

April 21, 2009

Ms. Margaret Gilligan  
Associate Administrator for Aviation Safety  
Federal Aviation Administration  
800 Independence Avenue,  
S.W. Washington, D.C. 20591

Dear Peggy:

As you are aware, Required Navigation Performance (RNP) and Area Navigation (RNAV) are fundamental components of NextGen and Trajectory Based Operations; two key components of what is now known as Performance-Based Navigation (PBN) Operations. Much of the guidance and advisory material used to implement these and many other aircraft capabilities have come from recommendations and the work of the Performance-based Operations Aviation Rulemaking Committee (PARC).

During the development and initial applications of RNP Special Aircraft and Aircrew Authorization Required (SAAAR) approach procedures, it was clear that SAAAR was offering much improved safety, operational and economic value to operators in situations where complex or demanding operational requirements existed. In addition, there are applications where non-SAAAR procedures can provide benefits to a broader range of operators without having to meet the stringent requirements of SAAAR. Based upon the experience gained with SAAAR, and based on strategies outlined in the Roadmap for Performance-Based Navigation (FAA, 2006), the PARC launched an Action Team to identify beneficial applications of terminal area arrivals, departures and approach procedures based on RNP without the need for SAAAR approvals. In parallel, the FAA published guidance material for aircraft and operator approval of RNP (non-SAAAR) terminal and approach procedures (FAA Advisory Circular 90-105); this AC was also based on work done by the PARC.

The early SAAAR successes in improving access, schedule reliability and safety are just the first glimpse of the full potential of RNP in the National Airspace System. One fundamental benefit that is largely untapped is RNP's potential to facilitate efficiencies in the terminal area and to reduce both emissions and noise of aircraft operations at large and small airports. This letter points to how this and other related benefits can be achieved and suggests actions needed to accelerate attainment of these benefits through RNP in NextGen.

The two papers included with this letter, "Concepts and Benefits for Terminal RNP Procedures" and "Applications and Benefits of Required Navigation Performance (RNP) for Large Airports with Surrounding Satellite Operations," are the products of the Terminal RNP Benefits Action Team, and provide principles, concepts and benefits of using RNP for terminal arrival and departure procedures as well as how and where those applications might be used. The second paper is a case study that illustrates how

applications of RNP may be useful in significantly improving both arrivals and departures, and allowing greater throughput, in a large Metroplex.

The key point of both papers is to show how RNP fundamentally improves conformance to a given path at a specified accuracy requirement. These two reports detail how RNP, when applied in high density terminal areas such as Atlanta, has the potential to enable more efficient traffic flows, and to increase both arrival and departure rates in IMC by:

- Reducing current long, highly variable downwind legs, which can be up to 25 NM in IMC and 15 NM in VMC, that increase emissions, fuel burn and flight times.
- Facilitating more efficient parallel runway operations by allowing inbound flights to be “established” earlier on an approach procedure by using RNP, as a means of providing aircraft-to-aircraft separation. This would be in lieu of the current requirement for either 3 NM horizontal or 1,000’ vertical separation for aircraft in parallel ILS operations.
- Enabling decreased spacing between routes without intervention by air traffic control (ATC).
- Providing additional arrival and departure track options and transition fixes to increase the efficiency of both lateral and vertical profiles thus reducing noise and emissions for the surrounding communities.
- Employing RNP tracks in a “multi-lane freeway” concept to accommodate non participating aircraft.
- Using the higher predictability of RNP to enable placement of additional closely-spaced departure tracks inside the bounds of existing ground tracks.
- Increasing flexibility to accommodate weather events by providing additional RNP-based routing options during periods of convective weather when conventional routes might be impacted.

The Action Team identified the enabling criteria to achieve the maximum benefit of RNP terminal procedures. As outlined in the second paper, safety studies and analysis in the following areas are necessary to establish criteria for:

- Adjacent RNP tracks to be considered procedurally separated,
- Appropriate spacing between RNP/RNP tracks
- Use of RNP to allow more efficient turns to final during simultaneous approach operations.

Other enablers to these benefits that are identified by the Action Team include:

- Changes to Order JO 7110.65, Air Traffic Control, to allow for aircraft on RNP approaches to be considered established on a lateral approach track prior to the turn onto final.

- Appropriate use of RF (Radius-to-a-Fix) turns to determine the appropriate applications that allow the downwind to be moved closer to the runway, while also providing a shorter downwind length.
- Reductions in angular divergence (less than 15 degrees) for diverging RNP departure tracks off the runway. These reductions could allow for an increase in the number of departure tracks off eligible runways, providing an increase in departure throughput.
- Controller automation tools that leverage the increased predictability of RNP such as merging and spacing aids

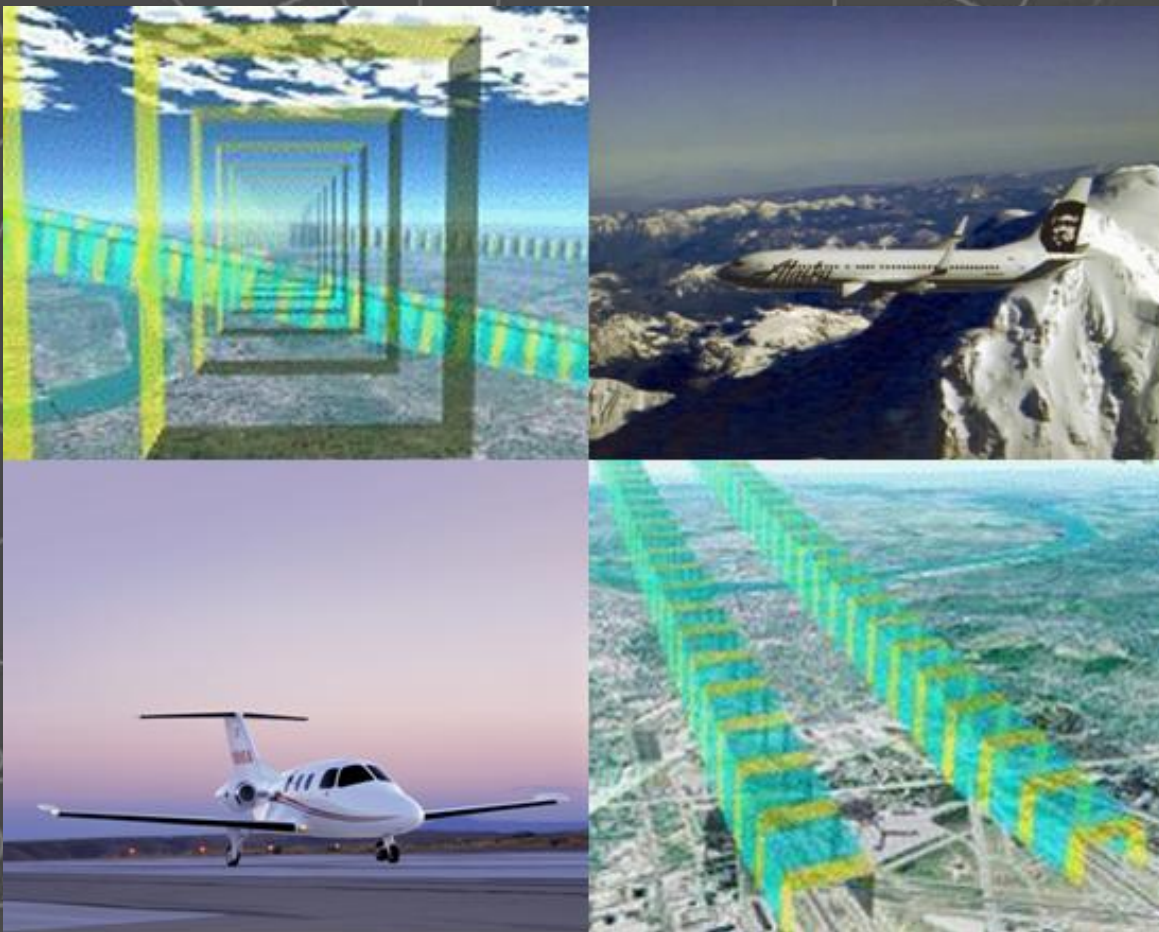
The PARC intends to refine and validate the concepts and benefits enumerated in the enclosed reports over the coming months. The PARC acknowledges that addressing the enablers listed above requires a joint understanding of the concepts and benefits, as well as collaboration between FAA and industry to resolve issues. We appreciate your continued support of our activities and invite you to join us to discuss these issues and how we can continue to work with your organization to help resolve them. Please call me if you have any questions or would like to set up a briefing on the subject.

Sincerely,

A handwritten signature in dark ink, appearing to read "Dave Nakamura". The signature is fluid and cursive, with the first name "Dave" being more prominent than the last name "Nakamura".

Dave Nakamura  
Chairman  
Performance-based operations  
Aviation Rulemaking Committee

Cc: J. McGraw  
J. Hickey  
H. Krakowski  
S. Dickson



# Concepts and Benefits for Terminal RNP Procedures

**Report by Performance-Based Operations Aviation  
Rulemaking Committee**

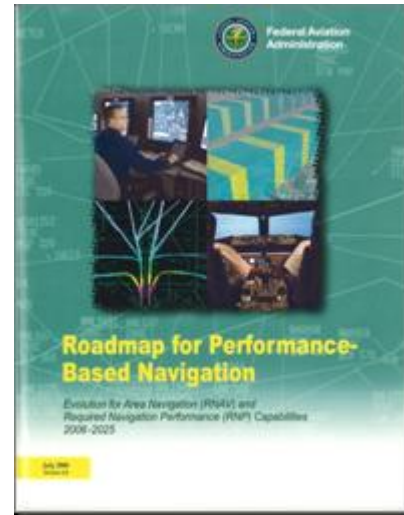
**April 2009**

# Concepts and Benefits for Terminal RNP Procedures

## 1. Introduction and Background

### *Performance-Based Navigation*

In July 2006, the Federal Aviation Administration (FAA) published the update to the *Roadmap for Performance-Based Navigation*, which was created in collaboration with the aviation community through the Performance-Based Aviation Rulemaking Committee (PARC). The *Roadmap* provides the FAA and industry with a documented consensus on a plan for transitioning to performance-based navigation achieving the highest levels of safety and security and will increase access, reduce delays, and improve the efficiency of the National Airspace System. It establishes milestones for near-term implementation of performance-based navigation and sets a strategy for mid- and far-term evolution in the en route, oceanic, terminal, and approach phases of flight.



Performance-based navigation is defined as navigation along a route, on a procedure or in airspace within which the aircraft operation must comply with specified performance requirements. This is a fundamental shift from a navigation paradigm that specifies equipment types and technologies. A key component of establishing a performance-based navigation system is the use of area navigation (RNAV) “everywhere” and Required Navigation Performance (RNP) where beneficial. RNAV operations remove the constraint that requires a direct link between aircraft navigation and a ground navigation aid, thereby allowing better access and permitting flexibility of point-to-point operations. Advisory Circulars (AC) and Orders exist for RNAV operations that define the aircraft, aircrew, and procedure requirements for the operation. RNAV-2 specifications for en route procedures require total system error of not more than 2 NM for 95 percent of the flight time, and similarly RNAV-1 specifications for terminal procedures require total system error of not more than 1 NM for 95 percent of the flight time. The FAA has published guidance material on aircraft and operator approval needs for RNAV operations as AC 90-100A, approval guidance for RNP operations as AC 90-105, and approval guidance for RNP operations with Special Aircraft and Aircrew Authorization Required (SAAAR) as AC 90-101. The FAA also has published standards for the design of RNAV en route and terminal instrument flight procedures.

RNP operations introduce the requirement for onboard navigation performance monitoring and alerting. The FAA is currently drafting the guidance material for aircraft and operator approval needs for RNP en route and terminal operations, as well as

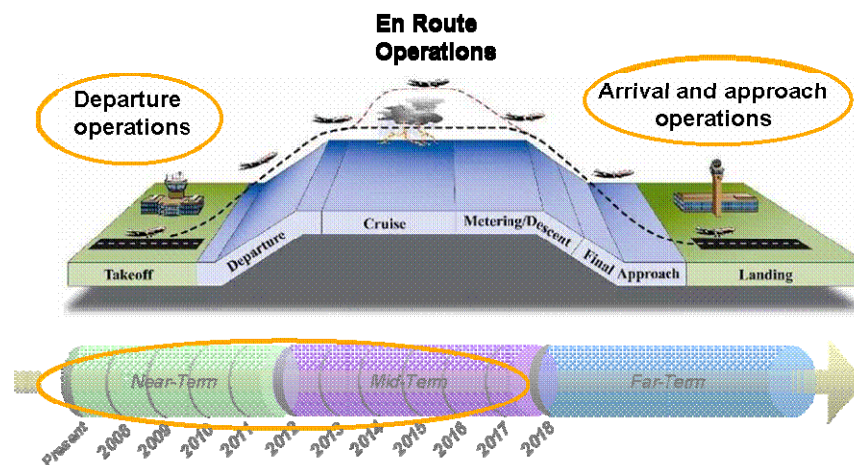
standards for design of RNP instrument flight procedures. The purpose of this document is to articulate concepts and benefits for terminal RNP procedures, to facilitate the development of guidance material and procedure design criteria.

The FAA publishes standard instrument approach procedures that leverage RNP and incorporate sophisticated features that require additional aircraft and operator approvals in order to be flown. These procedures are called RNP SAAAR procedures and provide particular benefit in selected locations. The aircraft and operator approval guidance material for RNP SAAAR approaches is published by FAA as AC 90-101. The FAA has also published procedure design criteria that enumerate the sophisticated features of these RNP SAAAR approaches. Based upon lessons learned and a better understanding of operational needs, the PARC continues to work on refining this guidance material and procedure design criteria.

Design and implementation of RNAV and RNP operations are intended to deliver benefits and these benefits vary depending on the needs of the airspace. The benefits include:

- Increase safety through continuous descent arrival and approach procedures that reduce the risk of controlled flight into terrain (CFIT) and loss of control. Predefined RNAV and RNP procedures enhance confidence and consistency, reduce complexity of terminal operations, and reduce the risk of communication errors.
- Improve airport and airspace access in all weather conditions both in radar and non-radar environments, and improve the ability to meet environmental and obstacle clearance constraints, through the application of optimized RNAV and RNP flight tracks. The result will be reduced lateral separation criteria and more accurate path keeping.
- Enhance reliability, repeatability and predictability of operations using a specific defined flight path, leading to increased throughput. More precise arrival, approach and departure procedures will reduce flight track dispersion, allow closer track spacing, 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 high traffic density 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 stratus.
- Promote design and use of environmentally beneficial arrival and departure procedures that allow the aircraft systems (i.e., the FMS) to manage flight performance (climb, descent, engine performance, etc.). Benefits include reduced fuel burn and emissions and environmentally-tailored noise footprints.

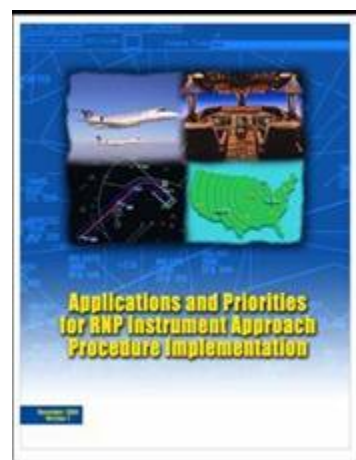




Performance-based navigation (PBN) will enable the needed operational improvements by leveraging current and evolving capabilities in the near-term timeframe (through 2012), that can be expanded to address the mid-term needs of NAS stakeholders and service providers (through 2018). This document addresses approach, arrival and departure operations.

PBN is characterized by the coordinated trade-offs between aircraft capabilities, flight deck and controller human factors, operational approvals (e.g., dispatch, maintenance, and flight crew training), and operational benefits. For RNP SAAAR, there are increased requirements on the aircraft in the form of performance monitoring and alerting and functionality to mitigate the reduced obstacle protection areas and narrower RNP values applied in procedures. For RNP (non-SAAAR), the aircraft performance monitoring and alerting and functionality requirements are less stringent due to the safety mitigations resulting from less complex applications, increased obstacle protection margins, and wider RNP values applied. The RNP (non-SAAAR) requirements for aircraft capabilities and operational approvals are less stringent and costly than those for RNP SAAAR.

In 2005, the PARC published a report on the applications and priorities for RNP SAAAR approaches, focusing on the operational benefits that are realized through the sophisticated features enabled by RNP SAAAR. In this report, the PARC outlined a strategy for implementation of RNP SAAAR approaches and identified site priorities through a three-tiered process of implementation. To date, 125 public procedures have been implemented based on the RNP SAAAR criteria. Five commercial operators and three General Aviation operators have obtained approval to fly these procedures, and several others are seeking authorizations. The strategy and site priorities for RNP SAAAR implementation are continuously being reviewed by the PARC, and recently the PARC set out to update the



strategy and priorities for RNP SAAAR. The updates will be determined and documented by a separate PARC working group later in 2008.

This report focuses on concepts and benefits for terminal RNP procedures.



## 2. Principles and Definitions for Terminal RNP (non-SAAAR) Procedures

In order to satisfy the requirements of all aviation stakeholders, RNP arrival, departure, and approach capabilities must allow for the maximum flexibility in application if the maximum benefit of the technology is to be realized. Without having a set of guiding “principles” to refer to during the development of the design criteria, operational approval guidance and ATC procedures, it will be difficult for the resulting materials to meet the needs of the end users. Below is a list of these principals that apply for implementation of Performance-based Navigation in terminal operations:

- Tactical intervention (i.e., “vectoring”) during RNAV and RNP operations is becoming increasingly difficult and has undesired effects as RNAV and RNP operations become more automated with lateral, vertical and speed profiles being managed by the FMS. Although radar vectoring paths may allow tight turn radii, they do not allow for the path repeatability and predictability that is enabled through RNAV and RNP. With that in mind, effort should be made to develop design criteria that allows for overlay of suitable radar vectoring paths. RNAV and RNP procedures that are more restrictive than what is currently allowed with radar vectoring may not be as successful and will not provide benefit everywhere. In spite of these limitations, the benefits of RNAV and RNP procedures may be accrued at a variety of locations and should not solely be measured by path length alone.
- Every RNP procedure considered for implementation should be analyzed to ensure benefits over RNAV alone.
- Lateral track-to-track separation and radar separation standards for flights operating on RNP procedures that leverage the RNP level for a given segment must be adopted.
- Vertical separation that accounts for performance-based capabilities must also be developed and adopted in order to achieve maximum airspace benefits. Consideration should be given to use of “procedural separation” for tracks established on RNP routings.
- Benefits of PBN procedures are more important than sheer number of published procedures. If there is not a clear benefit to the daily operation, then moving forward with development should require additional analysis to understand the benefit mechanism, such as reduced ground infrastructure costs and divestment of certain navigational aids.
- Standardization of RNAV and RNP functionality that is needed to accomplish beneficial applications should be identified and established as soon as practical, since the equipage timeline is fairly long and the process of determining standards takes considerable effort. This may also apply to flight crew use of autopilot, cost indexing, bank angle limits, etc.

To date, RNAV arrival and departure procedures have been developed at many of the major terminal environments to enable reduced workload, improved navigation accuracy and consistency of flight tracks. These procedures facilitate a variety of possible improvements, such as the ability to increase the number of ingress and egress points

between terminal and en route airspace, to increase capacity and throughput, minimize time and/or distance flown, and even to reduce noise and emissions. To maximize benefits, RNP applications are being defined for implementation in terminal operations in the near-to-mid term timeframe.

**RNP Arrival and Departure Procedures** are defined as RNP-1 procedures where navigation performance monitoring and alerting is required. Segment legs are straight and do not allow for radius-to-fix path terminators. Vertical constraints and speed constraints are applied in a manner comparable to constraints used in RNAV procedures. The operational performance requirements and specific functionalities needed to participate in RNP Arrival and Departure Procedures are being defined by the FAA in an AC 90-RNP to be published in the fall of 2008.

**Procedures with Advanced Features** are also defined for RNP-1 operations. As a first phase the advanced features will allow segment legs to be curved paths (using radius-to-fix path terminators). At later phases, vertical paths are allowed for through use of constraints at waypoints, vertical path guidance, or path angles using vertical RNP where aircraft capabilities and benefits can be realized; and use of required time of arrival (RTA) assigned by ATC could be applied at waypoints.

The system performance requirements to use advanced features for RNP will require operators to demonstrate the capability to use curved paths (radius to fix legs or fixed radius transitions) or any other future new capability.

Over the past two years, the PARC defined concepts and benefits for RNP approaches not requiring SAAAR. Those definitions are provided below:

**RNP Approaches (not requiring SAAAR)** are defined as RNP-1 in the initial, intermediate and missed approach segments and RNP-0.3 in the final approach segment. Navigation performance monitoring and alerting is required. Segment legs are straight and do not allow for radius-to-fix path terminators. Approach minimums are defined for lateral navigation (LNAV) or LNAV/vertical navigation (VNAV).

The system performance requirements for RNP Approaches are the same as for RNP Arrival and Departure Procedures plus operators seeking to use the VNAV line of minima will be required to have equipment with vertical navigation system performance that meets or exceeds criteria in Advisory Circular 20-129 or other approved standards.

**RNP Approaches with Advanced Features** allow for segment legs to be curved (using radius-to-fix path terminators) in the initial and intermediate segments, and missed approach segments<sup>1</sup>. In later phases of implementation, RTA could be assigned by ATC and applied at a waypoint such as initial or final approach fix, where aircraft capability

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<sup>1</sup> Discussions continue in the PARC regarding allowance for RF legs in the final approach segment or in any approach segment where the RNP value is less than 1.0, but for now this feature is only used in RNP SAAAR approaches.

and benefits exist. Operators will be required to demonstrate system and operational performance for the advance feature being sought.

### **Additional notes on capabilities for RNP operations**

Database process oversight through Letter of Authorization (LOA) is expected to be required for all terminal arrival and departure RNP operations, although it remains to be determined whether those IFR GPS units currently excluded from certain RNAV operations due to database certification issues will be included in Terminal RNP. Since this type of LOA is not currently required for RNAV(GPS) approach to LNAV minima today, the need for this type of LOA for an RNP Approach will depend on the eventual criteria for the RNP Approach.

It remains an area of future concept development how RTA will be applied from a traffic management standpoint, and future analysis will need to define how ground and flight deck automation will identify SIDs, STARs, and approaches that require RTA and other advanced capabilities. Database standards do not currently allow such identification.

Defined requirements for RTA are needed in order to assess the impact on equipment (e.g., additional database information required, acceptable tolerance for RTA, alerting requirements if RTA cannot be met, etc.).

## **3. Concepts and Benefits for RNP Terminal Operations**

For terminal airspace and airports across the National Airspace System (NAS), opportunities exist for benefits based on RNP from reduction of obstruction clearance areas, from performance-based vertical paths and obstruction clearance surfaces, and from path segments that are not straight in and straight out. These are the features of RNP departures, arrivals and approaches that operators and the FAA are planning to implement. The FAA will apply these procedures where needed to provide benefits in arrival and departure airspace, as well as along the approach and/or missed-approach segments. Because RNP procedures are being implemented with basic features and there is an allowance for advanced features, procedure can be tailored to the needs of the airspace and their application can be limited to those locations where aircraft capabilities exist and where benefits can be realized. This will provide opportunities for all operators that satisfy the requirements of the RNP operations and will enable incremental benefits for user capable of the advanced features.

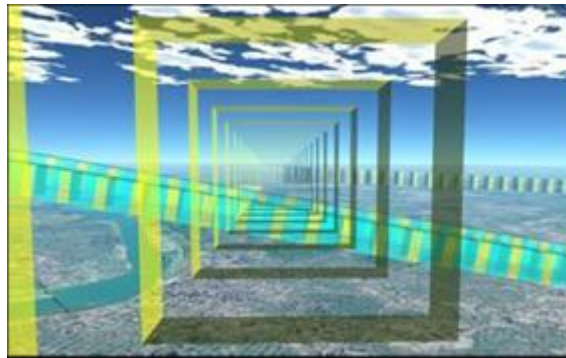
The following sections enumerate a number of concepts for terminal applications of RNP. *For each concept, it should be noted that if RNAV can be implemented such that it delivers sufficient benefit then RNAV should be used, but RNP should be used where required to achieve benefits and where/when sufficient aircraft equipage exists.* For each RNP concept, this report provides a description of the concept and one or more examples depicting the concept, along with potential sites, expected benefits, and areas needing

further analysis. There is also a section following the concepts on enabling criteria needed for achieving all of the concepts and examples.

All of these applications require some degree of change to existing standards and criteria for procedure design, separation criteria, ATC procedures, phraseology, training, and possibly surveillance and communication. All revisions to these items that are needed for implementing such applications will require dedicated effort and analysis, with established milestones and dependencies. A complete, integrated solution is needed to realize the benefits described in these concepts.

### **Concept 1. Make Better use of Airspace to Increase Throughput and Flexibility**

Through predictable and reliable aircraft performance with RNP operations, allow airspace to be used for more operations.



*Graphics: J. Giovanelli, MITRE*

1.1) Make better use of airspace in the vertical dimension through more predictable descent/climb profiles

Possible sites: most OEP airports; ASE (with changes in separation standards); SUN (with changes in separation standards)

Expected benefits: frees airspace for more efficient use; increased throughput, less vectoring for traffic (arrival and departure), fewer level-offs (departure), less holding and level offs (arrival), reduced fuel burn, emissions and noise; less impact to departures and arrivals in a sector due to the dynamic use of more available published route options in other sectors.

For further analysis: can a narrow vertical profile for arrivals (in terms of protected airspace) be defined that provides ATC benefit and is acceptable to airspace users?

1.2) Use RNP arrival and departure routings in the same airspace so that airspace previously dedicated for arriving and departing a major airport may accommodate flows for arriving and departing multiple major airports, satellite airports, and/or mountain airports that are one way in and one way out.

Possible sites: arrivals and departures in complex airspace such as New York TRACON, DAL/DFW, HOU/IAH, LAS/HND; operations out of Manassas or Leesburg de-conflicting from IAD operations; de-conflicting all ORD and MDW Operations (already being addressed by RNP Program); San Diego and Miramar; ASE, SUN, TEX

Expected benefits: closely spaced arrival and departure paths that co-exist in the same airspace; more throughput, less vectoring for traffic arriving and departing, less holding for arrivals; reduced fuel burn, emissions and noise; highly accurate vertical descent performance to enable more airspace for departures and arrivals transitioning with more efficient vertical profiles with less leveling off; less impact to departures and arrivals in a sector due to the dynamic use of more available published route options in other sectors  
For further analysis: airspace redesigns and air traffic procedures for complex operations described in this concept; need for ground and flight deck automation to support this type of operation

1.3) Use RNP procedures in confined airspace environments to enable predictable usage and access to constrained or otherwise unusable airspace

Possible sites: PWK, ORD, SMO, MDW, VNY, BUR, TEB, etc.

Expected benefits: increased throughput; reduced minima for lower RNP values; reduced pilot and ATC workload in currently high workload environment

For further analysis: required turn angles, turn radii, climb gradients, leg lengths, turn proximity to the departure end of the runway; does RF turn below 500' above the airport enable more benefit; how would participation be affected and is participation required to realize benefit; number of users who will actually be able to use the procedure due to system limitations

1.4) Procedural separation and reduced track-to-track separation for flights on RNP T-routes (low-altitude IFR transition routes through moderate to busy terminal airspace such as Class B and Class C)

Possible sites: moderately busy terminal airspace; more challenging sites such as high traffic density TRACONs like Chicago, NY, Northern and Southern California

Expected benefits: reduction in workload associated with GA over and through flights including low performance flights that originate in the airspace

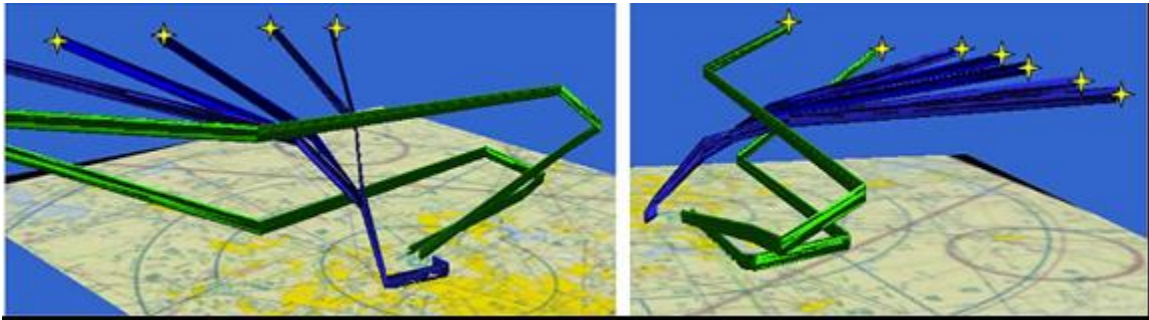
For further analysis: define and validate specific concept of use for procedural separation to reduce workload; reduced separation standards

1.5) Use multiple defined RNP and RNAV procedures to allow aircraft of different aircraft performance (climb & descent rates) to efficiently pass through airspace

Potential sites: most OEP airports

Expected benefits: less vectoring by controllers; increased throughput; more availability for high performance users; less delay for all users

For further analysis: how to accommodate different performance characteristics efficiently



*Graphics: E. Smith, B. Haltli, MITRE*

1.6) Use RNP procedures and reduced separation to enable access to currently unavailable airspace and to increase the number of available routes in high demand areas where additional routing is needed

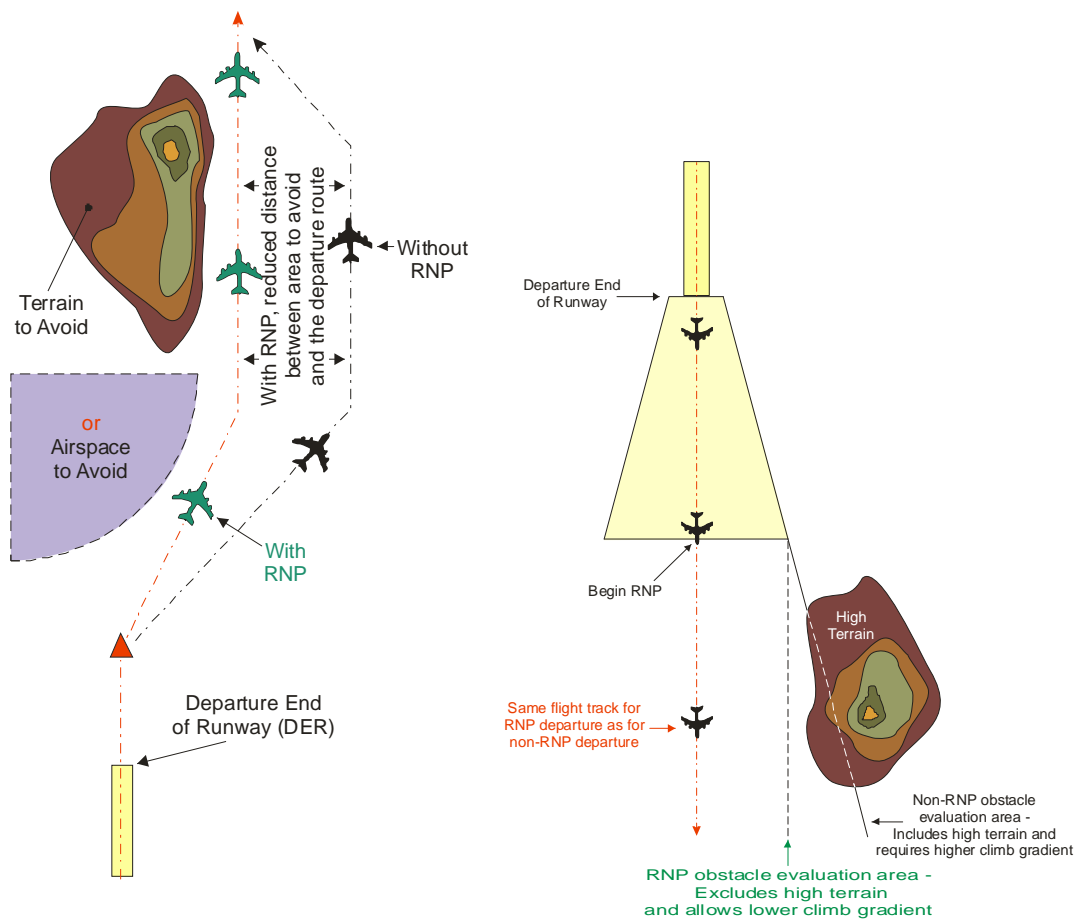
Potential sites: all OEP airports

Expected benefits: increased throughput; more availability for high performance users; less delay for all users; standardization on departures

For further analysis: separation standards; are RNP routes supposed to add to the current route structure or totally replace it, and if replacement is planned, how do we ensure all users are accommodated

### **Concept 2: Mitigate Obstacles, Terrain, and Special Use Airspace to Increase Access and Availability**

Make use of precise following of complex procedures to avoid obstacles, terrain, and special use airspace (SUA).



Graphics: Phil Prasse, AFS-420

2.1 Use RNP arrival, approach or departure procedures where none were possible before.

Potential sites: ASE, EGE, SUN, TEX, RNO, LAS, BUR, PSP, UDD, etc.

Expected benefits: better access to some airports through lower minima reducing deviations to alternate airports, reduced miles flown and fuel burn, emissions and noise

For further analysis: use of RF prior to gaining experience

2.2 Use of RNP to reduce climb gradient and flight distance requirements by avoiding obstacles, terrain, or SUAs

Potential sites: for terrain: EGE, SUN; for SUAs: DCA RWY 1 needs RF to RF; ASE, TEX, RNO, LAS, BUR, PSP, UDD, etc.

Expected benefits: modification of climb gradient requirements for departures from some airports; reduced flight time and distance to avoid obstacles and terrain, reduced miles

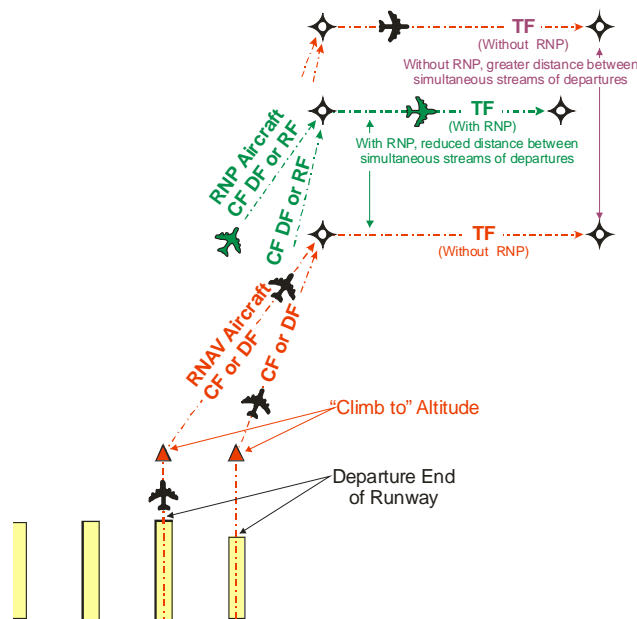


flown and fuel burn, emissions and noise; improvement in safety of abnormal egress procedures i.e., engine out procedures

For further analysis: loss of navigation signal safety requirement for width of obstacle evaluation areas as a function of distance from the runway

### Concept 3: Precise Path-Keeping to Increase Runway Throughput

Make use of precise following of complex procedures to increase the number of arrival or departure operations in high demand areas.



*Graphics: Phil Prasse, AFS-420*

3.1) Use RNP procedures to ensure safety while allowing aircraft to depart from parallel runways with reduced or simultaneous parallel (no divergence required) criteria

Potential sites: DEN, DFW, ORD, ATL, LAX, MCO

Expected benefits: less delay between push-back and take-off in high demand areas (increased departure throughput)

For further analysis: wake parameters for closely-spaced parallel runways; separation standards; minimum parallel runway separation and required navigation capabilities to ensure safe operations; emergency recovery options in closely spaced take-off situations (e.g., surveillance related); environmental impacts and methodology for compliance

3.2) Use precise path keeping of complex procedures to reduce 15-degree divergence required for same runway separation and parallel departures and thereby increase throughput

Potential sites: diverging departures with RF capabilities JFK 31L, BOS 22L 22R; 10 degree diverging departures: PHX, MIA, BOS

Expected benefits: less delay between push-back and take-off (increased departure throughput)

For further analysis: wake parameters; ATC and ground controllers' workload as the number of departures increases; separation standards; emergency recovery options in closely spaced take-off situations; JFK 31L and BOS 22L/R airspace and noise abatement issues; Environmental considerations

3.3) For operations without surveillance, use RNP procedures to reduce separation standards and achieve better than "one-in, one-out" operations where needed

Potential sites: airport areas without radar coverage with "one-in, one-out" operations

Expected benefits: reduction of pilot and controller work load; improved access and efficiency, reduced miles flown and fuel burn, emissions and noise; reduced time holding waiting for previous arrival or departure (one-in, one-out operations)

For further analysis: separation criteria; procedural separation

#### Enabling Criteria Needed for Achieving All Concepts:

- RNP arrival, approach and departure criteria
- Clear identification of aircraft capabilities in order to know what aircraft can perform an operation, so crews can know what clearance requests to accept or not accept
- RF legs where needed to provide repeatability of ground tracks through turns, and the resulting capacity/throughput/controller workload benefits
- RNP level: Use of various RNP levels ranging from RNP-1 down to RNP-0.3 or lower for terminal procedures (note that RNP values less than 1 are not currently included in the ICAO PBN Navigation Specification for terminal RNP)
- For departure: Use of RF turns as soon as possible to preserve capacity benefits of diverging headings, and avoiding environmentally sensitive areas, terrain and obstacles near airports
  - Need to define the climb and bank performance assumptions for the RF turn (200ft/NM) from end of runway
- Determination of how close RF turn can be to runway for approaches (e.g., use constraint defined in 8260.52 of 50 seconds stabilization after roll-out on final)
- Use of altitude windows or some other vertical performance to be determined

- Determination of bank angles/tight turn radii
- Determination of climb gradients
- Changes to ATC separation standards
- Updated (reduced) separation standards for mixed equipage and homogeneous operations
- Reduction of divergence criteria (separation standards) for mixed equipage and homogeneous ops
- Procedural separation criteria for non-radar operations
- Development of RNP charting, phraseology, training, automation tools
- Site specific analysis needed for all implementations

## 4. Next Steps

The near-term next steps in the implementation of criteria and procedures for RNP arrival, departure and approach procedures are captured below. The FAA and industry are encouraged to continue collaborative development along these lines to meet a criteria publication for high priority departure, arrival and approach operations within approximately 18 months:

- Further development and prioritization of concepts described in Section 3
- Scoping of analyses needed to realize high priority concepts
- Conduct of analyses related to high priority concepts
- Modeling of benefits for a selected set of airports
- Drafting of requirements for criteria to implement high priority concepts
- Criteria drafting
- Refining benefits expectations based on criteria, simulation and modeling
- Possible pursuit of “specials” (non-Part 97) and field trials to gain early experience
- Refining operational concepts and criteria based on modeling and field trials
- Criteria publication

# **Applications and Benefits of Required Navigation Performance (RNP) for Large Airports with Surrounding Satellite Operations**

This report, prepared by the Performance-Based Operations Aviation Rulemaking Committee (PARC), informs the Federal Aviation Administration (FAA) on the applications and benefits of Required Navigation Performance (RNP) in and around large metroplex airports with surrounding satellite operations. This information is intended to highlight examples of RNP applications across arrival operations, departure operations, and satellite operations, while providing guidance on some of the actions needed to advance these concepts towards implementation.

## **Introduction**

Area Navigation (RNAV) and Required Navigation Performance (RNP) are key components for improving the efficiency and capacity of the National Airspace System (NAS). RNAV operations improve airport access and permit more flexible, point-to-point operations. RNP introduces on-board monitoring and alerting requirements for aircraft navigation performance, providing alerts to the pilot if requirements cannot be met. RNP, when added to RNAV, improves conformance on a given route, at a specified level of precision, for decreasing the spacing between routes without intervention by air traffic control (ATC), for increasing the number of available routes, and for allowing more efficient traffic flows.

On typical days, Atlanta Center is able to flow more airplanes into the Terminal Radar Approach Control (TRACON)/A80 airspace than the TRACON can accept. This discrepancy can become more problematic during Instrument Meteorological Conditions (IMC), where arrival rates into Atlanta's Hartsfield-Jackson International Airport (ATL) typically drop from approximately 118 aircraft per hour during Visual Meteorological Conditions (VMC), down to approximately 102 aircraft per hour during IMC.<sup>1</sup> This reduction in capacity can result in longer flight paths due to increased vectoring and holding, contributing to delays and higher fuel usage that increase costs to operators. Regardless of issues related to weather, current criteria force long and inefficient downwind legs, up to 20 – 25 NM in IMC and 15 NM in VMC with little consistency among flight tracks. This concept holds true in a dual or triple runway configurations. These long lengths increase fuel burn, increase flight times, and reduce the efficiency of arrival operations.

Large, busy airports, such as Atlanta, stand to benefit from applications of RNAV and RNP in the form of improved airport access, capacity, and efficiency of flight operations. This paper utilizes the ATL model to present a set of potential solutions and benefits that may be achievable at many locations, through applications of RNP. In terms of access and capacity, RNP can be used to increase both arrival and departure rates in VMC and IMC. For arrivals, several concepts are introduced, including the use of additional arrival tracks, connecting Standard Terminal Arrivals (STARs) to standard instrument approach procedures (SIAP) through radius-to-fix (RF) turns, the potential for relaxing separation requirements via RNP containment as a result of

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<sup>1</sup> Average VMC and IMC arrival capacity rates for ATL were calculated based on data obtained from Aviation System Performance Metrics (ASPM) over the one-year period of September 1, 2007 through September 1, 2008.

flights being “established” earlier on approach procedures, and the reduction of both track miles flown and the length of downwind legs through more predictable routings. Mileage reductions and similar efficiencies can also be gained for departures. Ideas are presented to improve efficiency such as additional departure tracks through reductions in departure divergence, additional TRACON-to-en route transitions to lessen the impact of in-trail spacing requirements, and de-conflicting satellite operations to increase throughput.

## Uses of RNP for Arrival Operations

### Additional Arrival Tracks

One of the envisioned benefits of RNP is the possibility of enabling additional arrival tracks, which involves establishing multiple parallel arrival tracks and moving merge points farther downstream to the final approach area. RNP makes this possible by providing better predictability of where aircraft are going to be. This may allow for the creation of simultaneous<sup>2</sup> parallel RNP-RNP tracks with reduced track-to-track spacing for places other than final approach. Figure 1 illustrates the concept of additional arrival tracks and helps show one of its main benefits. The top half of Figure 1 shows a single arrival track operation, where aircraft are constrained by the characteristics and position of the aircraft in front. The bottom half of the figure illustrates that by having more than one track, aircraft are not restricted by other aircraft directly in front of them, which helps lessen the impact on in-trail spacing requirements and increases the opportunities to ensure optimal use of the runways. The RNP tracks provide additional airspace for non-participants and can be used to accommodate unexpected events, as necessary. Each arrival track can employ different speed assignments, so that faster moving aircraft assigned to one track can be safely segregated from, and routed past, slower moving aircraft on another track. By employing a multi-lane freeway concept, the entire arrival stream would not be adversely impacted by slower-moving aircraft, as would be the case in a single-lane arrival stream.

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<sup>2</sup> Simultaneous in this case refers to *independent* operations on parallel RNP tracks, without the need to stagger aircraft on adjacent tracks, as would be the case in a dependent operation.

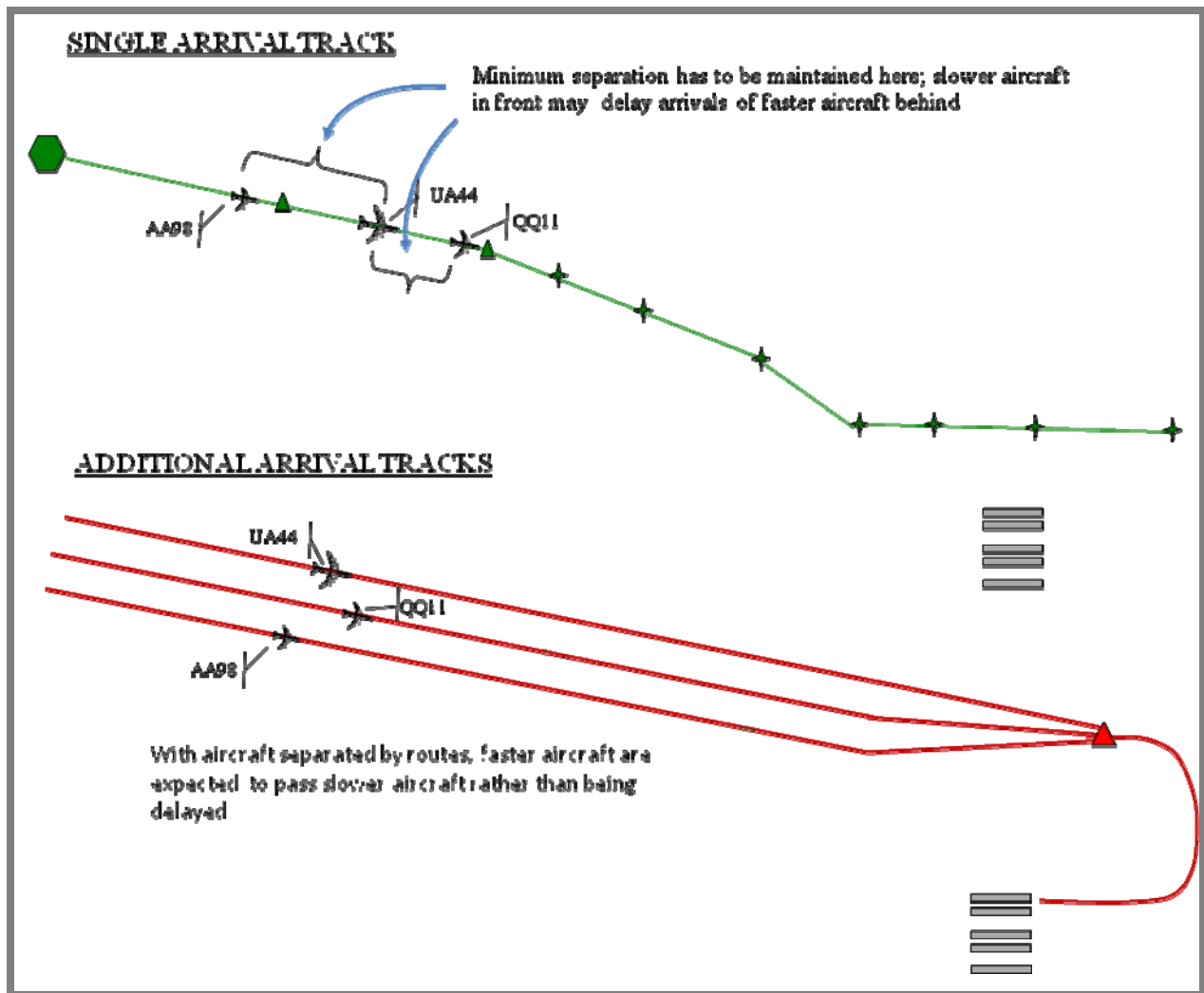
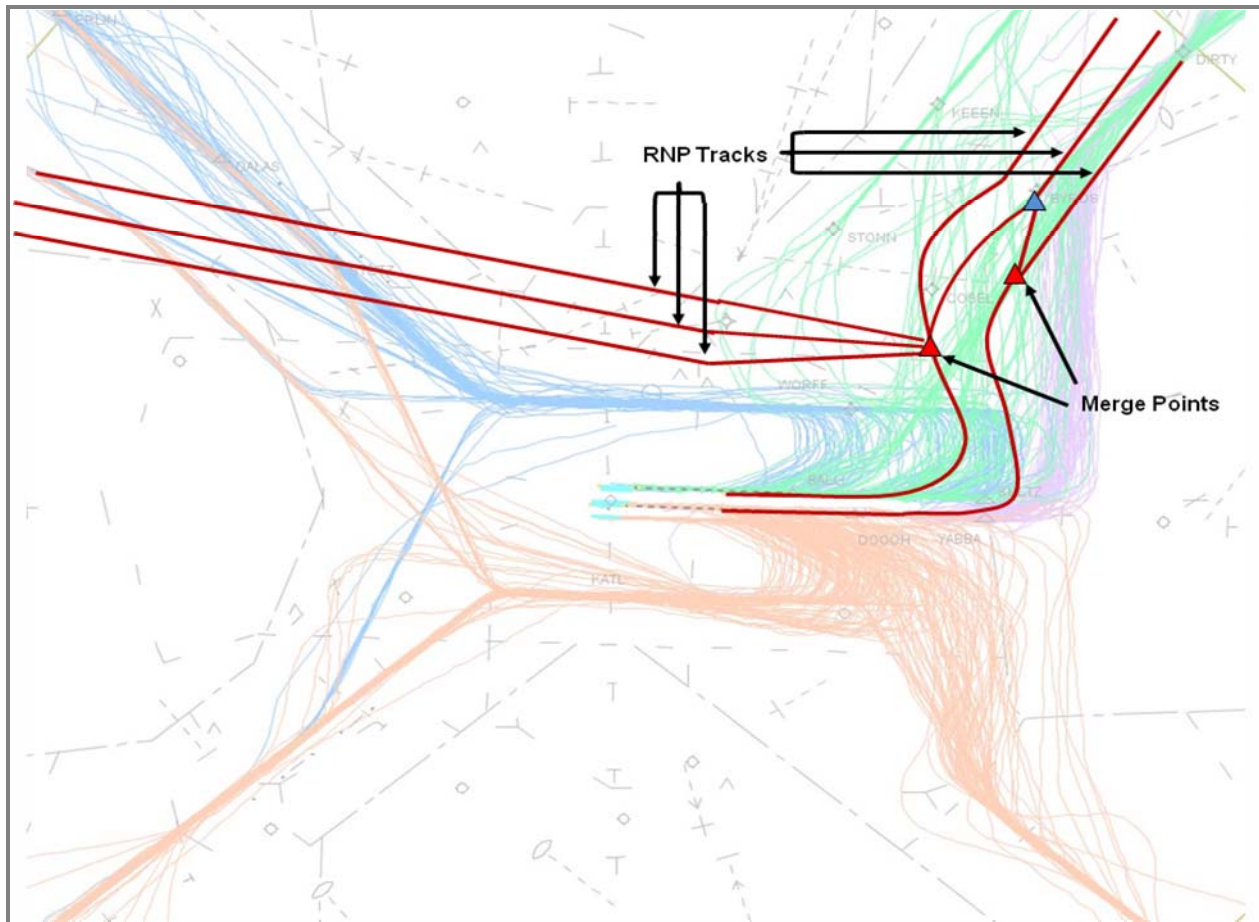


Figure 1: Using RNP for Additional Arrival Tracks

Aircraft on parallel arrival tracks will need to merge at some point into a single, in-trail flow for landing onto a particular runway, or alternatively, will need to be routed to separate runways. Merge points located farther downstream, near the final approach area, improve the benefits associated with having multiple arrival tracks by reducing the amount of time aircraft will need to remain in a single-file flow. Efficiently managing the sequence and merging of aircraft at the merge point will be critical to achieving the benefits provided by multiple arrival tracks. Merging and spacing tools can assist controllers with performing this task. A more efficient merge point closer to final approach also serves to reduce long downwind legs, and could better enable aircraft to fly optimized profile descents at faster speeds. Figure 2 depicts the concept of multiple RNP arrival tracks feeding multiple runways, with merge points located near final approach.





**Figure 2: Merging RNP Tracks Feeding Multiple Runways**

Additional arrival tracks could potentially facilitate the implementation of more efficient vertical profiles. Arrival aircraft with Flight Management Systems (FMS) and Vertical Navigation (VNAV) capabilities can fly very efficient descent profiles that are tailored to each individual aircraft's parameters (e.g., cost indices, weight) along the lateral path defined by the procedure. Flights participating in optimized profile descents (OPDs) can be segregated to one of the available RNP tracks, if needed, while non-OPD participants are allocated to a separate track. This separation could reduce the occurrence of removing aircraft from an optimized descent to avoid conflicts with non-participants, or moving non-participants out of the way, negating the cumulative benefits gained from the use of OPDs. Similarly, if the majority of aircraft are assumed to be OPD-participants, aircraft with similar performance characteristics can be grouped together on a particular track, providing a more predictable and easier operation for air traffic control to manage. While RNP is not a necessity for conducting OPD's, parallel RNP arrival tracks could improve the likelihood of flights remaining on the procedure down to the runway during periods of higher traffic volumes.

### **Connecting STARs to SIAPs with New RNP Transitions**

RNP is envisioned to be used to provide flexibility for spacing and for tighter finals through the use of RNP runway transitions onto final approach. Figure 3 illustrates how this concept could be employed on the ERLIN STAR into ATL. Additional waypoints serve as starting points for potential path options that extend or join a STAR to various glide path intercepts for an

instrument approach, supporting multiple options for the turn to base. The RNP transitions utilize RF turns to provide a more predictable flight path during the turn segment. RF legs may also permit the placement of more turn-on paths, in closer proximity to one another. These RNP transitions can be incorporated onto the end of a STAR procedure (essentially producing separate STARs) or as part of an instrument approach procedure. In the case of appending them to a STAR, each transition, in conjunction with the associated arrival procedure, is treated as an individual STAR that can be loaded into an aircraft's FMS. The multiple STAR options contribute to building a network of RNAV and RNP procedures, which connect en route routes, terminal arrival procedures, and approach procedures to provide a flexible network of routing alternatives.

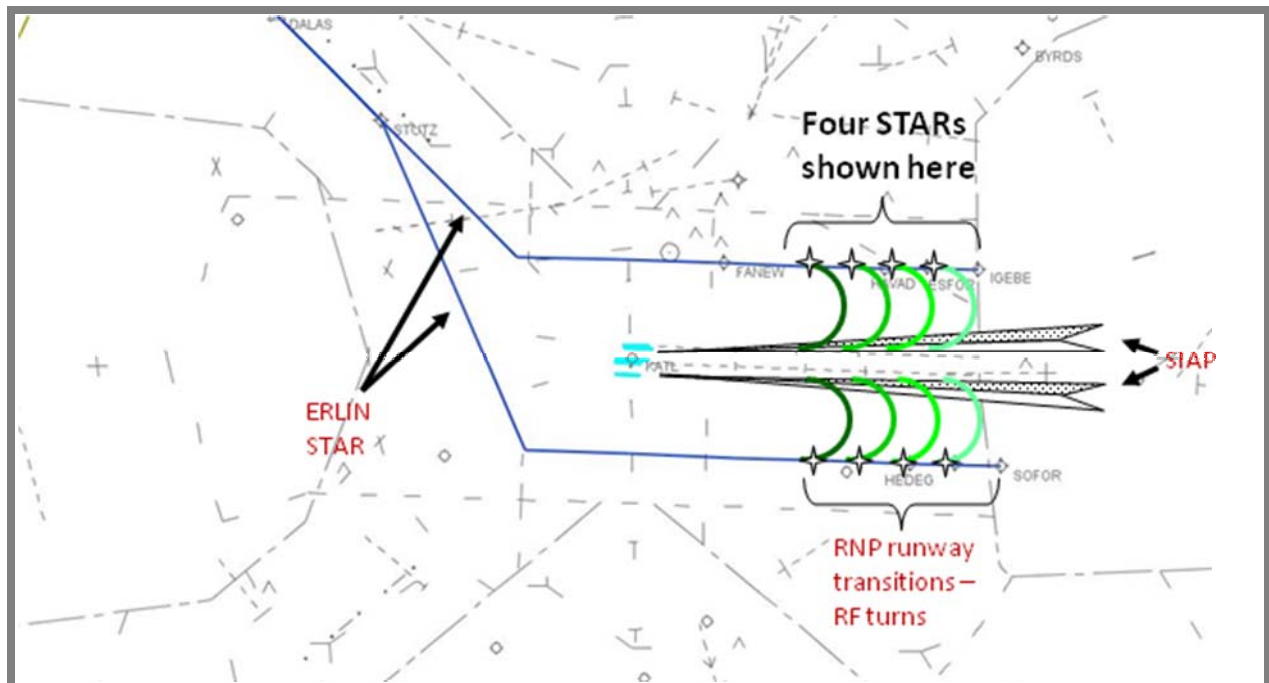


Figure 3: Using RNP Transitions to Connect Arrival Procedures to Approach Procedures

To provide additional flexibility, these RNP transitions could also allow multiple runway options off of a common RNAV/RNP STAR, with RF legs going to different glide path intercept fixes on a straight-in ILS segment. In the example shown in Figure 4, RNP transitions would connect the FLCON arrival to the final approach for the ILS on either runway 26R or runway 27L. Other variations of connecting a STAR to approaches could allow for RNP-capable aircraft to be routed to a designated RNP runway, such as ATL runway 26R in Figure 4, while non-RNP-capable aircraft are routed to an ILS fix on an alternate runway, such as runway 27L. This configuration would accommodate RNP participants in conjunction with non-RNP participants, and could also provide RNP aircraft with an alternative transition should they be unable to perform the RNP approach procedure at a particular time. Several challenges would need to be addressed before this application could be implemented. Appropriate phraseology would need to be determined in order to clear flights on one arrival procedure to different RNP transitions. Additional analysis is needed to assess impacts and modifications to air traffic control procedures, aircrew training and certification, aircraft equipment, and procedure criteria development.

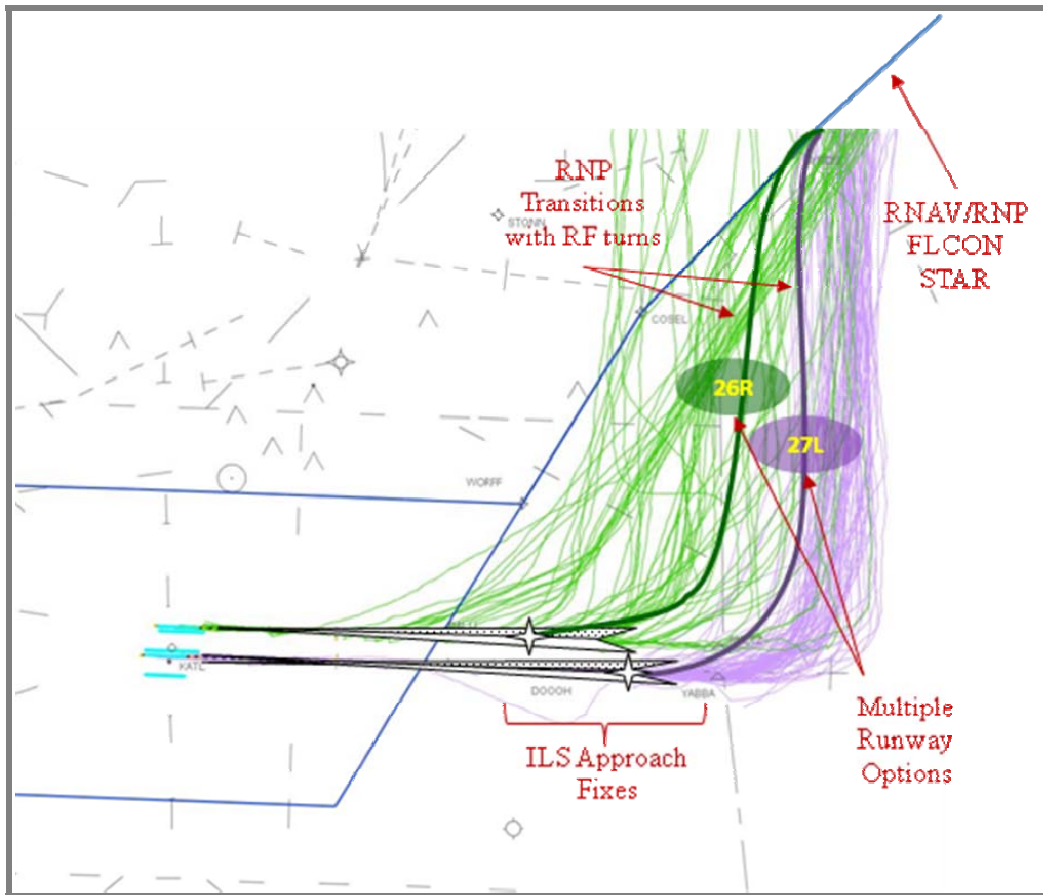


Figure 4: Using RNP to Connect Single STARs to Multiple Runway Approaches with Multiple Approach Fix Options

### RNP in Lieu of ILS for Simultaneous Approaches

RNP with vertical navigation (VNAV) guidance has applications as an alternative to ILS, ensuring airport access and capacity are maintained in the event an ILS on a particular runway fails or is down due to maintenance. RNP in lieu of ILS can be particularly useful for maintaining arrival throughput at airports that utilize simultaneous independent approaches. If the Precision Runway Monitor (PRM) (which enables triple simultaneous instrument approaches via ILS to be used) is out of service, simultaneous approach operations could continue with the use of RNP approaches with VNAV. Simultaneous approach operations using special RNAV GPS approaches on the outboard runways are approved for use at Houston (IAH) through a waiver. A new waiver, under development, would expand the application to allow for special RNP approaches. Safety risk assessment studies have been conducted on the application of special RNAV GPS approaches at IAH, and are expected to continue for the special RNP approaches, pending an approval of the new waiver. Results of these studies can provide guidance for establishing appropriate separation standards for simultaneous RNP approaches to parallel runways (dual and triple), and its applicability to other airports. The eventual goal would involve conducting these operations without the need for a waiver, using public procedures that have been specially designed for safety and efficiency. In addition to designing the necessary procedures, use of this application at other airports, such as ATL, would require changes to FAA Order JO 7110.65, Air Traffic Control, to allow the use of simultaneous RNP approaches.

### **Improved “Metering”**

Current terminal environments often involve air traffic controllers issuing tactical clearances (e.g., speed changes, vectors, changes in altitude) to aircraft to deliver them efficiently and safely from entry into the terminal area to the available runways. Automation tools, such as Traffic Management Advisor (TMA), help en route controllers sustain an airport’s arrival capacity by delivering the right number of aircraft to the terminal area, based on an assumption that the aircraft being delivered will follow a “nominal” route. Nominal routes represent an approximation of how an aircraft might fly under favorable circumstances. However, the actual time it takes for an aircraft to fly from the terminal boundary to the runway can vary significantly from the nominal route’s estimated flight time as aircraft compete for the same resources (e.g., routes, runways) and controllers issue tactical instructions to maintain safety and efficiency.

The higher accuracy of precision RNP approaches could improve metering by providing more efficient and consistent flight paths. Track variability associated with conventional procedures may be reduced, resulting in a reduction in the broad range of disparate flight times to meter fixes. The potential improvements in predictability provided by RNP routes and approaches may also reduce the occurrence of cases where flights are sped up to make meter point crossing times, only to be slowed when they approach slower-moving aircraft in front of them.

### **Increase IMC Arrival Rates While Reducing Mileage Flown**

RNP is envisioned to be used to increase the arrival rate at ATL during IMC. The conventional use of three arrival runways during IMC typically results in 20 – 25 NM finals with inconsistent arrival tracks, as depicted in Figure 5.



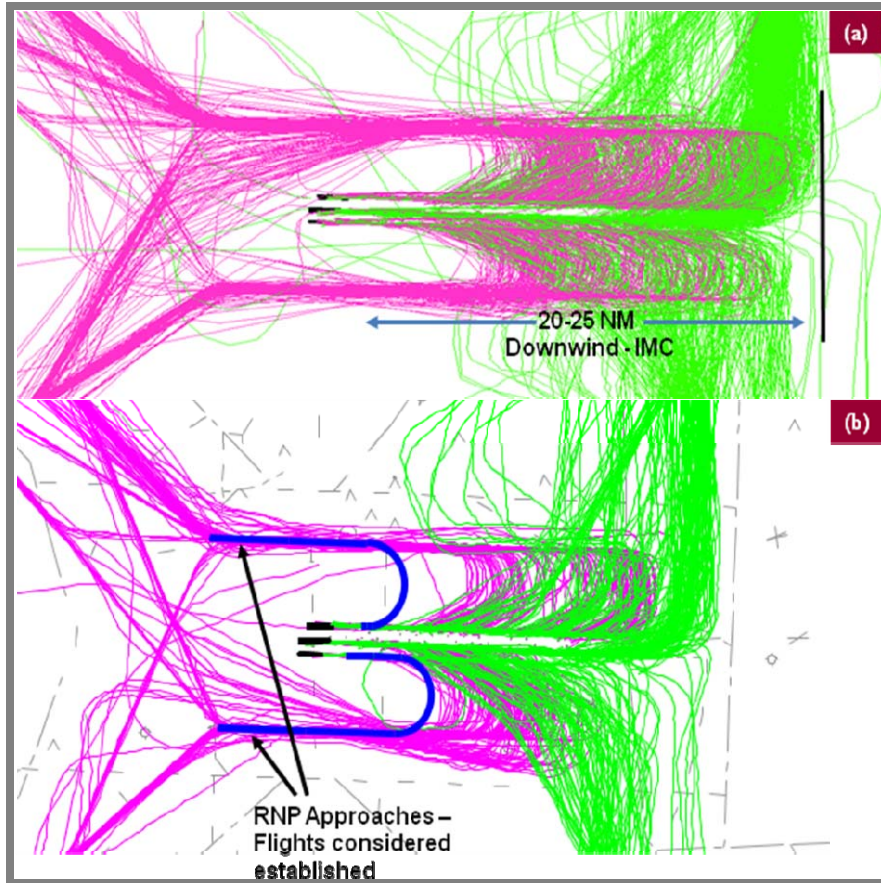


Figure 5: (a) ATL IMC Radar Tracks – Long Downwind Legs – (b) RNP approaches for shorter downwind lengths

The long downwind legs are the result of spacing requirements outlined in the air traffic control procedures of FAA Order JO 7110.65, Air Traffic Control, which specify that a minimum of 1,000 feet vertical or a minimum of 3 miles radar separation between aircraft is required during turn-on to parallel final approach. By incorporating RNP, the need for long downwind legs might be reduced by accounting for RNP (containment) during the turn on to final. The higher precision of RNP might provide the means to allow aircraft to be considered “established” on the Lateral Navigation (LNAV) track earlier, allowing aircraft to turn on to final at the same altitude and negating the need to extend the downwind to achieve the specified separation. This could enable the downwind legs to shrink to an arbitrarily small size, dependant on the altitude of aircraft flying the procedure. Consideration should be given for not making the downwind leg too short, otherwise aircraft may not be able to make it down. For the operation depicted in Figure 5a, aircraft typically enter the downwind at approximately 12,000 feet. A shortened downwind, like the one shown in Figure 5b, would require aircraft to join the RNP approach at approximately 6,000 – 7,000 ft to ensure that they would be able to descend in time.

The concept for incorporating RNP into a triple simultaneous independent approach operation would establish RNP approaches on the outboard runways and ILS approaches for the inboard/center runway, as illustrated in Figure 6. This configuration also accommodates non-RNP participants, providing them with a place to go. In order for the benefits of this concept to be realized, changes would be required to Order JO 7110.65, Air Traffic Control, to allow for aircraft on RNP approaches to be considered established on the lateral approach track, prior to

the turn on to final. Coupling RNP with procedural separation requires further analysis, to include determining ways to leverage advanced navigation and surveillance capabilities, such as local radar and PRM radar (which may already be in place at some locations), to reduce separation requirements when used in conjunction with RNP.

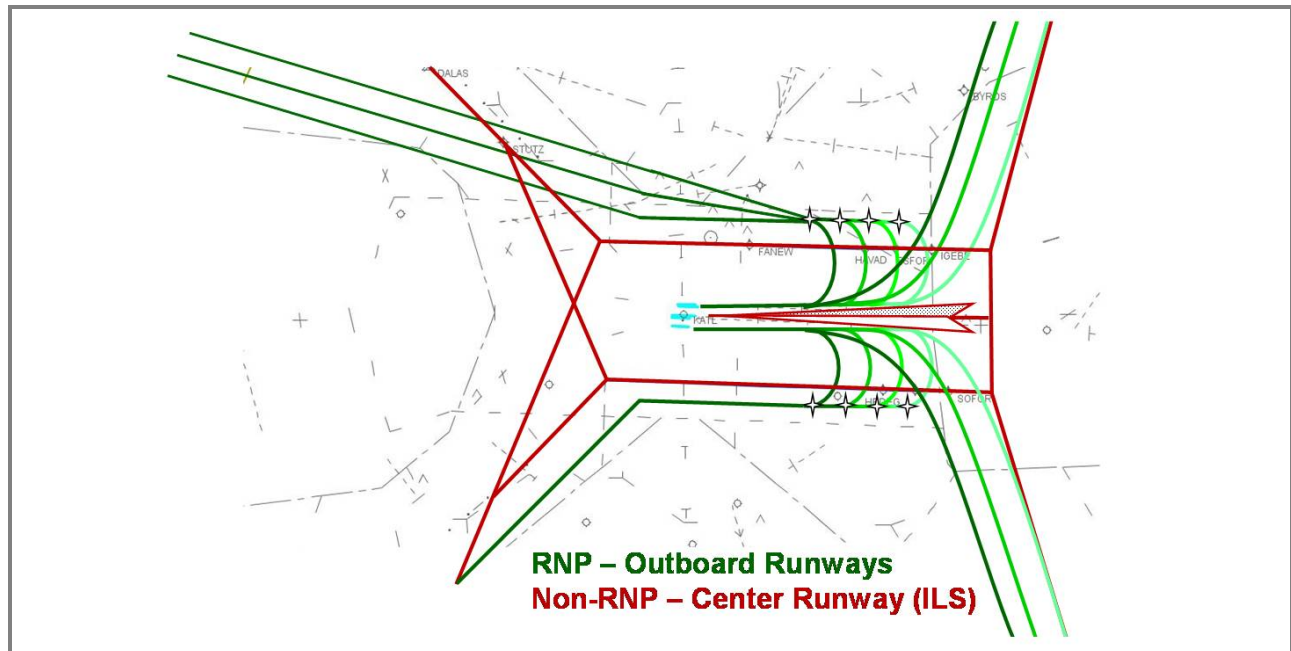


Figure 6: Concept for RNP in a Triple Simultaneous Independent Approach Operation at ATL

## Uses of RNP for Departure Operations

### Additional Departure Tracks

RNP may be applied to departure operations at ATL to improve efficiency and throughput. The higher predictability of RNP operations enables the placement of additional departure tracks inside the bounds of existing ground tracks, since RNP tracks could possibly be spaced closer to one another. RNP, in conjunction with diverging departure tracks, could be applied to departure operations to potentially increase the airport departure rate. In today's operations, ATL utilizes three runways for departures when departure demand is high. This configuration provides three departure flows off of the runway ends, as shown in Figure 7a. If RNP criteria were applied to this departure operation, a reduction in degrees divergence between departure flows may be possible. This reduction may allow for the placement of additional independent departure flows off of the runways, with 5 – 10 degrees divergence between the departure tracks, as shown in Figure 7b. In particular, the typical departure runway on the north side, 8R/26L, which is accessible without any runway crossings, would have two diverging departure tracks according to this concept, instead of just a single track, permitting less time between successive departures when aircraft courses diverge immediately after takeoff, increasing the departure rate of the airport. Further analysis would be needed to determine, and enable, the appropriate reductions in divergence, which, at a minimum, would maintain the current high-level of safety in departure operations.

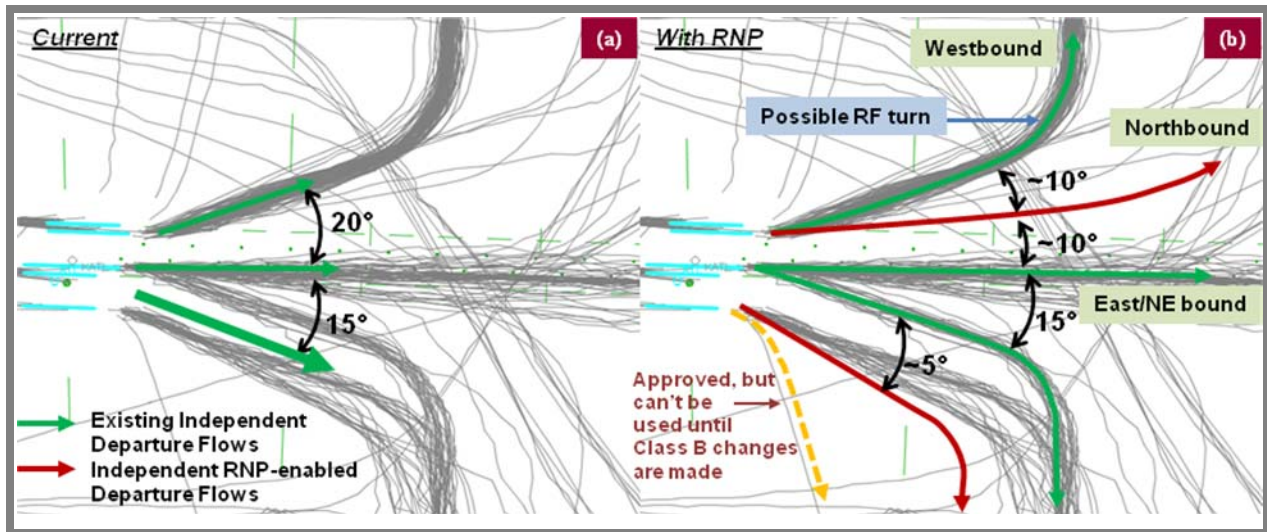


Figure 7: Using RNP for Additional Departure Tracks – (a) Current departure tracks at ATL (three) – (b) Five departure tracks possible with RNP

### Additional Transitions between TRACON and Center

Applications of RNP are envisioned to also be employed in the TRACON to provide additional transition points between the TRACON and Center. Currently, handoffs from A80 TRACON to ZTL Center are limited by in-trail restrictions over the transition fixes. ATL departures that are headed towards the same transition fix are required to remain 3 miles in-trail, increasing to seven miles by the time they enter ZTL airspace. RNP may allow for the placement of additional departure tracks within the same volume of airspace, laterally separated by 3 – 4 miles, allowing additional transition fixes to be established between the TRACON and the Center.

Currently, for ATL departures to the east, there are four transition fixes between A80 and ZTL. Six transition fixes, as illustrated in Figure 8, have desirable benefits such as redundancy, and may be conceivable with RNP operations, to improve throughput. Placing satellite traffic and Charlotte (CLT) arrivals on RNP routes (or minimally on RNAV routes), is expected to further deconflict operations and improve efficiency, while minimizing spacing needs. These additional, parallel routing options could potentially lessen the impact of in-trail spacing requirements and increase the TRACON-to-Center aircraft acceptance rate.



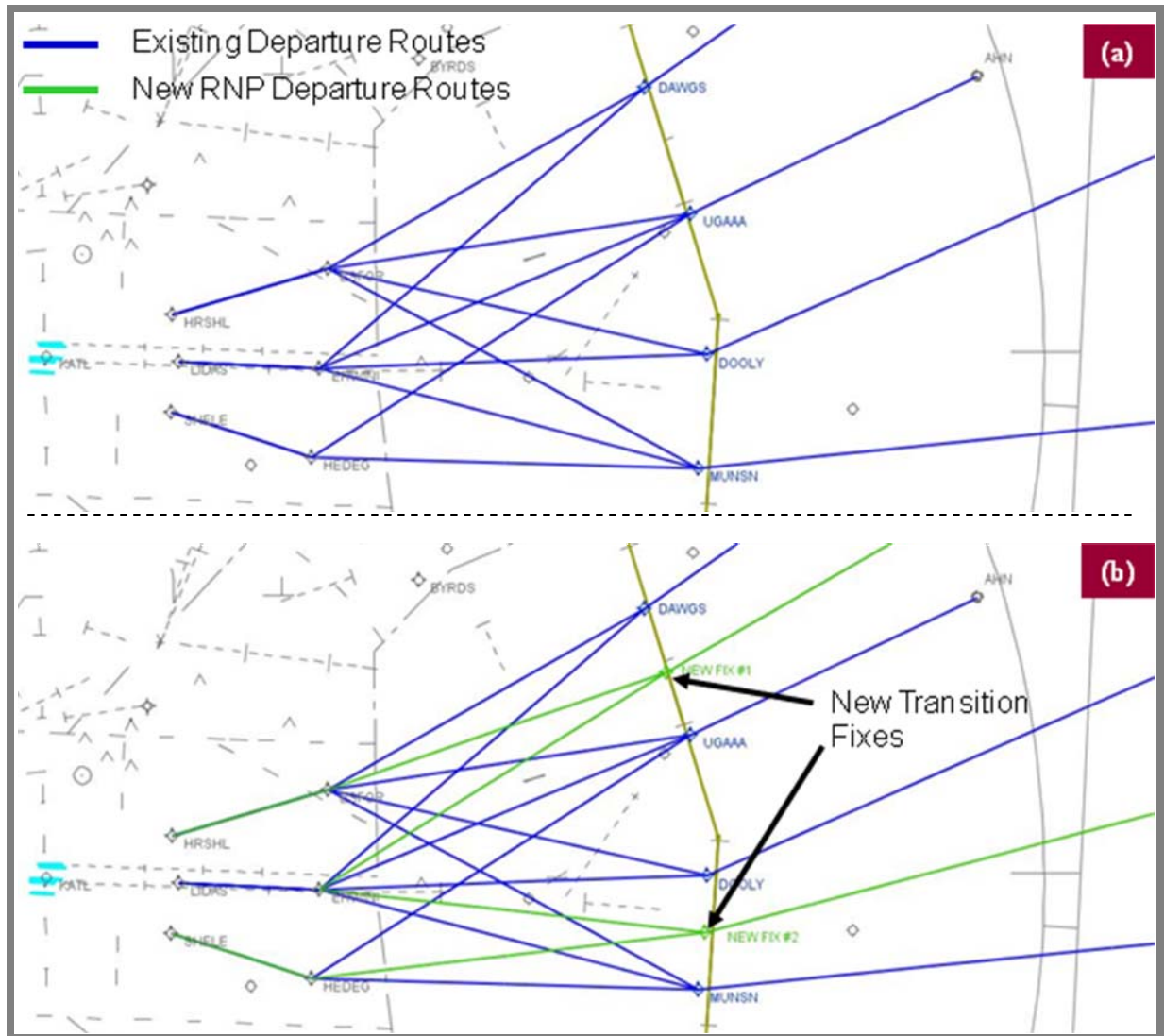


Figure 8: Additional Transitions from TRACON to Center – (a) Current configuration - four transition fixes to the east: DAWGS, UGAAA, DOOLY, MUNSN – (b) Two new transition fixes, enabled by RNP routes, placed in between existing departure routes

The additional routing options would also better accommodate weather events by providing alternate means of egress when weather impacts other routes. The example depicted in Figure 9 illustrates a situation where weather closes the southern departure gate to the east. RNP routes, as depicted, would allow for three separate departure flows to the east that avoid the weather, while still utilizing three runways for departures to minimize the impact on throughput.

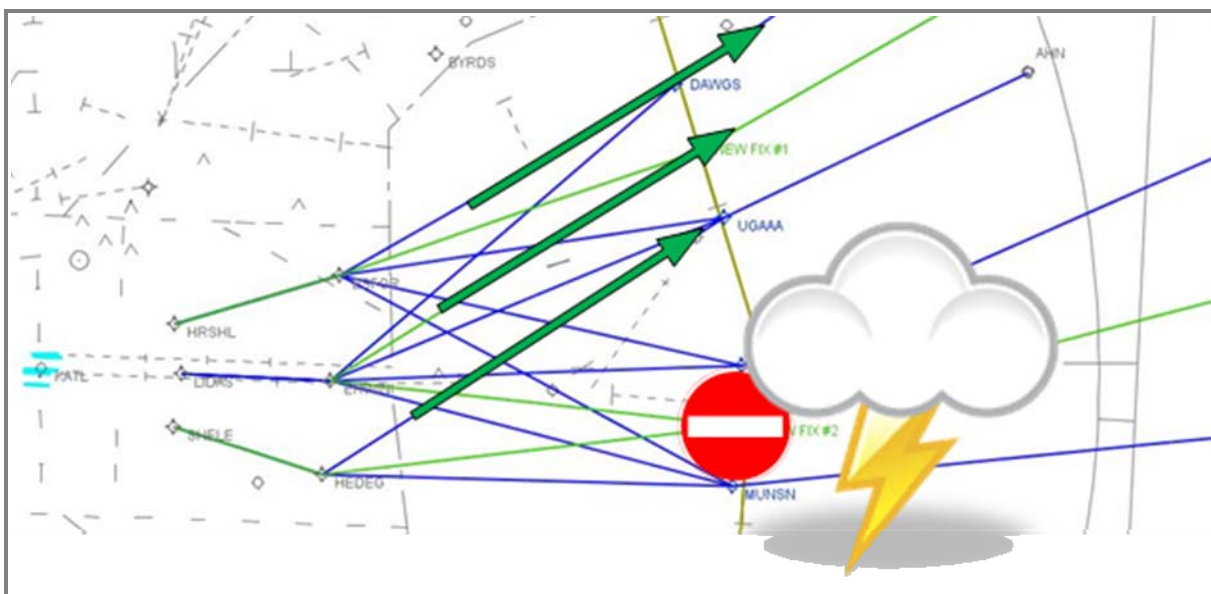


Figure 9: Accommodating Weather with RNP

The expected increase in departure tracks and transition fixes would provide more flexibility and support for mixed performance aircraft. Faster aircraft are expected to be better segregated from slower aircraft, so that all aircraft are not constrained to flying the same speed. Other benefits that RNP might provide to departure operations include reducing track mileage flown due to more direct and precise routings and more efficient vertical profiles due to fewer level offs, which are often necessary in congested airspace. RNP may be able to provide these benefits through more efficient use of existing airspace.

In order to assess locations for suitability and the placement of additional tracks, the appropriate spacing standards between RNAV/RNP tracks and RNP/RNP tracks need to be determined and published. These standards would encompass the separation between adjacent SIDs, between adjacent STARs, and between an adjacent STAR and SID. Standards for the en route and terminal environments should be compatible, such as 3-mile separation for RNP routes in both en route and terminal airspace, while not requiring that separation be constantly increasing when flights are on RNP tracks.

## Uses of RNP to De-conflict Satellite Airport Operations

### RNP to Segregate Satellite Traffic from ATL

Satellite traffic in the Atlanta TRACON airspace presents a number of challenges due to the proximity to ATL, as well as a wide variety of aircraft types. The RNP proposals for ATL arrivals and departures provide benefits to satellite airport traffic indirectly by freeing up airspace for arrivals and departures to the satellite airports; however, RNP procedures to and from these satellite airports may provide more direct benefits. Currently, aircraft are vectored from satellite airports to emulate ATL Standard Instrument Departures (SIDs). To streamline operations, departing aircraft from satellite airports could be joined to existing ATL SIDs at new waypoints. An example is given below in Figure 10, showing Peachtree-Dekalb (PDK) departures joining the ATL RMBLN SID.

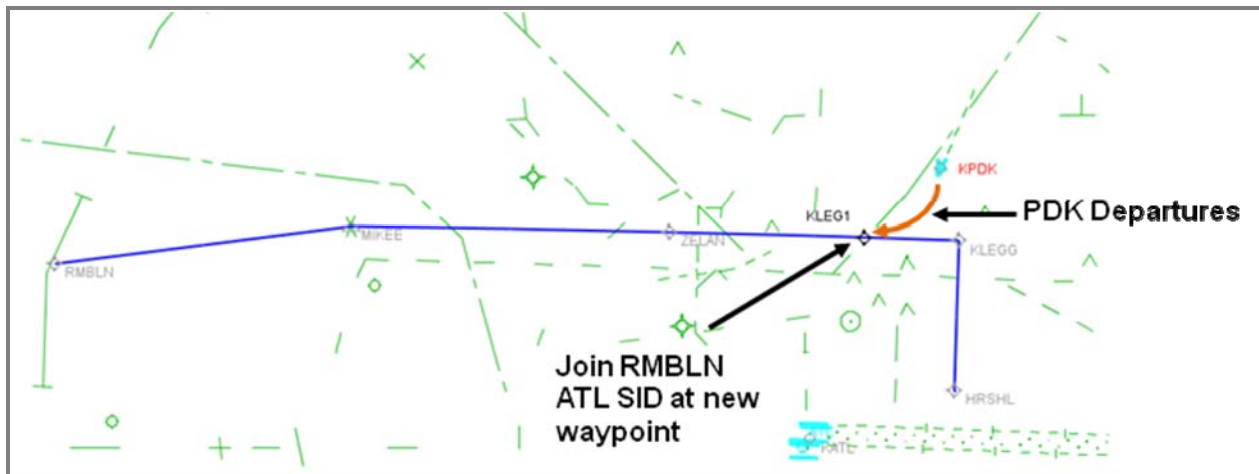


Figure 10: Joining Satellite Departures to Existing SIDs

Next steps could involve using RNP to generate dedicated SIDs for satellite airports that run parallel to the ATL procedures, segregating satellite traffic entirely from ATL traffic. Figure 11 shows PDK with a dedicated RNP SID parallel to the RMBLN, as envisioned in this concept.

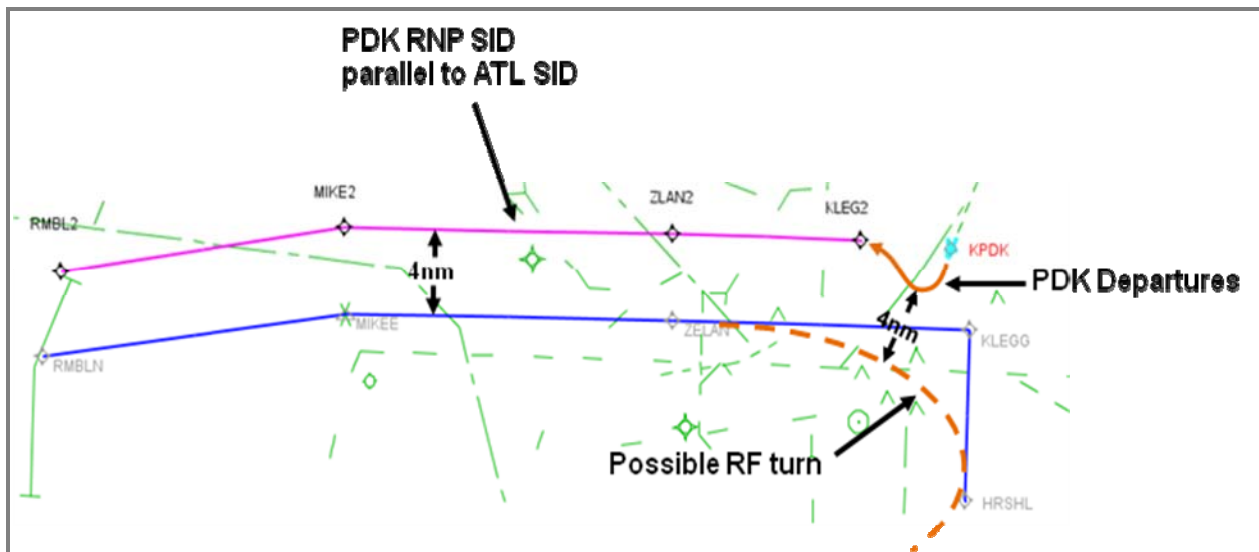


Figure 11: Separating Satellite Traffic Using Parallel RNP SIDs

### Transitions to Connect STARS to Existing RNP Approaches

Some RNP approach procedures have already been implemented at satellite airports to help deconflict satellite traffic from primary airport flows. PDK's RNAV(RNP) Z RWY approach (already published) is an example of RNP approach benefits, as obstructions south of the airport have prevented implementation of other kinds of approaches. In order to improve the efficiency of existing RNP approaches, feeding STARS should intercept the initial approach fixes (IAFs) of those approaches, or transitions should be published to connect the last waypoint of the STAR to an appropriate IAF for the RNP approach. Using PDK as an example, a transition is published in the RNAV (RNP) RWY 2R approach procedure to connect the TRBOW STAR at TUCKR to the waypoint FALTA, which serves as an IAF for the approach procedure. Similarly, a transition is published in the RNP approach procedure to connect the end of the AWSON STAR at DLUTH

to the IAF at POCIV. Figure 12 shows the STARs connected with the existing RNP approach procedure. Where existing RNP approaches do connect to existing STARs, further studies should be conducted to identify the potential benefits that this combination can provide, and its applicability to other reliever airports.

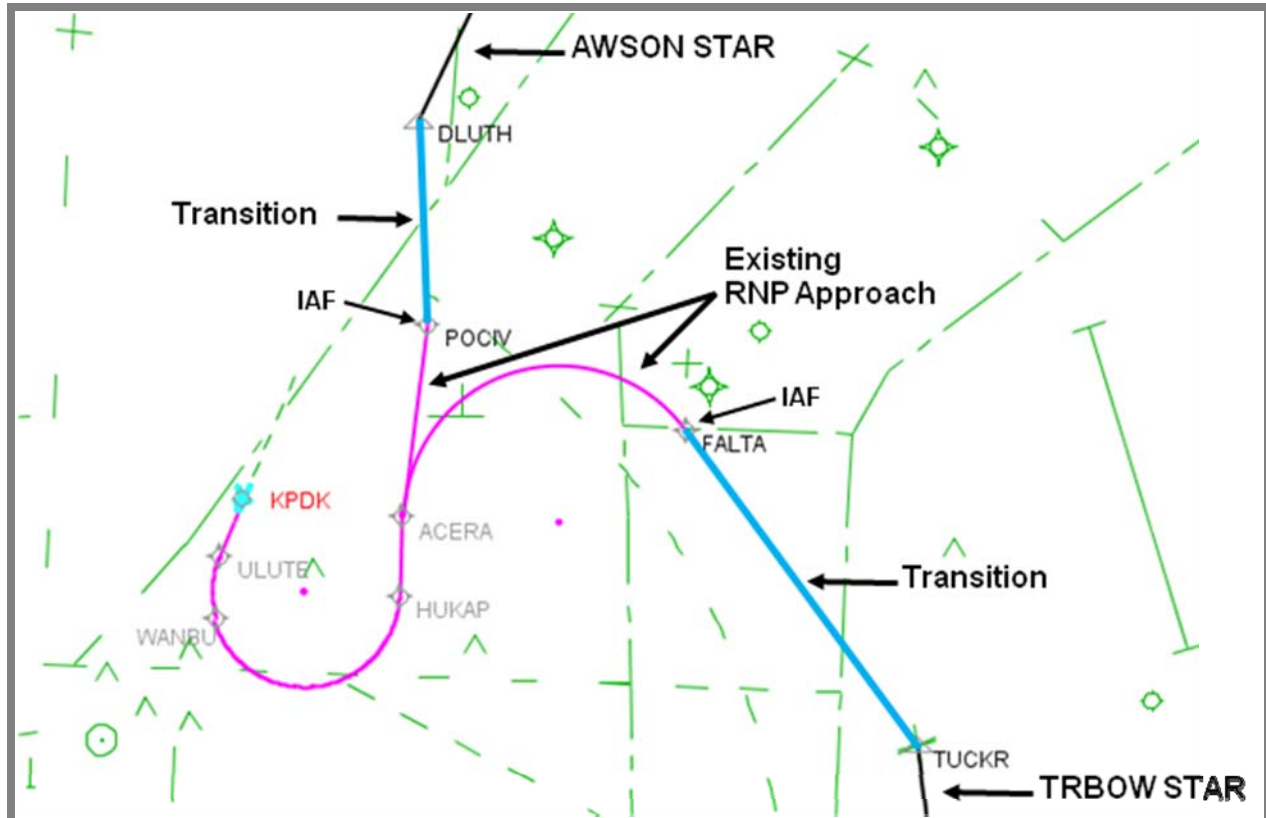


Figure 12: Connecting STARs to RNP Approach Fixes

It should be noted that the PDK STARs do not intercept the IAFs available for RNAV (GPS) approaches. Since RNAV (GPS) approaches are the basis for AC 90-RNP approach operations, similar consideration should be given to connecting the STARs to RNAV (GPS) approaches.

## Conclusions and Next Steps

In order to realize benefits of RNP at large airports such as ATL, additional actions are needed. This section outlines several study areas needed to better understand the applications and begins to enumerate the actions needed:

- Analysis is needed to determine the role of RNP (alone, and in combination with other NextGen technologies) as a separation tool, for instance to allow adjacent RNP tracks to be considered procedurally separated. (If aircraft on adjacent RNP tracks are considered procedurally separated, controllers may need to only monitor an aircraft's conformance to the track, reducing controller workload.)
- The appropriate spacing between RNAV/RNP tracks and RNP/RNP tracks needs to be analyzed.

- Analysis of separation standards should also revisit the assumptions regarding blunder mitigation on approaches, taking into account the use of RNP to potentially allow more efficient turns to final during simultaneous operations.
- Reductions in vertical separation requirements for the turn to final should also be considered for aircraft on RNP approaches. These reductions could allow for shorter downwind lengths by considering aircraft established on the approach track at an earlier point. Analysis is needed to determine the appropriate amount of reduction that would provide the desired benefits while maintaining safety.
- RF turns should be further studied to determine the appropriate applications that allow the downwind to be moved closer to the runway, while also providing a shorter downwind length. A schedule for introducing RF segments should be considered, so that operators know when they should equip.
- Reductions in degrees divergence (less than 15 degrees) should be considered for diverging RNP departure tracks. These reductions could allow for an increase in the number of departure tracks off of eligible runways, providing an increase in departure throughput. The benefits associated with this application and suitable airports for its use need to be determined.
- The need for controller automation tools, which leverage the higher predictability of RNP, should be analyzed to improve the efficiency of operations. The needs for improved metering should be studied and better metering tools, with the ability to meet meter point times to the accuracy of seconds, not minutes, should be implemented. Merging and spacing tools, to include preferred airborne tools using real-time data when/where available, and ground-based tools should be studied.