fuel-efficient flight profiles, better access to airspace and airports, greater capacity, and reduced delay. These incentives, which should provide an advantage over non-RNP operations, will expedite propagation of equipage and the use of RNP procedures. The FAA will offer beneficial access to RNP-2 routes and will introduce RNP-1 routes to improve flight efficiency.

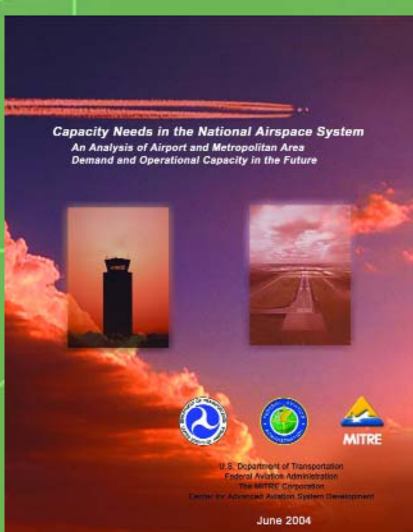
To increase the capacity of en route airspace, the FAA expects to mandate RNP-2 for operations at and above FL290 and RNAV-2 for operations at and above FL180 by the end of the mid term. In order to manage busy airport arrivals and departures safely and efficiently, RNAV-1 will be mandated for arrivals and departures at OEP airports by the end of the mid term. These mandates are needed to handle the increases in traffic demand and complexity, to relieve choke points, and to provide flexible routing options.

Concurrently, conventional routes and procedures meeting established policy for cancellation will be phased out during the mid term.

Airports needing additional capacity by the end of the mid term:

- Metropolitan Oakland International (OAK)
- Bob Hope (Burbank, CA) (BUR)
- Long Beach (LGB)
- John Wayne-Orange County (SNA)
- Tucson International (TUS)
- Albuquerque International Sunport (ABQ)
- San Antonio International (SAT)
- Houston Hobby (HOU)
- *Chicago O'Hare International (ORD)*
- *New York LaGuardia (LGA)*
- *New York Kennedy International (JFK)*
- *Newark Liberty International (EWR)*
- *Philadelphia International (PHL)*
- Palm Beach International (PBI)
- *Fort Lauderdale-Hollywood International (FLL)*

Airports in the OEP are italicized.



To achieve efficiency and capacity gains partially enabled by RNAV and RNP, the FAA and aviation industry will pursue use of data communications (e.g., for controller-pilot communications[6]) and enhanced surveillance functionality (e.g., ADS-Broadcast [ADS-B][7]). Data communications will make it possible to issue complex clearances easily and with minimal errors. ADS-B will expand or augment surveillance coverage so that track spacing and longitudinal separation can be optimized where needed (e.g., in non-radar airspace). Initial capabilities for flights to receive and confirm 3D clearances and time of arrival control based on RNP will be demonstrated in the mid term. With data link implemented, flights will begin to transmit 4D trajectories (a set of points defined by latitude, longitude, altitude, and time.) Stakeholders must therefore develop concepts that leverage this capability.

En Route Evolution

RNAV Operations

In the mid term, RNAV will continue to enable use of operator-preferred flight paths not tied to the location of ground-based NAVAIDs. RNAV-2 operations for flight in positive control airspace (i.e., at or above FL180) are expected to be mandated by 2015. This will enable airspace redesign and route optimization based on RNAV-2 operations. RNAV operations based on use of distance measuring equipment, inertial reference unit, and GPS are expected to continue through the mid term.

Where structure is needed for routing around and through busy terminal areas, the FAA will develop additional T routes serving low-altitude operators flying in close proximity to large airports. Where structure is not needed, these operators will fly direct routings.

Implementation of RNP

Currently, operations at and above FL290 comprise over 80 percent of en route operations in the NAS, and this traffic is expected to increase significantly during the mid term. RNP-2 operations in this airspace will enable better routing for managing en route efficiency. Airspace will be redesigned for RNP operations based on consistent, repeatable paths for improved throughput into en route airspace, primarily in the transition sectors from terminal airspace. By the end of the mid term the FAA expects to mandate RNP-2 capability for operations at or above FL290 to capture airspace benefits, permit fuel-efficient flight profiles, reduce controller workload, and improve capacity. Such a mandate would be driven substantially by the expected growth of airspace operations and the delivery of clear benefits that outweigh the costs.

NRR will support RNP routes that will extend from a departure waypoint (or “pitch” point) through the en route segment and terminate at an arrival waypoint (or “catch” point). These pitch and catch points will be more flexible and more numerous than today's departure and arrival fixes. As more operators take advantage of NRR, the use of the published route structure will decline. The completion of airspace redesign efforts and the expansion of NRR based on RNP will facilitate the elimination of conventional routes.

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[6]The FAA's data link efforts are currently focused on an imminent Investment Analysis Readiness Decision by the FAA's Executive Committee in September 2006, followed by a Joint Research Council (JRC) 2A scheduled for March 2007.

[7]The FAA's ADS-B Program recently completed JRC 2B. The next decision point is the JRC 2B scheduled for February 2007, which is the final investment decision for NAS-wide implementation.

By the end of the mid term other benefits of RNP will have been enabled, such as flexible procedures to manage the mix of faster and slower aircraft in congested airspace and use of low RNP values and narrow routing corridors to avoid convective weather or military use airspace. In addition, flexible RNP rerouting will be demonstrated as aircraft become capable of reroutes using fixed radius transitions and RF legs.

Automation for RNAV and RNP Operations

By the end of the mid term enhanced en route automation will allow the assignment of RNAV and RNP routes based upon specific knowledge of an aircraft's RNP capabilities. En route automation will use collaborative routing tools to assign aircraft priority, since the automation system can rely upon the aircraft's ability to change a flight path and fly safely around problem areas. This functionality will enable the controller to recognize aircraft capability and to match the aircraft to dynamic routes or procedures, thereby helping appropriately equipped operators to maximize the predictability of their schedules.

Conflict prediction and resolution in most en route airspace must improve as NRR usage increases. Path repeatability achieved by RNAV and RNP operations will assist in achieving this goal. Mid-term automation tools will facilitate the introduction of RNP offsets and other forms of dynamic tracks for maximizing the capacity of airspace. By the end of the mid term, en route automation will have evolved to incorporate more accurate and frequent surveillance reports through ADS-B, and to execute problem prediction and conformance checks that enable offset maneuvers and closer route spacing (e.g., for passing other aircraft and maneuvering around weather).

Oceanic Evolution

In the mid term, the United States will endeavor to work with international air traffic service providers to promote the application of RNP-10 and RNP-4 in additional subregions of the oceanic environment. The purpose is to achieve 50/50 and 30/30 NM separation minima between qualified aircraft with ADS-C and controller-pilot data link communication capabilities. This effort could yield a seamless oceanic standard across service provider boundaries. Benefits will include more direct, wind-efficient routings and greater flight path flexibility.

The FAA will also explore benefits and plans for implementing longitudinal/lateral separations below 30/30 NM. In addition, operator-preferred routes and dynamic rerouting will be expanded in the Pacific and implemented in the Atlantic.

Terminal Evolution

During this period, RNAV-1 will become a required capability for flights arriving and departing OEP airports. Specific OEP airport mandates will be based upon the needs of the airspace, such as the volume of traffic and complexity of operations. This will ensure the necessary throughput and access, as well as reduced controller workload, while maintaining safety during high traffic demand.

The FAA expects to employ RNAV-1 SIDs and STARs at many of the top 100 airports in the NAS, and at satellite airports located within busy terminal airspace. With RNAV-1 operations as the predominant form of navigation in terminal areas by the end of the mid term, the FAA will have the option of removing conventional terminal procedures that are no longer expected to be used.

RNP SIDs and STARs

RNP-1 SIDs and STARs will be implemented at the nation's busiest airports to provide efficient paths and optimal spacing of flows. RNP-1 SIDs will enable consistent, predictable flight tracks and additional egress routes for higher throughput to mitigate delays. RNP-1 STARs will connect to approaches using 3D operations and time of arrival control as appropriate to provide arrival efficiency. The aviation community will conduct trials that combine data link and enhanced automation capabilities to achieve improved strategic management for sequencing and spacing.

RNP SIDs and STARs based on lower RNP values will be introduced as necessary to achieve closer track spacing and efficiencies where aircraft capabilities exist. The FAA will pursue institution of curved parallel paths for both departures and arrivals in this time frame to achieve higher throughput and runway utilization at airports with parallel runways.

Terminal Automation

Terminal automation will be enhanced with tactical controller tools to manage complex merges in busy terminal areas. As data communications become available, the controller tools will apply knowledge of flights' estimates of time of arrival at upcoming waypoints, and altitude and speed constraints, to create efficient maneuvers for optimal throughput.

Terminal automation will also sequence flights departing busy airports more efficiently than today. This capability will be enabled as a result of RNP and flow management tools. Flights arriving and departing busy terminal areas will follow automation-assigned RNP routes.

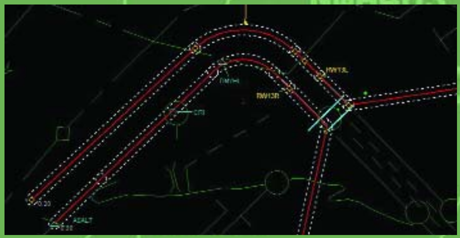
Approach Capability Evolution

In the mid term, implementation priorities for instrument approaches will still be based on RNAV and RNP. The FAA will continue to add approaches with LPV minima at a rate of 300 or more per year. As processes for developing approaches become streamlined or are delegated, the introduction of RNP SAAAR approaches will continue at a faster pace than in the near term, with at least 50 such approaches implemented per year. RNP SAAAR approach procedures will lay the foundation for reduced separation and will maximize throughput to parallel runways and converging runways.

To accomplish this, RNP SAAAR approach procedures will leverage enhanced surveillance capabilities. Flight deck automation that meets the requirements for aids to visual acquisition (e.g., cockpit display of traffic information with position/state information about proximate traffic) may be an option for this time frame.

Use of EFVS is expected to increase throughput as operators pursue additional taxi, take-off, and landing applications in conjunction with approach applications.

Development of public GLS approaches will lead to improved access and efficiency at airports without ILS.



Curved parallel RNP routes onto final approach.

Future ground-based tactical controller tools will assist the controller with compression management and merge points, to maintain efficient flow into the airport.

The FAA and industry are pursuing use of enhanced flight visibility systems to achieve "equivalent visual operations".

By end of mid term:

- *Mandate RNP-2 for operations at or above FL290*
- *Mandate RNAV-2 for operations at or above FL180*
- *Mandate RNAV-1 SIDs and STARs for arriving/departing OEP airports*

Summary of Mid-Term (2011-2015) Commitments

Implementation of Procedures and Airspace

- For domestic en route, RNP-2 required operations at and above FL290 at end of mid term
  - Lower RNP available where needed for benefit
- For domestic en route, RNP-2 available, RNAV-2 required operations at and above FL180 at end of mid term
  - Lower RNP available where needed for benefit
  - Enhanced automation incorporating aircraft navigation capabilities
- Oceanic RNP combined with other capabilities for reduced separation minima where beneficial, and increased use of operator-preferred routes in oceanic operations
- Additional T routes and lower MEAs
- For arriving and departing all OEP airports, RNP-1 SIDs/STARs available, RNAV-1 SIDs/STARs required at end of mid term
  - Controller tools for complex merges
  - Improved sequencing for arrivals and departures
- Airspace redesign and procedures for RNAV and RNP with 3D, CDA, and time of arrival control where beneficial and feasible
- At least 50 RNP approaches, 300 RNAV (GPS) approaches per year
- Development of public GLS approaches
- Closely spaced parallel and converging runway operations based on RNP
- Cancellation of conventional procedures meeting established policy (near-term)

Enabling Criteria and Standards

- Standards for integrated RNP, RSP, RCP
- Equivalent visual operations criteria

Policy

- Rulemaking for all mandates
- Enhanced flight visibility for takeoff, taxi, landing

Requirements Analysis and Concept Development

- Procedures and automation for integrating RNP, RCP, RSP
- Enhanced traffic flow management tools
- Procedures and automation for integrated flight planning, routing, sequencing

Far Term (2016-2025): Achieving a Performance-Based NAS

The far-term environment will be characterized by continued growth in air travel and increased air traffic complexity. For example, FAA forecasts suggest that in 2016 U.S. commercial air carriers will fly a total of 1.6 trillion aircraft seat miles and transport more than a billion passengers. Nearly 250 million passengers are projected to fly between the United States and the rest of the world, with the largest growth (averaging 5-7 percent annually) predicted in the Asian, Pacific, and Latin American markets. The hub-and-spoke system will probably remain the primary mechanism for transporting passengers in this time frame; however, as in the mid term, the demand for point-to-point service and on-demand air taxi service is expected to constitute an ever-increasing share of the total market. Socio-economic factors suggest that the majority of point-to-point services will be needed at satellite airports surrounding the busiest metropolitan airports. This growing segment of the market will likely be served by VLJs and regional jets. Forecasts for more than 200 metropolitan areas in the United States suggest that in this time frame more than 90 percent of the capacity at the OEP 35 airports will be used and numerous other airports will require additional capacity.

No one solution or simple combination of solutions will address the inefficiencies, delays, and congestion anticipated to result from the growing demand for air transportation. Therefore, the NAS needs an operational concept that exploits the full capability of the aircraft in this time frame and combines key performance-based elements (including RNP, RCP, and RSP) into a unified overall concept for achieving performance-based operations aligned with future goals of the JPDO.

The **key strategies** for instituting performance-based operations employ an integrated set of solutions.

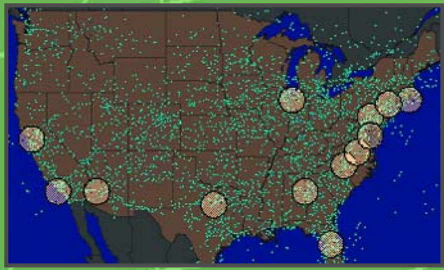
1. **Airspace operations will take advantage of advanced aircraft capabilities.**
   - ❒ Aircraft equipped with data communications, integrated displays, and FMS
   - ❒ Aircraft position and intent information directed to automated, ground-based problem resolution
   - ❒ Strategic and tactical flight deck-based separation assurance in selected situations, including problem detection and resolution[8]

2. **Strategic and tactical flow management will improve through use of NAS-wide, integrated airborne and ground information exchange.**
   - ❒ Ground-based system knowledge of real-time aircraft intent with accurate aircraft position and trajectory information available through data link to ground automation
   - ❒ Real-time sharing of NAS flight demand and other information achieved via ground-based and air-ground communication between air traffic management and operations planning and dispatch
   - ❒ Improved metering of traffic arriving and departing busy terminal areas

Airports expected to need additional capacity in the far term:

- ❒ Ontario International (ONT)
- ❒ *Las Vegas McCarran International (LAS)*
- ❒ *Chicago Midway International (MDW)*
- ❒ Birmingham International (BHM)
- ❒ *Hartsfield-Jackson Atlanta International (ATL)*
- ❒ Bradley International (BDL: Windsor Locks, CT)
- ❒ T.F. Green (PVD: Providence, RI)
- ❒ Long Island MacArthur (ISP)
- ❒ Metropolitan Oakland International (OAK)
- ❒ Bob Hope (Burbank, CA) (BUR)
- ❒ Long Beach (LGB)
- ❒ John Wayne-Orange County (SNA)
- ❒ Tucson International (TUS)
- ❒ Albuquerque International Sunport (ABQ)
- ❒ San Antonio International (SAT)
- ❒ Houston Hobby (HOU)
- ❒ *New York LaGuardia (LGA)*
- ❒ *Newark Liberty International (EWR)*

Airports in the OEP are italicized.



Numerous OEP airports will exceed their projected capacity in the far term.

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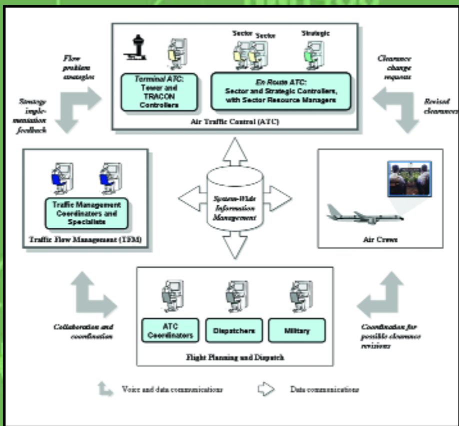
[8] Airspace employing this concept has been referred to as "autonomous" airspace.



System-wide integrated airborne and ground information exchange will improve strategic and tactical flow management.

Far-term strategies will leverage advanced flight deck automation and displays, taking advantage of the features of integrated CNS.

3. **Overall system responsiveness will be achieved through flexible routing and well-informed, distributed decision-making.**
   - System adapts rapidly to changing meteorological and airspace conditions
   - System leverages advanced navigation capabilities such as fixed radius transitions, RF legs, and RNP offsets
   - Increased use of operator-preferred routing and dynamic airspace
   - Increased collaboration between service providers and operators
4. **Operations at the busiest airports will be optimized through an integrated set of capabilities for managing pre-departure planning information, ground-based automation, and surface movement.**
   - RNP-based arrival and departure structure for greater predictability
   - Ground-based tactical merging capabilities in terminal airspace
   - Integrated capabilities for surface movement optimization to synchronize aircraft movement on the ground
   - Improved meteorological and aircraft intent information shared via data link

Elaboration of Key Strategies

Airspace operations in the far term will make maximum use of advanced flight deck automation that integrates CNS capabilities. RNP, RCP, and RSP standards will define these operations. Separation assurance will remain the principal task of air traffic management in this time frame. This task is expected to leverage a combination of aircraft and ground-based tools. Tools for conflict detection and resolution, and for flow management, will be enhanced significantly to handle increasing traffic levels and complexity in an efficient and strategic manner.

Strategic problem detection and resolution will result from better knowledge of aircraft position and intent, coupled with automated, ground-based problem resolution (nominally a 20-minute look-ahead time window for en route operations). In addition, pilot and air traffic controller workload will be lowered by substantially reducing voice communication of clearances, and furthermore using data communications for clearances to the flight deck. Workload will also decrease as the result of automated confirmation (via data communications) of flight intent from the flight deck to the ground automation.

With the necessary aircraft capabilities, procedures, and training in place, it will become possible in certain situations to delegate separation tasks to pilots and to flight deck systems that depict traffic and conflict resolutions. Procedures for airborne separation assurance will reduce reliance on ground infrastructure and minimize controller workload. As an example, in IMC an aircraft could be instructed to follow a leading aircraft, keeping a certain distance. Once the pilot agreed, ATC would transfer responsibility for maintaining spacing (as is now done with visual approaches).

Performance-based operations will exploit aircraft capabilities for “electronic” visual acquisition of the external environment in low-visibility conditions, which may potentially increase runway capacity and decrease runway occupancy times. Improved wake prediction and notification technologies may also assist in achieving increased runway capacity by reducing reliance on wake separation buffers.

System-wide information exchange will enable real-time data sharing of NAS constraints, airport and airspace capacity, and aircraft performance. Electronic data communications between the ATC automation and aircraft, achieved through data link, will become widespread—possibly even mandated in the busiest airspace and airports. The direct exchange of data between the ATC automation and the aircraft FMS will permit better strategic and tactical management of flight operations.

Aircraft will downlink to the ground-based system their position and intent data, as well as speed, weight, climb and descent rates, and wind or turbulence reports. The ATC automation will uplink clearances and other types of information, for example, weather, metering, choke points, and airspace use restrictions.

To ensure predictability and integrity of aircraft flight path, RNP will be mandated in busy en route and terminal airspace. RNAV operations will be required in all other airspace (except oceanic). Achieving standardized FMS functionalities and consistent levels of crew operation of the FMS is integral to the success of this far-term strategy.

The most capable aircraft will meet requirements for low values of RNP (RNP-0.3 or lower en route). Flights by such aircraft are expected to benefit in terms of airport access, shortest routes during IMC or convective weather, and the ability to transit or avoid constrained airspace, resulting in greater efficiencies and fewer delays operating into and out of the busiest airports.

Enhanced ground-based automation and use of real-time flight intent will make time-based metering to terminal airspace a key feature of future flow management initiatives. This will improve the sequencing and spacing of flights and the efficiency of terminal operations.

Uniform use of RNP for arrivals and departures at busy airports will optimize management of traffic and merging streams. ATC will continue to maintain control over sequencing and separation; however, aircraft arriving and departing the busiest airports will require little controller intervention. Controllers will spend more time monitoring flows and will intervene only as needed, primarily when conflict prediction algorithms indicate a potential problem.

More detailed knowledge of meteorological conditions will enable better flight path conformance, including time of arrival control at key merge points. RNP will also improve management of terminal arrival and departure with seamless routing from the en route and transition segments to the runway threshold. Enhanced tools for surface movement will provide management capabilities that synchronize aircraft movement on the ground; for example, to coordinate taxiing aircraft across active runways and to improve the delivery of aircraft from the parking areas to the main taxiways.

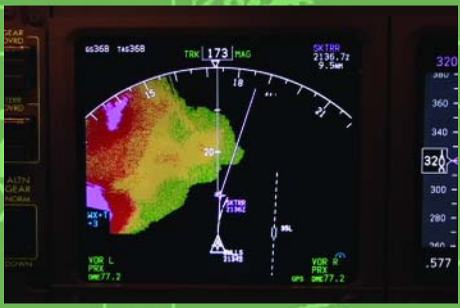
Key Research Areas

The aviation community must address several key research issues to apply these strategies effectively. These issues fall into several categories:

Navigation

- *To what extent can lower RNP values be achieved and how can these be leveraged for increased flight efficiency and access benefits?*
- *Under what circumstances should RNAV be mandated for arriving/departing satellite airports to enable conflict-free flows and optimal throughput in busy terminal areas?*

Continued improvements in instrument approach operations are expected through the far term as a result of using GLS to achieve approach minima equivalent to Categories II and III.



Better weather detection tools and RNP will allow accurate and reliable flight paths around weather, for more efficient operations.

Flight Deck Automation

- *What FMS capabilities are required to enable the future concepts and applications?*
- *How can performance-based communication and surveillance be leveraged in the flight deck to enable far-term strategies such as real-time exchange of flight deck data?*

Automation

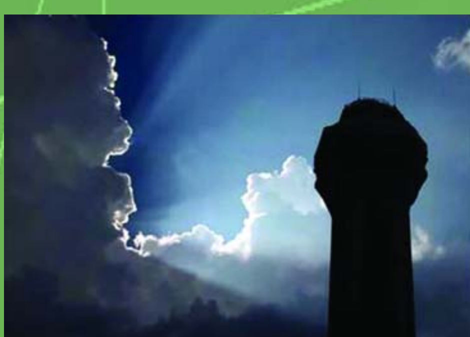
- *To what extent can lateral or longitudinal separation assurance be fully automated, in particular on final approach during parallel operations?*
- *To what extent can surface movement be automated, and what are the cost-benefit trade-offs associated with different levels of automation?*
- *To what extent can conflict detection and resolution be automated for terminal ATC operations?*
- *What are the situation awareness requirements for air traffic controllers in case of data link or other failures?*

Procedures

- *How can time of arrival control be applied effectively to maximize capacity of arrival or departure operations, in particular during challenging wind conditions?*
- *In what situations is delegation of separation to the flight crews appropriate?*
- *What level of onboard functionality is required for flight crews to accept separation responsibility within a manageable workload level?*

Airspace

- *To what extent can airspace be configured dynamically on the basis of predicted traffic demand and other factors?*
- *What separation standards and procedures are needed to enable smoother transition between en route and terminal operations?*



- *How can fuel-efficient procedures such as CDAs be accomplished in busy airspace?*

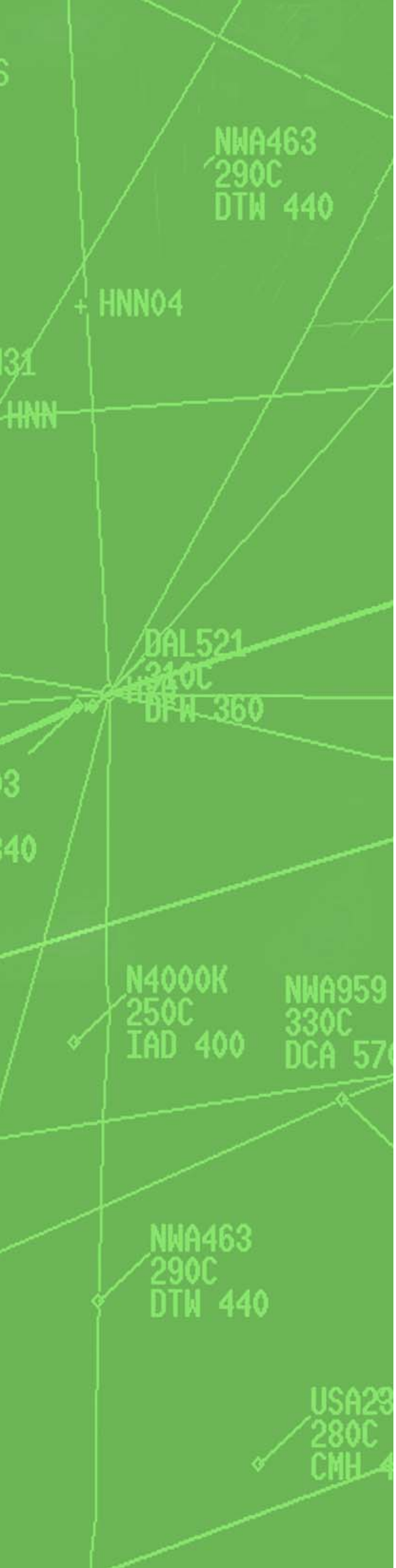
Policy

- *How is information security ensured as information exchange increases?*
- *What are the policy and procedure implications for increased use of collaborative decision-making processes between the service provider and the operator?*

The answers to these and other research questions are critical to achieving a performance-based NAS. Lessons learned from the near-term and mid-term implementation of the *Roadmap* will help answer some of these questions. The aviation community will address others through further concept development, analysis, modeling, simulation, and field trials. As concepts mature and key solutions emerge, the community will develop more detailed implementation strategies and commitments.

Glossary

3D	Three-Dimensional
4D	Four-Dimensional
ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
CDA	Constant Descent Arrival
CNS	Communications, Navigation, and Surveillance
EFVS	Enhanced Flight Visibility System
FAA	Federal Aviation Administration
GA	General Aviation
GBAS	Ground-Based Augmentation System
GLS	GNSS (Global Navigation Satellite System) Landing System
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
JCAB	Japan Civil Aviation Bureau
JPDO	Joint Planning and Development Office
JRC	Joint Research Council
LNAV	Lateral Navigation
LPV	Localizer Performance with Vertical Guidance
NAAT	North American Aviation Trilateral
NAS	National Airspace System
NAT	North Atlantic
NAVAID	Navigation Aid
NGATS	Next Generation Air Transportation System
NM	Nautical Miles
NRR	Non-Restrictive Routing
NRS	National Reference System
OEP	Operational Evolution Plan
PARC	Performance-Based Operations Aviation Rulemaking Committee



Glossary (concluded)

RCP	Required Communications Performance
RF	Radius-to-Fix
RNAV	Area Navigation
RNP	Required Navigation Performance
RNPSORSG	Required Navigation Performance and Special Operational Requirements Study Group
RSP	Required Surveillance Performance
SAAAR	Special Aircraft and Aircrew Authorization Required
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival
VLJ	Very Light Jet
VNAV	Vertical Navigation
WAAS	Wide Area Augmentation System