Roadmap for Performance - Based Navigation

Evolution for Area Navigation (RNAV) and Required Navigation Performance (RNP) Capabilities 2003 - 2020

July 2003
Version 1.0

U.S. Department
of Transportation
Federal Aviation Administration

Office of the Administrator

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

July 22, 2003

Dear Members of the Aviation Community:

I am delighted to present the Federal Aviation Administration's (FAA) *Roadmap for Performance-Based Navigation*, Version 1.0. The aviation community worked together for the past year to produce this Roadmap. By adopting performance-based navigation standards and leveraging existing and emerging navigation capabilities, we will be able to improve airspace design and air traffic procedures. This will let us increase access, reduce delays, and improve the efficiency of the National Airspace System.

We at the FAA are committed to moving to a performance-based system that produces the highest levels of safety and security. This system will have measurable capacity, efficiency, and environmental performance goals. Key parts of this performance-based system include communications, navigation, and surveillance. Thanks to the hard work of our employees and the aviation community, the FAA's new Required Navigation Performance Program Office now has the strategies it needs to implement the performance-based system for navigation. We will issue detailed strategies for other components as we develop them with the help of our domestic stakeholders and international counterparts.

The Roadmap defines operational goals and concepts, identifies steps and milestones to achieve those goals, presents key policy and technical issues we need to address, and outlines critical decisions we need to make along the way. It gives our stakeholders guidance to help them make business, equipage, maintenance, and training decisions consistent with the performance-based system.

We will update the specific implementation details in this Roadmap periodically as we learn from our current efforts, evaluate the effectiveness of our decisions, and incorporate the work of the Joint Planning Office on the development of a long-term national air transportation plan.

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

Marion C. Blakey
Administrator

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Introduction

Over the past two decades, air-traffic growth in the National Airspace System (NAS) has outpaced airport and airspace capacity. Recent successful implementation of the Federal Aviation Administration's (FAA) Operational Evolution Plan (OEP) commitments such as Free Flight Phase 1 and National Airspace Redesign continue to enhance airport and airspace capacity and to improve operator and service provider efficiencies.

Air transportation plays an essential role in our nation's economy and security and is expected to continue its historical pattern of growth. In 2001, 486.3 million passengers enplaned at the 32 large hub airports. Current projections show enplanements at these airports increasing by 68 percent to 818.5 million passenger enplanements by the year 2020. Furthermore, general aviation operations remain at a healthy level in the United States and are expected to grow in the future, while business aviation has increased recently with the expanding use of corporate jets for business travel. The projected increase in passengers and aviation activity will further strain a system that, prior to September 11, was already near full capacity. Increasing capacity and efficiency in the NAS will be critical to accommodating the expected growth over the next two decades.

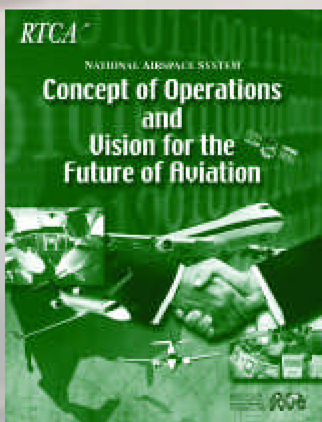
Constraints in en route airspace and the airspace surrounding U.S. and international airports often adversely impact air transportation and result in flight delays, schedule disruptions, passenger and operator inconveniences, and inefficient flight operations. What is needed is a set of solutions that leverage current and evolving capabilities in the near term and that can be expanded to address the future needs of NAS stakeholders and service providers.

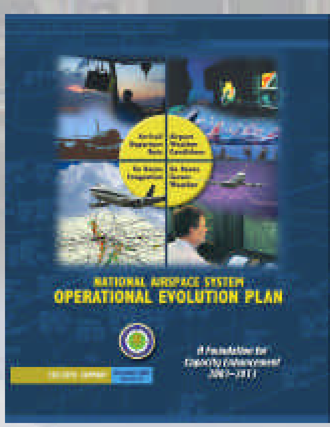
No one solution or simple combination of solutions will allow the aviation industry to continue to expand services safely and minimize environmental impacts in the face of these challenges. The aviation community needs to integrate viable and affordable solutions to move towards a performance-based NAS–one based on the highest safety and security performance goals with measurable and validated capacity, efficiency and environmental performance expectations.

Increasingly, the aviation community is defining concepts and applications based on performance standards and metrics, rather than specific technologies and equipage configurations. Among these performance-based concepts are area navigation (RNAV), Required Navigation Performance (RNP), Required Communication Performance (RCP), and Required Surveillance Performance (RSP). These concepts define specified levels of performance, functionality and capability as agreed-upon standards. The purpose is to facilitate more efficient airspace and procedure design and to improve safety, access, capacity and operational efficiencies. RCP and RSP are still emerging concepts in the developmental stages. On the other hand, the aviation community is broadly adopting RNAV and RNP—key components of performance-based navigation. Other key components in performance-based navigation are procedures and airspace redesign.

Air transportation plays an essential role in our nation's economy and security, and is expected to continue its historical pattern of growth. For example, commercial passenger enplanements are forecasted to increase by nearly 70 percent by the year 2020.

The aviation industry and the FAA worked together to develop this *Roadmap for Performance-Based Navigation* as part of a collaborative effort that included aircraft and avionics manufacturers, airlines, business and general aviation, research organizations and the Department of Defense (DOD). Joint government/ industry groups such as the Terminal Area Operations Aviation Rulemaking Committee (TAOARC) and the RTCA Free Flight Steering Committee provided recommendations for strategic direction, operational concepts, implementation priorities, and regulatory action.





For the purposes of the *Roadmap*, we define performance-based navigation as navigation along a route, in a procedure or in airspace within which the aircraft operating must comply with specified performance requirements. This is a fundamental shift from a navigation paradigm that specifies equipment types and technologies.

The FAA is adopting a performance-based navigation strategy that has three key features:

- Expediting the development of enabling performance-based navigation criteria and standards, and implementing airspace and procedure improvements in the near term. Implementation will leverage the large base of qualified aircraft.
- Continuing support of conventional procedures during a transition period allowing operators time to evaluate their business cases for retrofit and new aircraft acquisitions.
- Establishing target dates for the introduction of performance-based navigation for selected airspace, routes and procedures.

It is in this context that the FAA and industry have developed this *Roadmap*, which is consistent with the RTCA's *NAS Concept of Operations*, aligned with the *FAA Strategic Plan* and *Operational Evolution Plan*, and takes into account the results of additional FAA programs to expedite benefits to operators and service providers.

The *Roadmap* divides the implementation timetable into three planning periods: the near term is between 2003 and 2006; the mid term is between 2007 and 2012; and the far term is between 2013 and 2020. For each time period there is a description of operational capabilities for the following phases of flight: en route, oceanic, terminal and approach procedures.

The FAA and industry will update this *Roadmap* periodically based on the evolution of aircraft capabilities, lessons learned and key decisions. Future versions will document more detailed plans for the mid- and far-term implementations; while maintaining the overall strategy and vision of this version.

Key Terms and Concepts

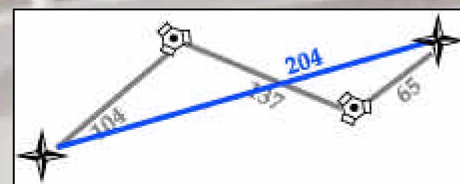
Before presenting the performance-based navigation strategy, it is important to define a set of key terms and concepts. Over the past two decades, various forums and standards organizations (e.g., International Civil Aviation Organization [ICAO], RTCA, FAA, EUROCONTROL) have developed a number of terminologies, some of which have served to articulate concepts in broad terms whereas others have served to specify detailed functional requirements and standards. The aviation industry broadly recognizes that there is a need to harmonize these terminologies to ensure successful implementation of an international performance-based navigation strategy.

The FAA is implementing two concepts—RNAV and RNP—that pertain to certain NAS operations conducted under Instrument Flight Rules (IFR), but are not required for operations conducted under Visual Flight Rules (VFR) in any airspace. The FAA and industry will document, via standards publications, the airworthiness and operational approval requirements for RNAV and RNP within designated airspace or along designated routes.

This *Roadmap* defines RNAV and RNP as follows:

RNAV: A method of navigation that enables aircraft to fly on any desired flight path within the coverage of referenced navigation aids (NAVAIDS) or within the limits of the capability of self-contained systems, or a combination of these capabilities.[1] Routes and procedures using RNAV provide improved access and flexibility through point-to-point navigation and are not restricted to the location of ground-based NAVAIDS. The target level of safety is achieved through a combined use of aircraft navigation accuracy, radar monitoring, automatic dependent surveillance (ADS) and/or additional separation buffers. Examples of systems used for RNAV operations today are Flight Management Systems (FMS) and panel-mount IFR Global Positioning System (GPS).

RNP: RNAV operations with navigation containment and monitoring. A critical component of RNP is the ability of the aircraft navigation system to monitor its achieved navigation performance and to identify whether the operational requirement is not being met during an operation. Some aircraft already have this monitoring capability as part of their RNP demonstration. RNP capability of the aircraft is a major component in determining the separation criteria to ensure that the target levels of safety are met; this is a distinguishing feature that RNP capability provides. RNP-*x* capability is applied to a route, procedure or airspace which requires the aircraft to remain within +/- *x* nautical miles laterally from the track centerline. The lateral containment requirement is 2xRNP or less depending on the operation.[2] Examples of RNP systems are FMSs that have real-time RNP monitoring tied to the operational requirement or IFR GPS for RNP-2 en route operations, RNP-1 terminal operations and certain RNP-0.3 approaches.



RNAV and RNP (point-to-point navigation) are key components of performance-based navigation.

Graphic provided courtesy of Alaska Airlines.

RNP-x capability is applied to a route, procedure or airspace which requires the aircraft to remain within +/-x nautical miles laterally of the track centerline, and potentially in other dimensions as the specifications for RNP evolve.

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[1] ICAO Doc 9613 Manual on Required Navigation Performance (RNP).

[2] Performance requirements for longitudinal, vertical and time will be defined in standards publications and later versions of this *Roadmap*.

RNAV and RNP provide benefits to airspace operators and service providers in the areas of safety, access, capacity, predictability, efficiency and environmental impacts. For example, continuous descent approach procedures enabled by RNAV and RNP at many airports will reduce the risk of controlled flight into terrain (CFIT) accidents.

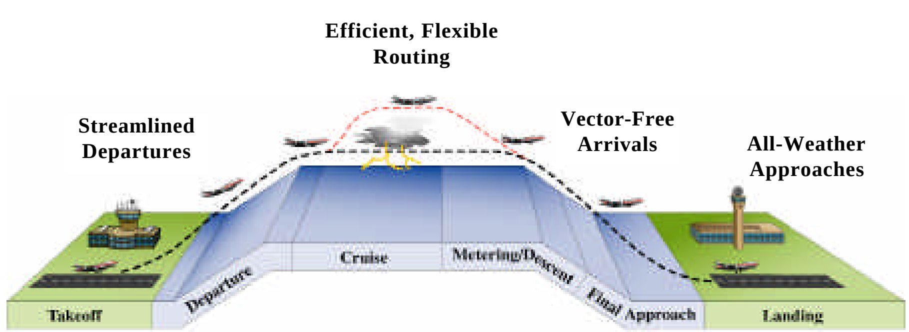
Benefits of Performance-Based Navigation

The benefits of performance-based navigational capability are safety, access, capacity, predictability, efficiency and environmental impacts. Current airspace design and utilization are a result of several contributing factors, including the location of ground-based NAVAIDS and conventional navigation methods, i.e., navigating from one very high frequency (VHF) omni-directional range (VOR) to another. These conventional navigation methods lead to less efficient routes, procedures and airspace. Inefficiency also is driven by large airspace separation buffers that are required to mitigate the operational risks due to inaccuracies associated with conventional navigation methods.

Once operators and controllers are fully equipped and sufficiently trained for performance-based navigation, the FAA will redesign airspace to increase capacity and improve operational efficiencies. With automation and other infrastructure improvements, such as automatic dependent surveillance-broadcast (ADS-B) and tools that permit controllers to optimize new airspace design through improved sequencing and traffic management, we expect synergistic benefits to accrue.

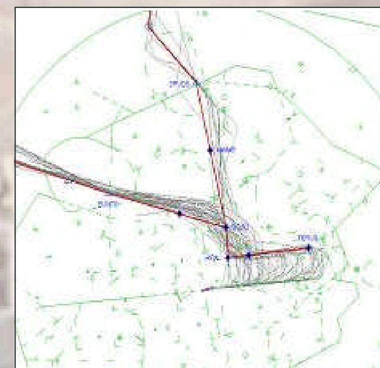
Performance-based navigation benefits apply to airspace operators and service providers alike. Performance-based navigation will:

- ❐ **Increase safety** through continuous descent procedures that reduce the risk of **controlled flight into terrain (CFIT) and loss of control**. Predefined RNAV and RNP procedures enhance confidence and consistency and reduce the risk of communication errors.
- ❐ Improve **airport and airspace access** in all weather conditions and the ability to meet environmental and obstacle clearance constraints through the application of optimized RNAV-based flight tracks. The result will be reduced lateral separation criteria and more accurate path keeping.
- ❐ Enhance reliability, repeatability and predictability of operations, leading to increased **throughput.** More precise arrival, approach and departure procedures will reduce dispersion and facilitate smoother traffic flows.
- ❐ Increase **schedule reliability through more consistent** access and throughput in all weather conditions.
- ❐ **Reduce delays** at airports and in certain dense airspace through the application of new parallel routes; newly enabled ingress/egress points around busy terminal areas; improved flight re-routing capabilities, making better use of closely spaced procedures and airspace; and de-conflicting adjacent airport flows.



- Increase **efficiency** through less circuitous routes and optimized airspace, especially in lower flight altitude stratums.
- Enable **flexible routes** such as wind-optimal and great circle routes when beneficial.
- Promote design and use of **environmentally beneficial arrival and departure procedures** that allow the aircraft systems (FMS) to manage flight performance (climb, descent, engine performance, etc.). Benefits include reduced fuel emissions and environmentally-tailored noise footprints.

Moving forward with a performance-based navigation strategy offers a variety of opportunities to realize benefits for the user community. Many of these benefits can and must be realized in the near term, leveraging sufficient levels of aircraft and automation capabilities in certain airspace.



PHL RNAV STARs

- ***A/G Communications reduced by 30 percent to 50 percent***
- ***Average Time Savings: 2 minutes - 4 minutes per flight***
- ***Average Distance Savings: 13 - 15 nmi***

Implementation of Performance-Based Navigation

In this *Roadmap*, we organize the three time frames for implementation of performance-based navigation as follows: near term (2003-2006), mid term (2007-2012) and far term (2013-2020).

For each time frame, we describe operational capabilities for the following phases of flight: en route, oceanic, terminal and approach procedures. Gate-to-gate performance-based navigation spans all phases of flight.

Near Term (2003-2006)

The near term will mark a beneficial change in operations as the FAA implements a first set of public RNAV and RNP procedures in all phases of flight. Also in the near term, the FAA will continue to develop enabling criteria and guidance for more advanced RNAV and RNP operations.

LAS RNAV STAR

* *Average distance savings 25 - 30 nmi*
* *Procedure ingress free from location of ground base NAVAIDS*

En Route Operational Capabilities and Milestones

In the domestic en route environment, the FAA will publish the first RNAV routes based on a series of waypoints that are charted and included in navigation databases (aircraft and ground system). These designated Q routes will provide flexibility and efficiency in the airspace.

The FAA will develop new separation criteria for RNP-2 routes in 2005. These criteria are to be applied to Q routes and will leverage RNP-2-capable aircraft and operator capabilities with the goal of reduced en route separation standards and modified surveillance requirements. The FAA will convert Q routes to RNP-2 and will initiate reduction of route spacing where operationally feasible by the end of 2006. Conventional (non-RNAV) routes and procedures will continue to be available.

En Route Parallel Offsets Opportunities

* *Improved en route trajectories and aircraft efficiencies*
* *Reduced in-trail restrictions*
* *Reduced departure delays*
* *Reduced block times for users (taxi-out and en route)*
* *Reduced workloads and improved situational awareness for controllers and pilots*
* *Greater access to the overhead streams*

Also during the near term, en route air traffic control (ATC) facilities will use flight management computer (FMC) offsets—procedures flown in parallel from assigned routes—for flight efficiencies. The FAA is conducting offset trials at Houston, Minneapolis and Albuquerque to fully understand operational capabilities and issues and to collect data for the purposes of enabling future tactical passing maneuvers and weather avoidance.

For IFR operations from the surface to FL 180 (including in Class B airspace), the FAA will publish new RNAV transition routes and lower minimum en route altitudes (MEAs) at or above the minimum obstruction clearance altitude (MOCA). Operators need lower MEAs where icing and other weather constraints are prevalent, and where they prefer lower altitudes (i.e., helicopters, general aviation and regional operators).

Oceanic Operational Capabilities and Milestones

In the Pacific Oceanic region today, the FAA requires RNP-10 for all aircraft operating on the Pacific Organized Track System (PACOTS), the Central East

Pacific (CEP) routes and the North Pacific (NOPAC) tracks.[3] Use of RNP in this airspace today safely provides routing efficiency and flexibility to operators, as well as 50 nautical mile (NM) separation standards that improve capacity. The Pacific Oceanic airspace is not technically exclusionary (i.e., non RNP-10 aircraft may file via random track, at any altitude, at least 100 NM from any CEP, PACOTS or NOPAC track); however, access is limited around these RNP tracks.

Following the implementation of 50 NM of lateral separation, starting with the South Pacific region, the implementation of RNP-4 will achieve additional reductions in lateral and longitudinal separation. The implementation of this more stringent RNP capability, as well as other communications, navigation and surveillance (CNS) elements, is part of a worldwide ICAO-coordinated effort to improve air traffic management (ATM) and CNS services.

In the North Atlantic (NAT) oceanic region, minimum navigation performance specification (MNPS) will continue in the near term. This performance capability requirement is equivalent to RNP-12.6. Application of RNP-4 for NAT MNPS is under study.

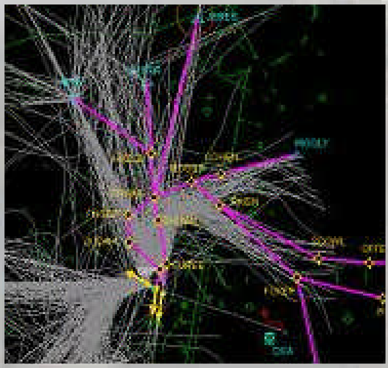
Terminal Operational Capabilities and Milestones

Usage of RNAV and RNP in the terminal domain optimizes airspace design through better use of arrival and departure corridors. Relocation of ingress and egress points without reliance on locations of ground-based NAVAIDS increases throughput. Standard terminal arrival (STAR) and standard instrument departure (SID) procedures applying RNAV and RNP improve safety, capacity and flight efficiency. These procedures reduce the risk of communication errors for pilots and controllers and take advantage of 3D flight management by the aircraft system. These are the goals of the terminal capabilities and milestones described in this section.

Initially, the FAA will design RNAV procedures by overlaying historical vector patterns and existing conventional (ground-based) procedures. Although not operationally optimal, these overlays will aid in the transition to non-overlay RNAV procedures. The FAA will implement non-overlay procedures in conjunction with airspace redesign (e.g., Potomac terminal) for more flexible and efficient terminal operations.

During 2004, the FAA will publish selected RNP-2 and RNP-1 SIDs and STARs where aircraft capabilities and benefits exist. Additionally, they will publish approximately 30 of these procedures annually during 2005 and 2006. The aviation community is currently engaged in an effort to prioritize these procedures and develop achievable implementation timetables. Examples of some early opportunities are shown in the following table.

Initially, RNAV procedures will be designed as "overlays" which are tracks aligned with historical vector patterns and in some cases existing procedures.



IAD RNAV Departure

* ***Enables simultaneous independent departures during instrument meteorological conditions.***

[3] 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. In order to be qualified as RNP-10 capable, operators are required to obtain an approval by State of registry or State of operator, as defined in FAA Order 8400.12. All RNP-10 approved aircraft entering the Oakland FIR must file an "/R" equipment suffix in their ICAO flight plan in accordance with ICAO Doc. 4444, Appendix 2, provided they will maintain RNP-10 eligibility for the entire route segment within the Oakland FIR.

Terminal RNAV Opportunities	Operational Benefits
Dulles SIDs	Enables simultaneous independent parallel departures during instrument meteorological conditions (IMC).
Dallas-Ft. Worth SIDs	Enables increased departure rates via multiple departure posts and increased runway usage. Reduces ground congestion and improves taxi-out times.
Las Vegas STARs	Improves en route times through reduced mileage. Improves ATC/pilot workload via reduced communications, and improves predictability and aircraft efficiency in the terminal.
Newark SIDS	Enables improved access to departure gates via reduced interactions with adjacent airports. Increases departure throughput through predictable course divergence (fanning). Improves taxi-out times and reduces ground congestion and potential for gridlock.
Charlotte SIDs and STARs	Enables more reliable and predictable flight tracks, and additional ingress/egress points.

Optimize Departure Operations

DFW RNAV Departures

* ***Increased throughput by 20 percent***
* ***Better use of runways***
* ***Airspace and procedures not reliant on location of NAVAIDS***
* ***Multiple departure gates***

Aircraft without RNAV capabilities will continue to be served by conventional (non-RNAV) SID and STAR procedures, as well as radar vectoring, throughout the near-term period.

Approach Operational Milestones

For the approach segment, the FAA has committed to providing vertically-guided approaches to all runway ends that support IFR operations.[4] New and modified procedures will apply techniques such as offset final approach course, step-down fixes, varying angles of descent, and linear obstacle clearance surfaces. These procedures will mitigate obstacle and environmental constraints at certain locations and lower existing minima, in particular for the more maneuverable Category A and B aircraft.

The FAA will develop new approaches with vertical navigation (VNAV) guidance at certain airports or runways where no instrument approach exists, reducing the risk of CFIT and providing access during IMC.

For certain sites, opportunities exist for lower RNP values and for approach and missed-approach paths that are not straight in and straight out. Operators will apply these procedures where needed to avoid obstacles or airspace along the approach or missed-approach area. Because these approach features apply to certain operators and not to others, their application is limited to those locations where aircraft capabilities exist and where benefits can be realized. These will provide benefits for any operator that satisfies the special aircrew and aircraft authorization required (SAAAR).

[4]Commerical Aviation Steering Team Plan, 2002.

A key milestone for this *Roadmap* is the implementation of the RNP Parallel Approach Transition (RPAT). This RNP application will improve access to airports with parallel runways (separated by 4300' or less). RPAT applies during marginal visual meteorological conditions (VMC), when the airport acceptance rate is reduced, due to discontinued use of simultaneous independent parallel approaches. The FAA will implement RPAT at seven airports by 2005, with a target roll-out schedule of three sites in 2004 and the remaining in 2005.

In the table below, we summarize operational goals and implementation dates for RNAV and RNP approaches, examples of specific operational restrictions, and approach applications to solve those restrictions. Usage of RNAV (GPS), and VOR and non directional beacon (NDB) approaches also will continue in the near term.

The FAA designed the implementation of the RNP approaches described earlier using linear performance-based obstacle clearance surfaces. They also will implement performance-based approaches with angular obstacle clearance surfaces. The primary motivations for angular performance criteria are: consistency with Instrument Landing System (ILS) performance; the possibility to achieve tighter approach paths where obstacles exist along an approach segment; and the need to achieve a suitable aim point for touchdown on the runway (see table on next page).

RPAT can reduce the impact of marginal weather on arrival rates.

Airport	Potential Arrival Rate Increase (Aircraft/Hour)
Boston, MA	24
Cleveland, OH	10
Newark, NJ	21
Portland, OR	20
Philadelphia, PA	12
Seattle, WA	14
San Francisco, CA	20

- ***Applicable at airports with closely spaced runways***
- ***Beneficial during marginal weather conditions (5-20 percent occurrence at airports in table)***
- ***Does not require precision runway monitor (PRM)***

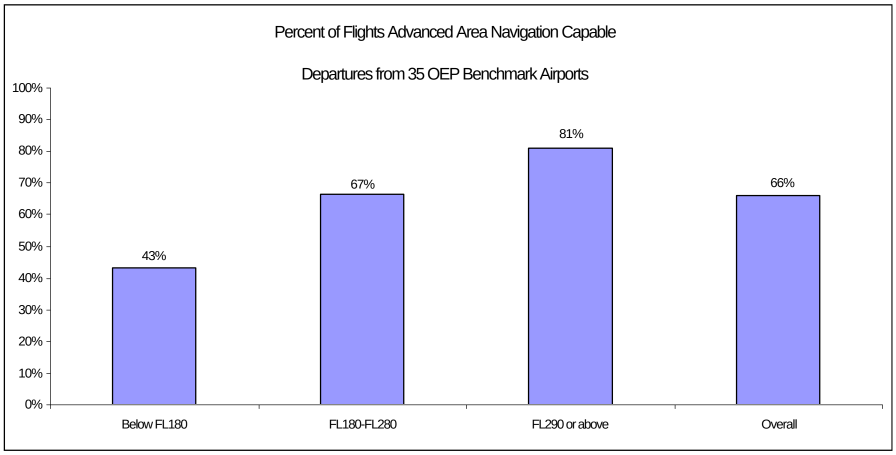
Operational Goals and Implementation Dates	Examples of Specific Operational Restrictions	RNAV and RNP Solutions
Better ACCESS and SAFETY at major airports with terrain/obstacles. **Date of First Application: 2004**	Washington Dulles' Runway 30 is only accessible through a circle-to-land procedure and constrained by airspace 4 miles east designated for arrivals into Washington National. This problem is exacerbated by a new 300' ATC tower being installed.	New instrument approach procedures using other than straight-in path segments to improve access and enhance safety.
Better ACCESS and FLIGHT EFFICIENCY at major airports with environmental constraints. **Date of First Application: 2004**	Boston's Runway 4L is accessible only through a tight circle-to-land procedure not feasible with transport and regional jets. Philadelphia's Runway 35 is constrained by airspace due to environmental considerations.	New instrument approaches using other than straight-in path segments, and narrow RNP segments with VNAV to avoid noise-sensitive airspace and to streamline arrivals.
Improved EFFICIENCY through better handling of mixed performance aircraft. **Data of First Application: 2005**	Boston general aviation (GA) arrivals to the north during IMC are not able to take advantage of Runway 33R due to lack of an appropriate instrument approach.	New RNAV approaches for GA to shorter runways at busy airports.
Better ACCESS and CAPACITY at major airports with converging runways. **Date of First Application: 2005**	Pittsburgh and Chicago O'Hare have existing converging runway operations limited by high minima due to conflicting missed-approach paths.	Missed approach procedures with RNP values <1 improve minima and access during IMC.
Better EFFICIENCY at major airports with conflicting traffic flows. **Date of First Application: 2006**	Newark and LaGuardia have approaches to runways constrained by adjacent traffic flows and airspace. Chicago O'Hare departures are constrained by the approach path into adjacent Midway airport, causing departure delays.	RNP with narrower paths (RNP<.3) for traffic and airspace de-confliction. Other than straight-in path to final approach course inside the final approach fix at Midway for de-confliction with O'Hare traffic and improved departures.

Operational Goals and Implementation Dates	Examples of Specific Operational Restrictions	RNAV and RNP Solutions
Better ACCESS and CAPACITY at airports during outages of ILS and other NAVAIDS. **Date of First Application: 2004**	Long Beach, CA, has only one instrument runway, where the ILS is planned to be out of service. RNAV approach is lateral navigation (LNAV) only with high minima.	Narrower path and vertical guidance with RNP improves safety and access during ILS outage.
Improved ACCESS to satellite and secondary airports constrained by terrain, airspace and traffic flows. **Date of First Application: 2004**	Numerous satellite and secondary airports have RNAV approaches with minima tailored for maneuverable aircraft (Category A/B).	Vertically guided approaches with tailored angles of descent for lower minima for Category A and B aircraft operations, and improved vertical accuracy for lower minima and improved access. Use of step down altitudes for improved minima for Category A and B airplanes on LNAV-only approaches.
Better ACCESS and SAFETY at airports with terrain/obstacles. **Data of First Application: 2005**	Roanoke, VA, has existing RNAV approaches to Runways 6 and 24, and ILS to Runway 33 has very high minima due to terrain. Buffalo, NY, has Runways 5 and 23 with straight-in minima that are high due to terrain. Burlington, VT, has an existing RNAV approach to Runway 33 with high minima due to terrain and no vertical guidance.	RNP with VNAV using narrow path down the valley and/or an offset final approach course that could be flown by all and would particularly benefit the target operators (GA). Narrower RNP path to improve minima and access. Vertical guidance for improved safety. RNP with VNAV and/or curved path segments for improved access.
Improved EFFICIENCY and traffic management through improved predictability and repeatability in ground tracks. **Date of First Application: 2005**	Portland, ME, has a visual approach to Runway 29 that is constrained to avoid over-flight or environmentally sensitive areas. State College, PA, has an existing RNAV approach to Runway 6 (needed for certain wind conditions) that lacks vertical guidance and has very high minima.	RNP or RNAV approach to improve repeatability of ground tracks and improve noise abatement. Curved path segments to overlay existing visual approaches. RNP with VNAV using narrow-path and/or curved segments could mitigate obstacle and improve access.

Usage of ILS for precision approaches and the lowest possible minima will continue in this timeframe. The FAA may introduce public-use Category I instrument approach procedures using Local Area Augmentation Systems (LAAS) at a limited number of airports towards the end of the near term.

Transition Opportunities and Challenges

In the near term, the aviation community is faced with a mixed capability environment. In today's NAS, aircraft departing from the 35 OEP benchmark airports (see figure on next page) a mixture of two-thirds RNAV capable and one-third non-RNAV capable. Based on the current aviation economic condition, additional investments in avionics capabilities by many operators will not be forthcoming in the immediate future, except to the extent that they are included as standard equipment on new aircraft. As a result, a mixture of RNAV and non-RNAV capability will continue for several years. Starting in the mid term, aircraft capability enhancements by various operators may resume, especially as they formulate business cases and strategies based on benefits.



The situation faced in the near term, however, presents opportunities as well as challenges. There are opportunities to provide benefits to those aircraft owners and operators who have invested in advanced capabilities and training and who expect to participate in new procedures. Those operators with less capability will not realize these specific benefits but will continue to enjoy their current level of service.

A mixed-aircraft capability environment remains a challenge that the community will need to address in its transition strategy for the far term. The FAA and industry must assess global differences in air traffic operations, ground infrastructure, and services in terms of their effect on standardization of aircraft capability. They need a consensus on how to achieve operationally feasible airspace and procedure solutions when and where mixed equipage exists. The FAA is committed to providing benefits to operators who are capable of performance-based navigation without adversely impacting non-capable operators. This involves ongoing benefits, trade-offs and policy considerations.

A mixed aircraft capability environment remains a challenge that the community will need to address in its transition strategy for the far-term.

Near Term Transition Considerations

In moving forward with the operational goals in the near term, the aviation industry will need to address key transition considerations, as follows:

- How to expedite procedure implementation to accrue benefits to those segments properly equipped?
- What are the key criteria, standards and guidance needed for the propagation of these procedures in the NAS?
- What are the near-term international harmonization issues that need to be addressed?
- What are the expected benefits and how are they related to the percentage of equipage needed for implementation?

A number of operators have offered to collaborate with the FAA to help expedite the implementation of these procedures. Some have offered to initially implement limited procedures so as to gain operational experience and to optimize implementation. These procedures will enable FAA development of NAS-wide implementation guidelines, criteria and standards.

Implementation Methods

In expediting implementation of procedures in the near term, the FAA will collaborate with the operators to employ the following implementation methods and approvals for expediting user benefits. The intention is to reach broad application of public procedures across the NAS in all flight phases. These methods and approvals are defined below and apply to en route, terminal and approach operations:

- *Public procedures* are FAA approved and maintained procedures through enabling FAA orders, Advisory Circulars (ACs) or guidance. Public procedures are available to all qualified operators at an airport or for a segment of airspace and apply to all phases of flight.
- *Special* instrument flight procedures for en route, terminal and approach operations are approved by the FAA for certain operators but are not published in Title 14 of the Code of Federal Regulations (CFR). Special procedures must meet the equivalent level of safety to public procedures.
- *Convertible Specials* are those special instrument-flight procedures developed for certain operators according to 14 CFR standards intended for conversion into public procedures. Through joint effort, the FAA, the proponent for a particular procedure and other stakeholders will develop these convertible specials according to FAA guidelines for conversion from a special into a public procedure.
- *Special Aircrew and Aircraft Authorization Required* (SAAAR) is a method of FAA approval for instrument flight procedures that requires special aircraft equipment and/or crew training and procedures. SAAAR requires that operators receive FAA approval through a specified process, which is similar to ILS Category II/III authorizations. These higher levels of equipage and overall operator performance are the basis for expanded RNP capability.

Enabling Criteria, Standards and Guidance Milestones

To implement performance-based navigation throughout the NAS, FAA and industry need to develop a set of streamlined processes, enabling criteria, standards and guidance. Ultimately, these enabling materials will facilitate the proliferation of public procedures. The FAA already has established some of these criteria, while others are under development:

- *FAA AC 120-29A, "Criteria for Approval of Category I and Category II Weather Minima for Approach."* Criteria for air carriers to obtain and maintain approval of operations in Category I and II Landing Weather Minima including the installation and approval of associated aircraft systems. It includes Category I and II criteria for use in conjunction with RNAV, RNP, VNAV, and satellite navigation systems. GA operators will find this guidance in CFR Part 97.
- *FAA AC 90-RNP, "Operational Approval for RNP."* Guidance for obtaining RNP approvals for use by operators, their principal operating inspectors, and approval authorities. This document is due for publication by 2004.

- *RTCA DO-283, "Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation,"* and *RTCA DO-236a, "Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation."* Standards for RNP implementation in all three time frames of this *Roadmap*, as determined by user needs, benefits or mandates. The FAA will use criteria from these standards to develop appropriate advisory and guidance materials such as AC 90-RNP. These standards will evolve over time as operational requirements change.
- *FAA Order 8260.48, "Area Navigation (RNAV) Approach Construction Criteria."* Criteria for developing instrument approach procedures for area navigation including VNAV. The FAA will develop additional criteria to include linear and SAAAR criteria by the end of February 2004.
- *FAA Order 8260.51, "Required Navigation Performance (RNP) Instrument Approach Procedure Construction."* Criteria for developing RNP instrument approach procedures based on a minimally capable RNP configuration. This is to enable usage by a wide range of operators. The FAA will publish additional criteria for SAAAR procedures by the end of January 2004.

In addition to the above documents, there are other enabling orders and guidance material that will facilitate procedure development and implementation. These address operational domains and applications including STARs, SIDs, GPS, and FMS.

Finally, the FAA and industry will need to address important implementation issues and operator business decisions to ensure a successful outcome:

- Charting for en route, terminal and approach procedures taking into account RNAV and RNP.
- Pilot and controller phraseology.
- Aircraft capability categories (flight plan suffixes) that identify RNAV and RNP equipment while conveying required information to ATC for procedure assignments and other clearances.
- Ground automation improvements that can process the revised flight plan suffixes. Procedure assignment decisions that identify and assign a flight based on the aircraft's RNAV or RNP capability. The current system is based on identifying specific equipment present on the aircraft rather than identifying performance capabilities that are a requirement for a procedure or airspace.
- Compatible navigation databases between aircraft and ground automation systems.
- Pilot, principal operations inspector, controller and procedure designer training.
- Safety analysis methodology that considers all three CNS elements.
- Contingency and emergency procedures for situations such as aircraft engine and system failures and weather deviations.
- Timing for regulatory changes, including benefit/cost analysis for the associated Regulatory Impact Analysis.

Examples of Key Implementation Issues

The FAA is committed to working with international stakeholders to harmonize the implementation of the performance-based navigation strategy. Harmonization issues will be coordinated through international forums.

<u>Near Term Harmonization Milestones</u>

Since 1998, European aviation authorities have mandated basic area navigation (B-RNAV), which applies generally above FL 95 and requires 5 NM cross-track accuracy.[5] Starting in 2004, European ATC is moving towards the implementation of precision RNAV (P-RNAV) in major terminal areas, which requires 1 NM cross track accuracy. While authorities will not mandate P-RNAV, a significant segment of European operators are expected to be capable of P-RNAV operations. EUROCONTROL estimates that approximately 80 percent of European carriers are P-RNAV capable and they expect benefits to accrue with P-RNAV operations. P-RNAV capability by U.S. operators will be based on approval guidelines that the FAA will provide through appropriate advisory material.

Another related harmonization issue for P-RNAV operations is navigation-database integrity. EUROCONTROL is considering the introduction of regulatory provisions to achieve the necessary aeronautical data accuracy and integrity performance particularly covering the data chain from origination to publication, as required by ICAO.[6] European and U.S. authorities and industry are coordinating these considerations.

To assist in the resolution of these issues, ICAO established a study group focusing on these harmonization issues. The FAA/Joint Aviation Authority (JAA) All-Weather Operations (AWO) Working Group will continue to work on key coordination activities throughout the near term period.

Mid Term (2007-2012)

By the end of the mid term, RNAV becomes the predominant means of navigation in the NAS. This accomplishes a fundamental shift from a ground-based to a performance-based system. In the early stages of this time frame, RNP procedures also will propagate throughout the NAS as various operators begin to invest in aircraft capabilities. As a result, FAA will remove some of the existing ground-based navigation infrastructure from service starting in 2010, along with some associated routes and procedures.[7]

Advances in navigation capability during this time frame will enable improvements in airspace design based on applicable route spacing, separation

[5] The operations approval for B-RNAV was provided through the Joint Aviation Authority's (JAA's) Temporary Guidance Leaflet (TGL) No 2, ACJ 20X4, entitled, "Advisory Material for the Airworthiness Approval and Operational Criteria for The Use of Navigation Systems In European Airspace Designated for Basic RNAV Operations." European carriers obtain operational approval through Temporary Guidance Leaflet (TGL) No 2 in order to operate in this airspace. For harmonization purposes, the FAA published an equivalent document, *AC 90-96 , Approval of U.S. Operators and Aircraft to Operate Under Instrument Flight Rules (IFR) in European Airspace Designated for Basic Area Navigation (B-RNAV/RNP-5),* providing guidance to U.S. carriers for operational approval of B-RNAV.

[6] These guidelines are part of an Advanced EUROCONTROL Notice of Proposed Rulemaking (A-ENPRM) located at *www.eurocontrol.int/enprm*.

[7] Federal Radionavigation Plan, 2001; and Navigation and Landing Transition Strategy, 2002.

minima, new sectors and terminal airspace structures. This will allow for higher degrees of flexibility for aircraft operations. It also will allow increased routes and multiple terminal ingress and egress points to facilitate throughput between en route and terminal airspace.

In the mid-term, the FAA will leverage RNAV capability through the implementation of Non-Restrictive Routing (NRR), which will be similar to the National Route Program (NRP) but will involve the use of origin (pitch) and destination (catch) points instead of arcs and will not impose a minimum distance from airports for the pitch and catch points. In addition, the FAA and industry will conduct operations involving the National Reference System (NRS), facilitating the implementation of random routings. The NRS is an improved grid-navigation system using named waypoints (instead of latitudes and longitudes) stored in navigation databases and available for routing purposes.

During the mid term in the en route domain, RNAV operations will become prevalent. RNP-2 routes will become available at all altitudes. In addition, the FAA will introduce RNP-1 routes above FL 390 and at lower altitudes where beneficial (except for oceanic operations). By 2012, the administration will mandate RNP-2 performance above FL 290 in continental airspace. Airspace redesign efforts also will address impacts of these mandates on adjoining airspace (vertically and horizontally). The FAA will apply RNP to en route offsets to produce benefit through flexibility and optimized traffic management. Implementation of controller decision-support tools and collaborative decision-making capabilities will maximize benefits.

During the mid term for the oceanic domain, the Pacific Oceanic RNP-10 operations will evolve to RNP-4 mandate (applying exclusionary airspace only where aircraft capability is sufficiently high). NAT MNPS will evolve to RNP-4 mandate in the same manner. Additional CNS capabilities (including aircraft equipage) and enhanced airspace and traffic management tools are required to obtain the maximum benefits of reduced track separation (e.g., 30 NM horizontal separation).

In the terminal, the FAA will implement RNP-1 SIDs and STARs at busy terminal areas with the operational need for RNP-1. As the use of RNP SIDs and STARs increases in busy and congested terminal areas, merging and sequencing abilities will be critical to achieving the full benefits. The FAA will implement appropriate merging and sequencing decision support systems in conjunction with these RNP procedures.

As conventional SIDs and STARs are no longer used in certain locations, these sites will instead use overlay and non-overlay RNAV or RNP procedures. In this time frame, the FAA will remove from service VORs no longer necessary.

The expectation is that the rate of technology development and equipage will result in the need for some conventional (non-RNAV) terminal procedures in addition to ground-based NAVAIDS as back-up systems. Where beneficial, the FAA will develop and publish multi-flow, multi-airport, SID/STAR combinations incorporating RNP-1. They will also restructure en route and terminal adjacent airspace during this time frame in many areas, based on RNP, to enable greater throughput benefits.

In the mid term, RNAV becomes the predominant means of navigation in all phases of flight and capable operators will benefit from RNP. For example, RNP-1 SIDs and STARs will be implemented at busy terminal areas and RNP-2 performance will be required above FL 290 in domestic airspace.

During the mid term, the FAA will aggressively implement and demonstrate commitment to RNAV and GPS by publishing new procedures as an incentive to growth in equipage. The implementation of SAAAR procedures (described in the near term section) will increase at a number of sites where beneficial. As ground-based NAVAIDs are removed from service, starting in 2010, the FAA will eliminate associated instrument approaches no longer in use due to the existence of vertically guided performance-based approaches. Operators will continue to use instrument approaches based on the remaining ground-based NAVAIDS at those sites and by those operators still requiring their use.

Far Term (2013-2020)

Far term concepts will require additional investments by stakeholders. These investments need confirmation that the proposed enhancements are necessary for the realization of the benefits envisaged. Operators will make far-term aircraft investments based on those business plans. During the far term, to achieve higher benefits, the application of RNP will be mandatory in some airspace (not just applied along particular routes). Demonstration of benefits in the near and mid terms will lay the foundation and build the business case for continued modernization of aircraft fleet capabilities by the operators.

RNP airspace enables significant capacity and efficiency gains through airspace restructuring, allowing multiple flows, routes and ingress/egress points where needed to reduce delays. It also enables flexible navigation through an increase in random routes, moving toward the RTCA Task Force 3 vision of Free Flight. Stakeholders will not realize the maximum benefits of RNP until airspace is redesigned, avionics and operator capabilities are standardized, and advanced CNS and ATM technologies are implemented.

During the far term, ATM evolves into a more strategic management of airspace and aircraft trajectories. Far-term ATM will include the use of 4-D path descriptions, common information infrastructure, decision support tools that share real-time airport, airspace and aircraft performance data among aviation decision makers. A key milestone of this future state is having a significant part of the fleet achieve required time of arrival capability for 4-D RNP.

Use of performance-based navigation in combination with systems such as ADS-B and the Traffic Alert and Collision Avoidance System (TCAS) will enable the transition of tactical separation responsibility to the pilot for certain situations and for limited time periods. Tactical separation will remain, in most situations, a controller-based responsibility; however, aircraft-to-aircraft optimized separation will emerge in certain airspaces and operational scenarios (e.g., passing, crossing and merging situations).

At the end of this period, operators will use RNP-based RNAV universally in all domains, with the retention of a minimal operational network of ground-based NAVAIDS used as backup. The robustness and specific geometries of such a back-up infrastructure will require a comprehensive, validated plan reflecting user needs. Operators and service providers will require airspace redesign and automation systems as the route structure changes from a fixed to a flexible, user-preferred and random route system.

The FAA and industry will continue to pursue far term implementation of RNAV and RNP, with near term and mid term research questions focusing on the following concepts:

- Multiple terminal ingress and egress points connecting to multiple en route transitions and moveable/changeable tracks.
- Procedurally separated random RNP routes.
- Evolution of navigation databases to aircraft and automation systems.
- Synergistic effects of improved CNS and ATM on reducing separation standards.
- Far term separation between aircraft based on CNS capabilities versus segregation of routes (applies to oceanic and domestic operations).
- Application of RNP to ongoing airspace review and redesign.

For oceanic regions, the oceanic infrastructure needs to support the implementation of user-preferred routes that will not be dependent on any organized or published track system. RNP-4 is expected to become the universal navigation performance standard; however, as the transition progresses toward a Free Flight environment, the required navigation performance values for international airspace may change contingent on traffic growth and the ability of the ATM automation to support additional capacity where needed.

For terminal airspace, the FAA will mandate STARs and SIDs supporting operations at airports employing RNP-1 as operationally necessary for managing the terminal flows and for environmental considerations. Through procedure design and to the greatest extent possible, the FAA will segregate aircraft requiring radar vectors from the major terminal flows. At major airports terminal procedures will be RNP-2 or lower. The FAA will mandate RNP-1 for IFR operations in certain Class B airspace at the end of the far term.[8] They may also require RNP-0.3 where it is beneficial for terminal and approach transition operations.

For instrument approaches, RNP provides increased access and efficiency, and it simplifies the complexity of busy airport operations. The FAA will continue to tailor approach procedures to meet the requirements dictated by aircraft capabilities, efficiency, runway spacing, environmental concerns or existing obstacles.

By 2020, the end of the far term phase, RNP operations will be available for almost all airspace and operations supporting FAA and industry goals and objectives (e.g., OEP, RTCA NAS Concept of Operations, Free Flight). Operators will continue to use published routes and tracks for flight planning and ATM personnel will continue to use them for strategic planning. A full complement of automation tools that will provide strategic and tactical-conflict detection and resolution, based on both published and random routes, will characterize the ATM system. A cooperative system established between the service

[8] En route transitions through Class B airspace, and SIDs and STARs for secondary airports in Class B airspace, will not be subject to RNP-1 mandates.

provider and the operators that will aid in coordinating the traffic flow into major terminal areas will be another facet of the system. Satellite navigation will be the primary base for the navigation infrastructure, although there will be a network of ground based NAVAIDS to provide continued safe operation in the event of a failure of the Satellite Navigation (SATNAV) system.

Acronyms

AC	Advisory Circular
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
ATC	Air Traffic Control
ATM	Air Traffic Management
AWO	All-Weather Operations
B-RNAV	Basic Area Navigation
CEP	Central East Pacific
CFIT	Controlled Flight Into Terrain
CFR	Code of Federal Regulations
CNS	Communications, Navigation, and Surveillance
DOD	Department of Defense
FAA	Federal Aviation Administration
FMC	Flight Management Computer
FMS	Flight Management System
GA	General Aviation
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
JAA	Joint Aviation Authorities
LAAS	Local Area Augmentation System
LNAV	Lateral Navigation
MEA	Minimum En Route Altitude
MNPS	Minimum Navigation Performance Specification
MOCA	Minimum Obstruction Clearance Altitude
NAS	National Airspace System
NAT	North Atlantic
NAVAIDS	Navigation Aids
NDB	Non Directional Beacon
NM	Nautical Mile
NOPAC	North Pacific
NRP	National Route Program
NRR	Non-Restrictive Routing
NRS	National Reference System
OEP	Operational Evolution Plan

Acronyms (Concluded)

P-RNAV	Precision Area Navigation
PACOTS	Pacific Organized Track System
PRM	Precision Runway Monitor
RCP	Required Communication Performance
RNAV	Area Navigation
RNP	Required Navigation Performance
RPAT	RNP Parallel Approach Transition
RSP	Required Surveillance Performance
SAAAR	Special Aircrew and Aircraft Authorization Required
SATNAV	Satellite Navigation
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival
TAOARC	Terminal Area Operations Advisory Rulemaking Committee
TCAS	Traffic Alert and Collision Avoidance System
TGL	Temporary Guidance Leaflet (JAA)
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VOR	Very High Frequency Omnidirectional Range