Performance-Based Navigation: Area Navigation (RNAV) and Required Navigation Performance (RNP) Program

Presentation to:  EWG Ops SC
Name:  Jim Arrighi, RNAV/RNP Group
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Overview

• What is Performance-Based Navigation (PBN)?
• History of PBN
• Stakeholders
• 18 Step Process
• RNAV/RNP Implementation Sites
• RNAV/RNP Benefits
• RNAV/RNP Implementation Projects
• Moving Forward – Integrated Procedures Concept
• RNAV Equipage
• Aircraft and Operator Approvals
• Challenges to RNAV/RNP
• International Harmonization
Performance Based Navigation (PBN)

- Performance-Based Navigation (PBN) Instrument Flight Procedures (IFPs) include:
  - RNAV - Standard Instrument Departure (SID)
  - RNAV - Standard Terminal Arrival Route (STAR)
  - RNAV - Q & T Routes
  - RNAV (RNP) Approach (RNP SAAAR)

- Over 18,000 Instrument Flight Procedures in the NAS
  - Nearly half (48 percent) are now PBN Procedures

- 45 Major Airports (346 Runway Ends)
  - By the end of FY09 - 97% will be served with PBN Procedures
History of PBN

- Industry requests the establishment of an RNAV/RNP Program at FAA-RTCA Spring Forum 2002
- FAA Administrator issued a policy statement committing FAA to aggressively pursue the implementation of RNAV and RNP in the National Airspace System - July 22, 2002
- Roadmap for Performance-Based Navigation published with industry coordination - July 2003, August 2006 (v2)
- Roadmap initiatives incorporated into NextGen Implementation Plan and FAA Enterprise Architecture - 2008/2009
Summary of FAA & Industry Interactions to Achieve PBN Evolution

- Mid-term capabilities and long-term benefits (Integration with ADS-B, Data Comm & TFM)
- Airspace Changes (RNAV Everywhere & RNP Where Beneficial)
- Criteria, Standards, and Guidance Materials
- Avionics & Certification
- Operator Approvals
- Equipage
- Procedures Implementation
- Automation
- Training
- Issue Resolution
- International Harmonization

NextGen & PBN Roadmap Concepts and Implementation

Nav Modernization & Services (AJW and AJR)

Procedures, Issues Resolution, SMS, Data Collection and Analysis (AJR, AFS, AIR, AJW, AOV, & Industry)

PBN Criteria, Standards, Rulemaking/Policy (AJR, AFS, AIR, & AJW)
Stakeholders in PBN Procedure Development Process

- RNAV/RNP Group
- Aviation System Standards
- Flight Standards
- Aircraft Certification
- Lead Operator
- ATC Facilities
- Service Center
  - Ops Support
  - Environmental Office
  - Safety Management Office
- Airport Authority

Procedure Proponents

- National Initiatives
- Lead Operators
- Airports and/or Air Traffic Facilities
- Industry User Groups
18-Step RNAV Implementation Process

- Developed through FAA, Industry, and MITRE collaboration
- 18 systematic manageable steps
- Provides RNAV Working Groups with standardized process for the development and implementation of Terminal RNAV procedures (STARs and SIDs)
- Defines the specific roles and responsibilities of the collaborative Working Group members
- Supports a collaborative effort
- We are now expanding the process for RNP applications
RNAV Arrival and Departure Procedure Sites

2005 – July 2009 [Cities in bold have OEP airports]

- Alaska (Adak, Akhiok, Anaktuvuk Pass, Anchorage, Arctic Village, Atka, Golovin, Juneau, Kaltag, Ketchikan, King Cove, Nondalton, Palmer, Perryville, Petersburg, Ruby, Sitka, Willow)
- Arizona (Glendale, Goodyear, Phoenix, San Carlos, Sedona, Tucson)
- California (Alturas, Borrego Valley, California City, Long Beach, Los Angeles, Mojave, Oakland, San Diego, San Francisco, Santa Monica)
- Colorado (Aspen, Holyoke, Lake County, Nucla, Rifle, Walden)
- Florida (Boca Raton, Ft. Lauderdale, Ft. Myers, Miami, Naples, Orlando, Tampa, West Palm Beach)
- Georgia (Atlanta-Hartsfield, Augusta-Regional, Augusta-Daniel)
- Hawaii (Hana)
- Idaho (Arco, Driggs, Grangeville, Hailey)
- Illinois (Chicago-O’Hare, Chicago-Midway)
- Kentucky (Covington, Louisville)
- Maryland (Baltimore)
- Massachusetts (Boston, Nantucket)
- Minnesota (Minneapolis-St. Paul)
- Montana (Colstrip)
- Nevada (Carson City, Las Vegas, Reno)
- New Hampshire (Manchester)
- New Jersey (Newark, Teterboro)
- New York (New York-Kennedy)
- North Carolina (Charlotte)
- Ohio (Cleveland)
- Oregon (Portland)
- Pennsylvania (Philadelphia)
- Puerto Rico (Isla de Vieques, San Juan)
- Rhode Island (Providence)
- Tennessee (Memphis)
- Texas (Dallas-Ft. Worth, Houston-Bush Intercontinental)
- Utah (Heber City, Richfield, Salt Lake City)
- Virginia (Washington-National, Washington-Dulles, Virginia Tech)
- Washington (Seattle-Tacoma)
- Wyoming (Afton, Kemmerer, Ten Sleep)
RNP SAAAR Approach Procedure Sites

2005 – July 2009 [Cities in bold have OEP airports]

- Arizona (Phoenix, Prescott, Scottsdale, Tucson)
- California (Bishop, Burbank, Long Beach, Los Angeles, Monterey, Ontario, Palm Springs, San Francisco, San Jose)
- Colorado (Hayden, Rifle)
- Ecuador (Quito)
- Florida (Ft. Lauderdale, Miami, Tampa)
- Georgia (Atlanta-Hartsfield, Atlanta-Fulton, Atlanta-Dekalb)
- Guam (Agana)
- Hawaii (Honolulu, Lihue)
- Idaho (Hailey)
- Illinois (Chicago-Midway)
- Indiana (Gary, Indianapolis)
- Kentucky (Covington, Louisville)
- Maryland (Baltimore)
- Minnesota (Minneapolis-St. Paul)
- Missouri (Kansas City)
- Montana (Helena, Kalispell)
- Nevada (Reno)
- New Hampshire (Manchester)
- New Jersey (Newark)
- Oklahoma (Oklahoma City)
- Oregon (Portland)
- Pennsylvania (Pittsburgh)
- Tennessee (Memphis)
- Texas (Dallas-Ft. Worth, Houston-Bush Intercontinental)
- Virginia (Washington-National, Washington-Dulles)
- Washington (Seattle-Boeing Field)
- Wyoming (Jackson)
En Route Example – RNAV Routes
Increased Capacity and Access

- T-routes requested by Aircraft Owner’s Pilot’s Association (AOPA)
- Better access to Class “B” and Class “C” airspace
- Reduced mileage and increased en route capacity due to lower Minimum En Route Altitudes (MEA) based on GPS
RNP Approach with Authorization Required
Enabling Features (RNP SAAAR)

- Narrow lateral linear segments
- Curved segments anywhere along the approach
- Guided, narrower turns on missed approaches
- Performance-based Vertical Buffers

Vertical Error Budget &
Guided Missed Approach

• Note – RNP AR is the international equivalence of RNP SAAAR
De-confliction of Chicago O’Hare/Midway Using RNP SAAAR

- Effort allows procedural separation for aircraft departing Runway 22L at Chicago O’Hare Airport (ORD) from RNP aircraft landing Runway 13C at Midway Airport (MDW)
- RNP instrument approach procedure allows greater use of Runway 13C during certain configurations
PBN Addresses Complexities in the Terminal Domain

Satellite Vectored Ops
ATL RNAV STARs
ATL RNAV SIDs
Atlanta (ATL) Departure Procedures Before and After

- Approximately 94% of daily departures are RNAV-capable
- More departure lanes and exit points to the en route airspace
  - Capacity gain of 9-12 departures per hour
- Repeatable and predictable paths
- Benefits
  - Increased throughput
  - Reduced departure delays
  - $30M annual benefit (at 2007 demand levels)
  - Cumulative savings through 2008 is $105M
Dallas Fort Worth International (DFW)

- RNAV enabled diverging departures at DFW
- Diverging departures allow for the application of same runway separation standards, reducing inter-departure times
- Reduction of inter-departure times yields an increase in departure capacity
  - 11 to 20 additional operations per hour
- Increased departure capacity results in approximately between $8.5M and $12.9M in delay savings per year
  - At 2005 demand levels
- Cumulative savings through 2008 is $30M
RNAV Arrivals

Optimized Profile Descent (OPD) Arrivals

- **OPDs provide large benefits for fuel, emissions, and flight time**
  - May 2008 Demos
    - DIRTY STAR at Atlanta (ATL)
      - 38 gallons of fuel savings and 360kg reduction in CO$_2$ emissions per flight
    - RUTLG STAR at Miami (MIA)
      - 48-52 gallons of fuel savings and 460-500kg reduction in CO$_2$ emissions per flight
  - 600 OPD nighttime demos at ATL from August - November 2008
    - VIKNN and NOTRE STARs
      - 40-60 gallons of fuel savings and 380kg reduction in CO$_2$ emissions per flight
RNAV Example OPD Site Selection Process

• Conducted a NAS-wide high-level analysis for prioritization of OPD implementation sites (Feb 09)
• Analyzed 4,000 flows at 1,800 airports and ranked by complexity of implementation, relative benefit, and resource readiness
  • Complexity ranks sites by challenges to OPD implementation
  • Site impact ranks sites on greatest impact
  • Resource readiness identifies sites that are currently planned for RNAV
• Next steps
  • Compare various weighted rankings
  • Develop a composite site list for detailed site evaluation
  • Continue targeted site development and implementation
Industry Collaboration Example - Delta Air Lines

- Currently, we are refining a technical proposal for a multi-year project in the Atlanta (ATL) terminal area to utilize radius-to-fix (RF) legs on RNP procedures to improve the efficiency of simultaneous independent parallel approach operations.
- The concept of operations is based on PARC's 2008 report, "Applications and Benefits of RNP for Large Airports with Surrounding Satellite Operations" and is strongly supported by Delta Air Lines.
- Potential benefits include multi-million dollar annual fuel cost savings for RNP procedure users based on proposed reductions in downwind leg distance flown prior to joining straight-in final approach course.
Industry Collaboration Example—Southwest Airlines

- RNPs scheduled for publication on August 27, 2009
  - Raleigh Durham, NC (Curved Path)
    - RNAV (RNP) Z Rwy 5R
    - RNAV (RNP) Rwy 23L
    - RNAV (RNP) Rwy 23R
    - RNAV (RNP) Z Rwy 5L
  - Boise, ID (Curved Path)
    - RNAV (RNP) Z Rwy 10R
    - RNAV (RNP) Rwy 10L
    - RNAV (RNP) Rwy 28R
    - RNAV (RNP) Z Rwy 28L
Begin Integrated Procedures Concept: Benefit Focused

- An integrated procedures concept will provide a framework for integration of PBN initiatives from departure to approach.

- Integration of Procedures includes:
  - Utilization of additional TRACON ingress/egress points that are not tied to ground-based NAVAIDS.
  - Concurrent development and implementation of SIDs and STARs (including OPDs) to ensure integration.
  - Decoupling of operations between primary and satellite airports in complex TRACON airspace.
  - Development of direct city/TRACON pair procedures through congested airspace.
Integrated Procedure Development

Benefits

**En Route**
- More efficient routing
- Multiple Q-routes for better utilization of available airspace
- Direct routes between busy city/TRACON pairs
- Reduction in bottlenecks and delay propagation

**Terminal**
- Integrated STAR and SID procedures
- Optimal operation of primary and satellite airports without interference
- More efficient management of TRACON flows via additional ingress/egress waypoints
- Fuel efficient routing
- Reduced overall noise and emissions

More efficient routing
- Reduction in bottlenecks and delay propagation
- Direct routes between busy city/TRACON pairs
- Multiple Q-routes for better utilization of available airspace

Reduced delays with increased throughput, predictability, and flexibility of the system
- Seamless integration of TRACON and en route domains
- Fuel efficient routing

Optimal operation of primary and satellite airports without interference
- More efficient management of TRACON flows via additional ingress/egress waypoints
- Reduced overall noise and emissions
Integration of Procedures Example
Applications for De-confliction, Optimization, and Benefits

• Segregate traffic flows
  • Between arrival/departure and transitions operations
  • Between primary and satellite airport operations
  • Between city pairs
Integration of Procedures Example
Integrated Development of RNAV SIDs and STARs

- Current STARs at Dallas-Fort Worth (DFW) are conflicting with departure flows
- The aircraft would cross vertically within 1,000 feet if the procedures were used at the same time
- Controllers are unable to use the two procedures simultaneously

- Integrating the development of the SIDs and STARs allows for simultaneous use of the airspace without conflict
- Enables the development of OPDs while reducing the impact to departures
- Enables utilization of airspace by neighboring airports
Current RNAV Equipage – Top 34 Airports
RNAV Equipage Capability
Aircraft Approval

• RNAV and RNP are *Performance-Based* initiatives in that the required performance is specified for the operation, rather than a required system or sensor
  ▪ This allows technology evolution, without recurring procedure development or operational training

• The performance requirements were developed to capture capabilities that had already been deployed by individual manufacturers
  ▪ Allowed thousands of aircraft to immediately qualify, without further investment
  ▪ Requires criteria to accommodate aircraft differences
  ▪ Performance requirements depend on the operation
  ▪ RNP SAAAR approaches are the most demanding
  ✔️ Note – RNP AR is the international equivalent of RNP SAAAR
Aircraft Approval

- Current (estimated) aircraft capability:

<table>
<thead>
<tr>
<th>Type of Operator</th>
<th>RNAV-Capable</th>
<th>RNP AR Approach - Capable</th>
<th>Total U.S. Fleet (Active)</th>
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<tr>
<td>Air Carrier[1]</td>
<td>6285</td>
<td>2631</td>
<td>7250</td>
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<tr>
<td>General Aviation[2] (including business and personal)</td>
<td>80000</td>
<td>100</td>
<td>131700</td>
</tr>
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</table>

[2] Fleet size from CY2007 GA and Air Taxi Survey, for active fixed wing aircraft and on-demand rotorcraft operators. GPS equipage estimated from CY2005 survey (latest year for which detailed avionics information is available).
Operational Approval

• Air Commerce: Operators must obtain approval prior to conducting PBN operations
  ▪ Provides FAA with ability to ensure highest level of safety is met

• General Aviation
  ▪ RNP SAAAR Approaches: Operators must obtain approval prior to conducting operations – due to complexity of operation
  ▪ All other PBN: Operational approval is not required

• Flexible approval process – FAA provides several methods to obtain approval
  ▪ Coordinated with aircraft approval
RNP SAAAR/RNP AR Aircraft Approvals

- **Aircraft approved**
  - Boeing: 737
  - Airbus: 318/319/320/321
  - Gulfstream: 450/550

- **Future Aircraft approvals**
  - Boeing: B-777, -767, -757
    - Application by Boeing for fleet-wide documentation and qualification is pending
  - Embraer: E-170, -190
  - Cessna: TBD
  - Bombardier: TBD
  - Dassault: TBD
Future Manufacturer RNP AR Fleet Approvals

- Boeing*: B-777, -767, -757
- Embraer: E-170, -190
- Cessna: Citation
- Bombardier: TBD
- Dassault: TBD

*A number of airlines are approved to use these aircraft models for RNP AR operations. Application by Boeing for fleet-wide documentation and qualification is pending.
RNP SAAAR/RNP AR Operator Approvals

- Alaska Airlines: B-737
- American Airlines: B-737/757/767/777
- Boeing Flight Test: B-737
- Continental: B-737/757/767/777
- Delta Air Lines: B-737/757/767/777
- JetBlue: A-320
- Johnson and Johnson: G-450/550
- Honeywell flight department: G-450/550
- Verizon: G-450
- Netjets International: G-450/550
Future Operator RNP AR Fleet Approvals

- Qualcomm: G-450
- Coca-Cola: G-550
- Southwest Airlines: B-737
- US Airways- Airbus: E-190
- JetBlue: E-190
- Motorola: G-450
- Zenith: G-450
- Connoco Phillips: B-737
- Wayfarer Aviation: G-450
- Reyes Holdings: G-450
Challenges

**FAA**
- Mixed Equipage
- Separation Standards
- Environmental
- Surveillance & Automation
- Part 77 Obstacle Notification

**Operators**
- Aircraft Capabilities
- Phraseology
- Procedure Design
- International Harmonization
- Benefits & Analysis
- Training
- Human Factors
- Criteria

**Surveillance & Automation**
- Flight Management Computer (FMC) Variations & Capabilities
- Procedure Coding Database
- Charting
- Cockpit Displays
- Equipage

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 EWG Ops SC
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Federal Aviation Administration

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Environmental Challenges

- All new procedures are reviewed to assure compliance with environmental laws and regulations.
- The review will determine the level of environmental study appropriate for the proposed procedure:
  - Categorical Exclusion (CATEX)
  - Environmental Assessment (EA) - costs run approximately $500K to $1M
    - Focused EA - Time and cost can be reduced substantially if there is no potential for significant impacts
  - Environmental Impact Study - costs vary widely, can be anywhere from $1M to millions
- Schedule is also impacted by the various types of environmental actions:
  - Environmental Assessment - a year to 18 months
  - Environmental Impact Study - 24+ months
Safety Risk Management Efforts

- The RNAV/RNP Group is actively working on a number of Safety Risk Management Documents (SRMD) and Decision Memorandums (SRMDM) in conjunction with System Operations Safety Management Office (SOSM)
  - SRMDs currently under development
    - Guidelines for the Development and Implementation of RNAV STARs (18 Step Process)
    - Houston/George Bush Intercontinental Airport (KIAH) Parallel Dependent and Simultaneous Independent ILS/RNAV Approaches, Resume Normal/Published/Terminate Speed (final draft submitted to the AJR SOSM Office for review and approval)
    - Climb Via
  - Coordination/approval status of SRMDM currently under development
    - Deconfliction of MDW RNAV (RNP) Y RWY 13C arrivals from ORD RWY 22L departures
    - RNAV Visual Flight Procedures
    - ATL/DFW RNAV “Off the Ground” Phraseology implemented June 1, 2009
    - Revised ATC Surveillance Requirements – GNSS Aircraft Operating on RNAV ATS/Random (Impromptu) Routes
International Harmonization

- **International Civil Aviation Organization (ICAO) PBN Study Group**
  - Developed ICAO PBN Manual (Apr 04-Mar 07)
  - Working advanced concepts for RNP
- **ICAO-IATA Global PBN Task Force (new initiative)**
  - Coordinate/leverage government-industry resources to accelerate PBN implementation worldwide
  - Ops approval guidance/training
  - EUROCONTROL-FAA PBN Airspace Planning seminars
- **ICAO-FAA-EUROCONTROL PBN seminars**
  - 10 worldwide seminars
- Regional Task Force Participation
- Bilateral Agreements
  - China
  - Australia
- CANSO Operational Standing Committee

![Map of ICAO-FAA-EUROCONTROL Joint PBN Seminars June 2007 – December 2008](image-url)
Questions?
B/U Slides
PBN Studies on Separation
Completed Since June 2008

Examples of Analysis: Upcoming PBN Studies and Support

• Decision altitude in a turn
• Analysis of navigation system capability
• Flight Standards Aviation Inspector workshops
• Update Flight Standards Aviation Inspector handbook guidance
• Predictive Receiver Autonomous Integrity Monitoring (RAIM) services