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

Federal Aviation Administration

Presentation to: EWG Ops SC

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Date: July 28, 2009

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)

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- Airspace Changes (RNAV Everywhere & RNP Where Beneficial)

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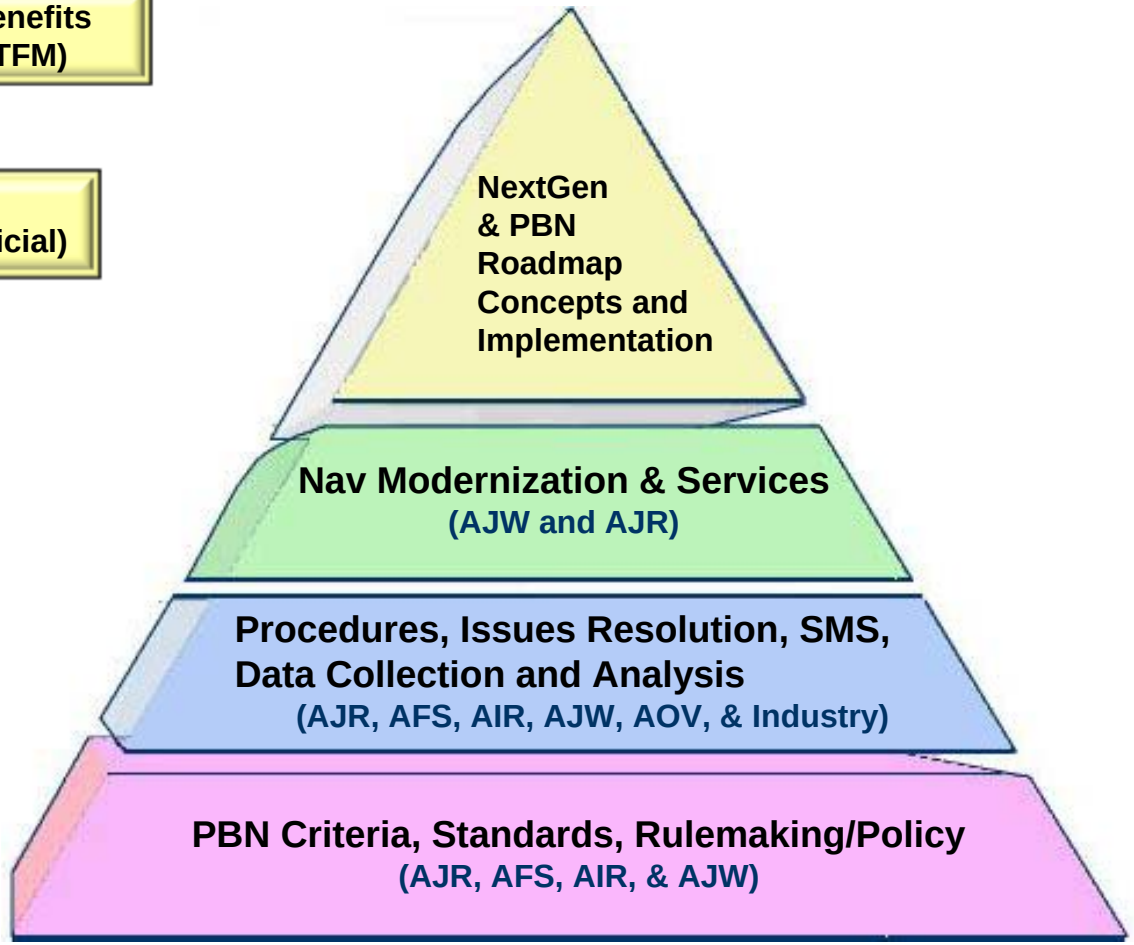
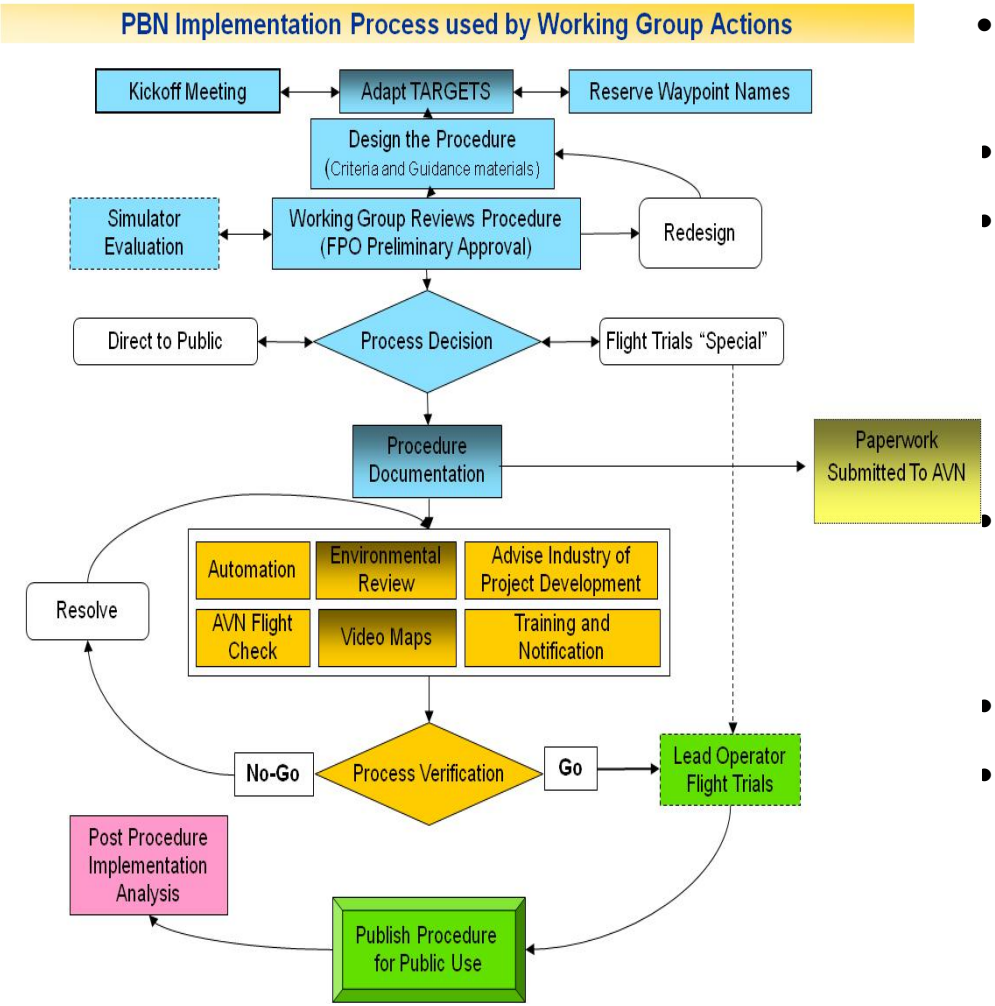
- Criteria, Standards, and Guidance Materials
- Avionics & Certification
- Operator Approvals
- Equipage
- Procedures Implementation
- Automation
- Training
- Issue Resolution
- International Harmonization



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

18-Step RNAV Implementation Process

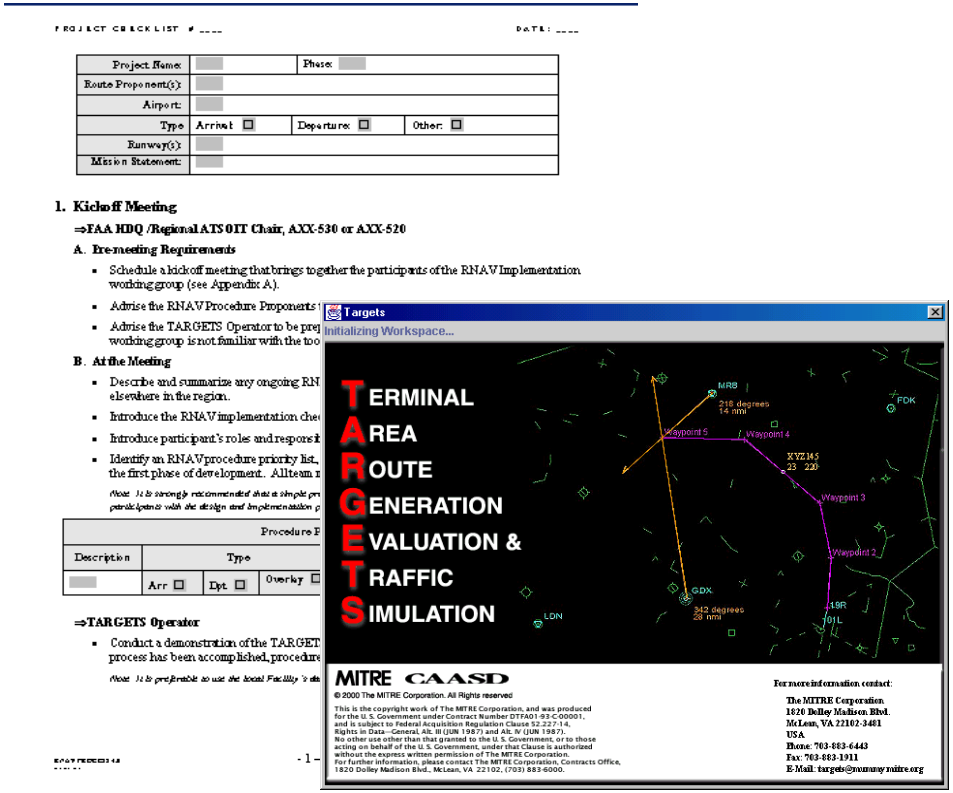


- Developed through FAA, Industry, and MITRE collaboration
- 18 systematic manageable steps
- Provides RNAV Working Groups with standardized process for the development and implementation of Terminal RNAV procedures (STARs and SIDs)
- Defines the specific roles and responsibilities of the collaborative 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]

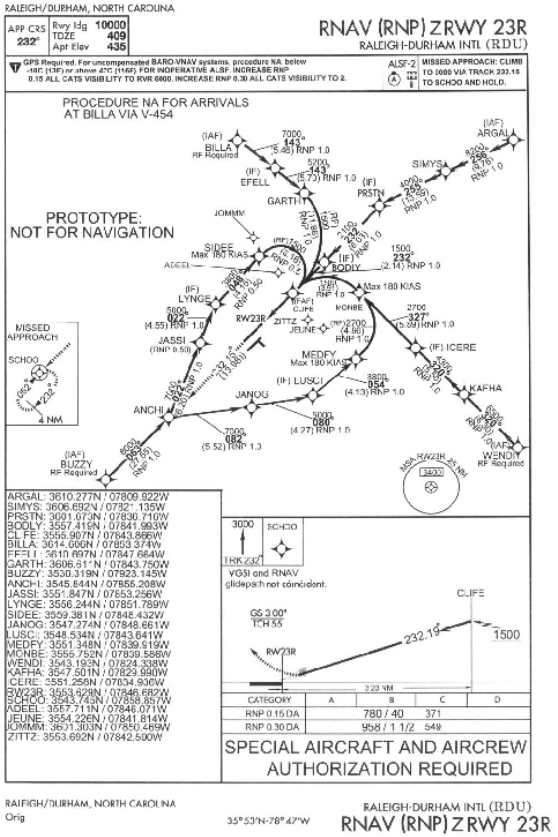
- Alaska (Adak, Akhiok, Anaktuvuk Pass, Anchorage, Arctic Village, Atka, Golovin, Juneau, Kaltag, Ketchikan, King Cove, Nondalton, Palmer, Perryville, Petersburg, Ruby, Sitka, Willow)
- Arizona (Glendale, Goodyear, **Phoenix**, San Carlos, Sedona, Tucson)
- California (Alturas, Borrego Valley, California 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

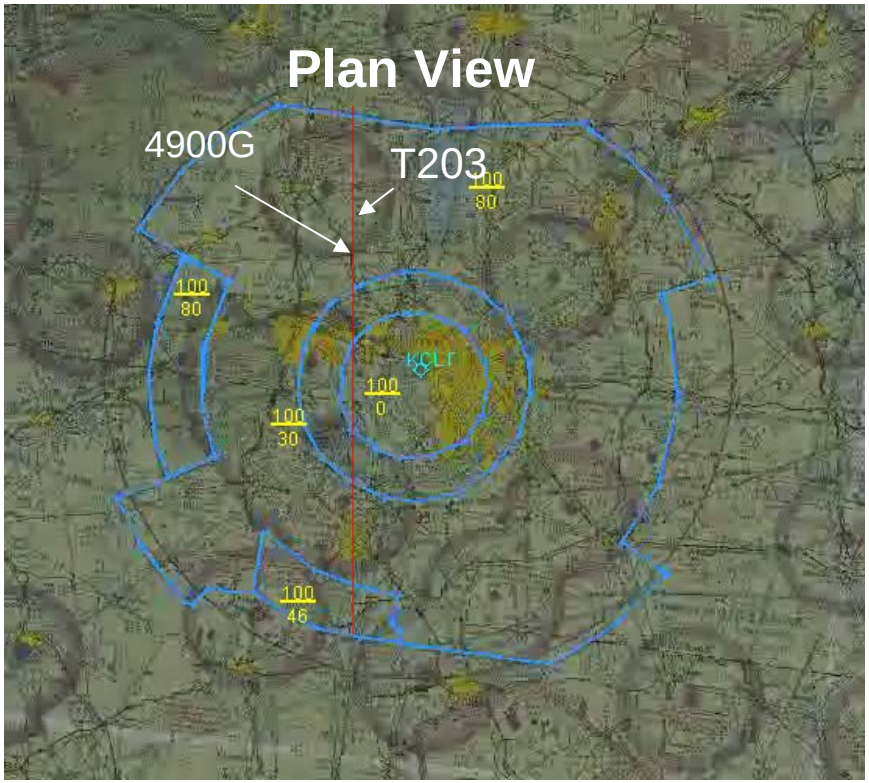
2005 – July 2009 [Cities in bold have OEP airports]

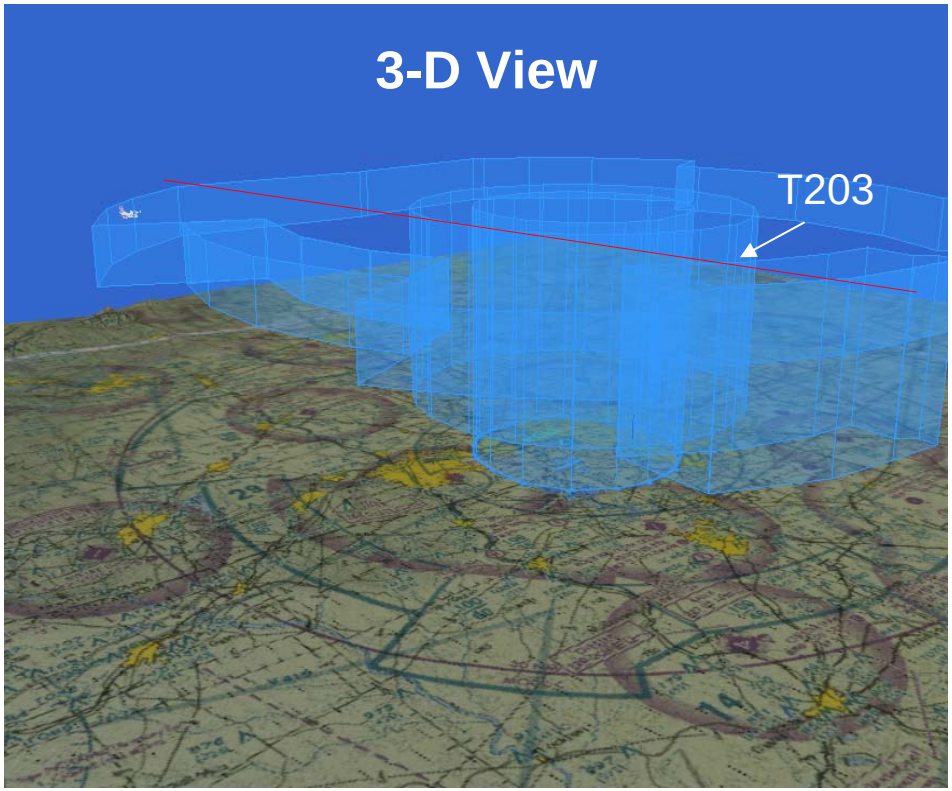
- Arizona (**Phoenix**, Prescott, Scottsdale, Tucson)
- California (Bishop, Burbank, Long Beach, **Los Angeles,** Monterey, Ontario, Palm Springs, **San Francisco**, San Jose)
- Colorado (Hayden, Rifle)
- Ecuador (Quito)
- Florida (**Ft. Lauderdale, Miami, Tampa**)
- Georgia (**Atlanta-Hartsfield**, 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**)
- New York (**New York-Kennedy, New York-Laguardia**)
- 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

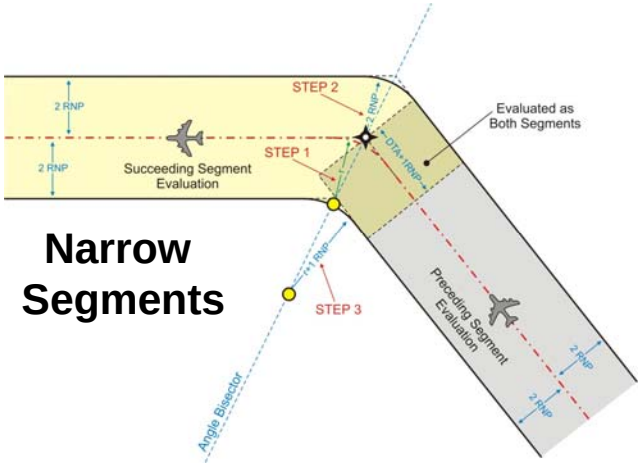
Increased Capacity and Access





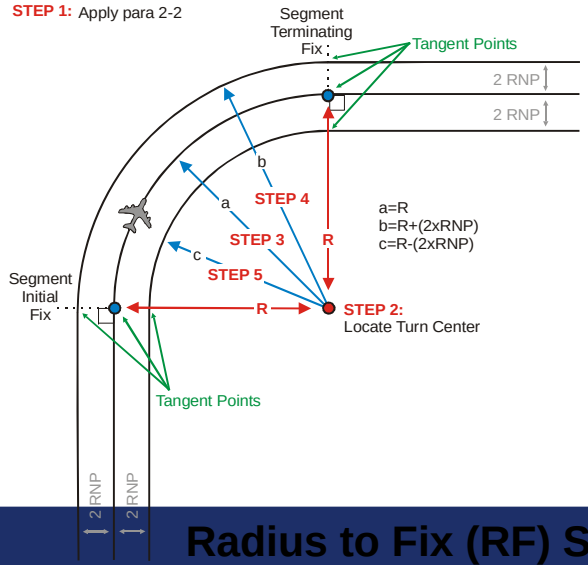
- T-routes requested by Aircraft Owner's Pilot's Association (AOPA)
- Better access to Class "B" and Class "C" airspace
- Reduced mileage and increased en route capacity due to lower Minimum En Route Altitudes (MEA) based on GPS

RNP Approach with Authorization Required Enabling Features (RNP SAAR)

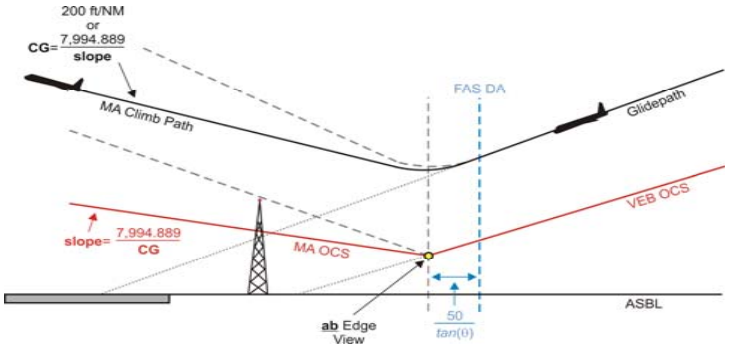


Narrow Segments

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



Radius to Fix (RF) Segments

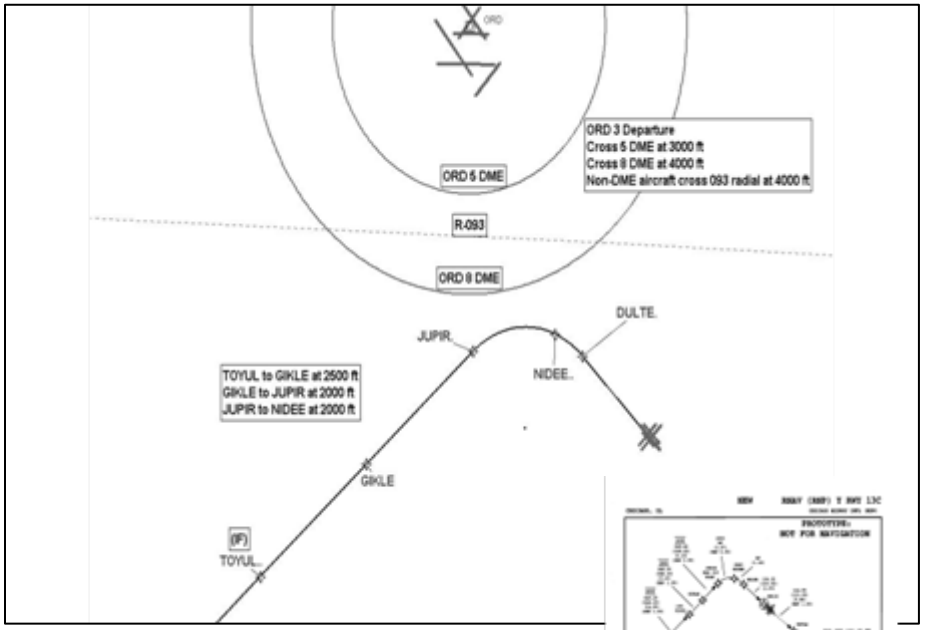


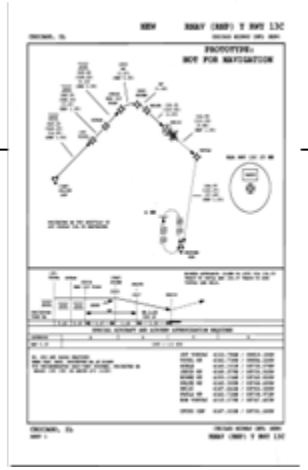
Vertical Error Budget & Guided Missed Approach

- Note – RNP AR is the international equivalence of RNP SAAR

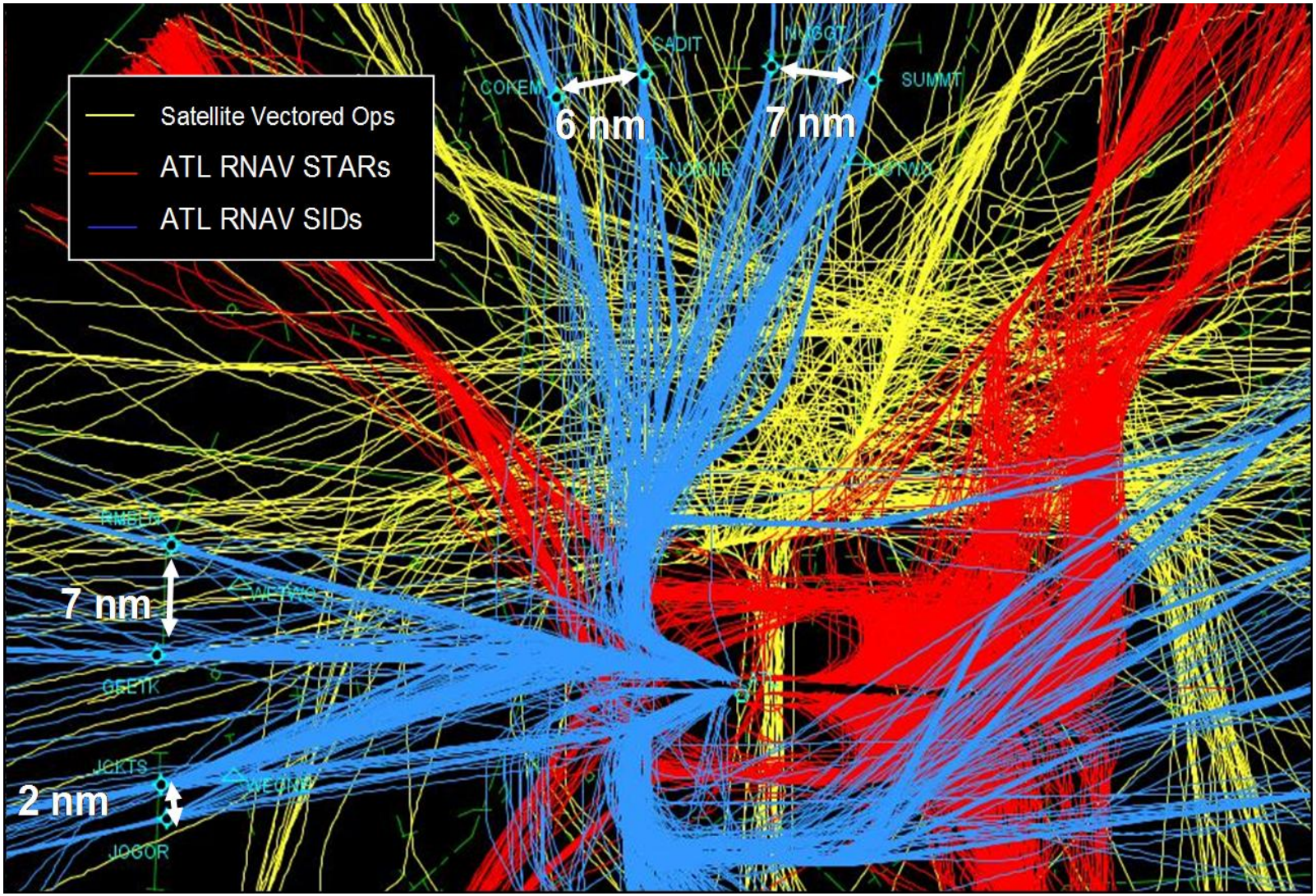
De-confliction of Chicago O'Hare/Midway Using RNP SAAAR

- 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





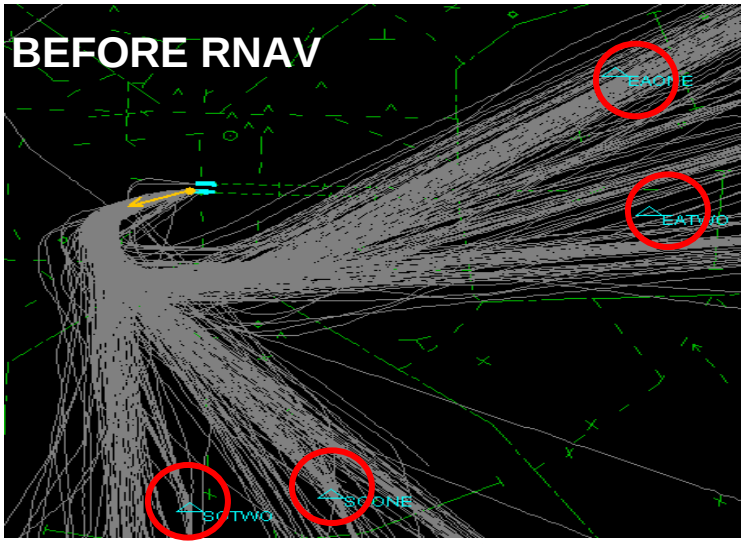
PBN Addresses Complexities in the Terminal Domain

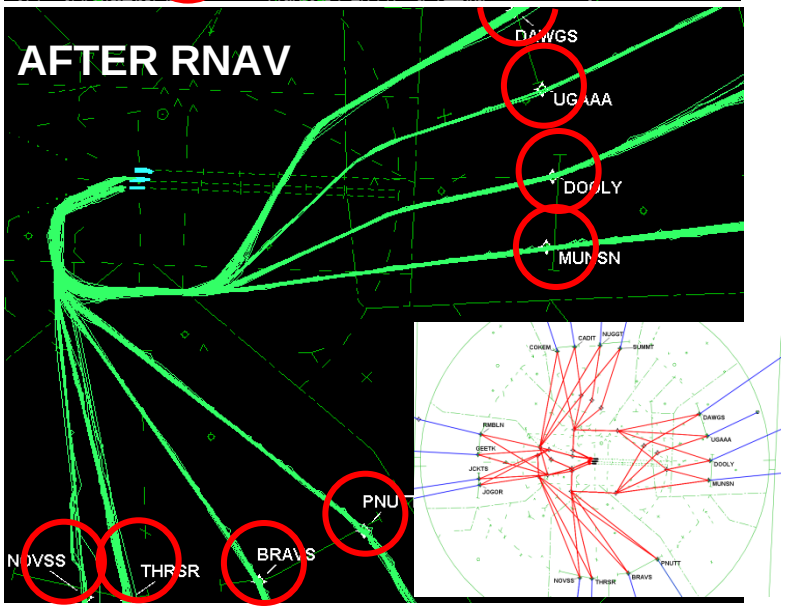


Atlanta (ATL) Departure Procedures

Before and After

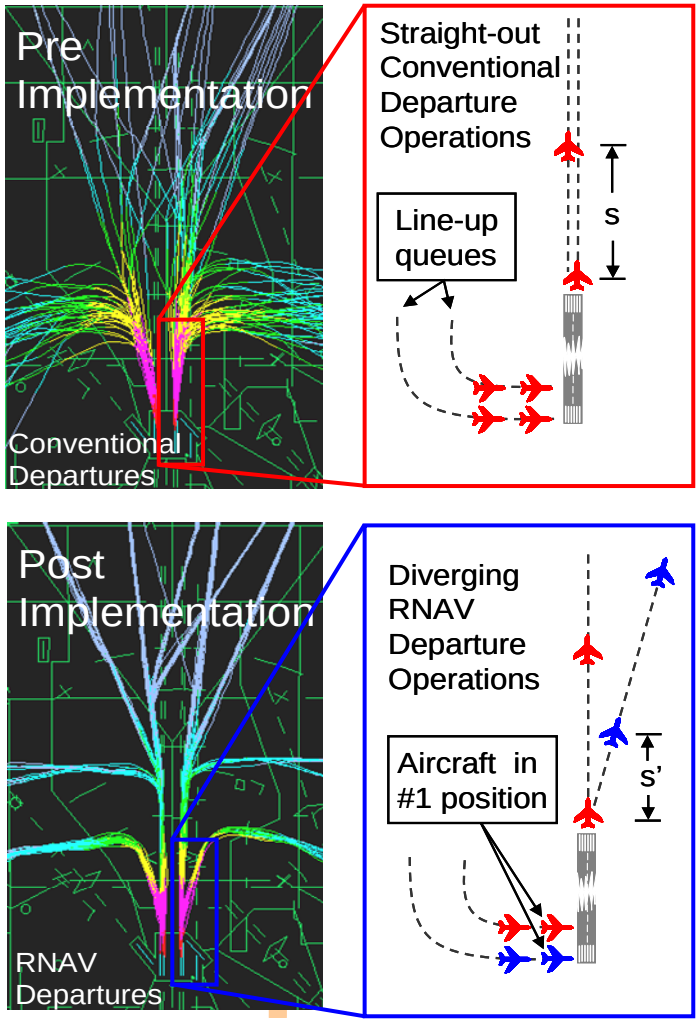
- Approximately 94% of daily departures are RNAV-capable
- More departure lanes and exit points to the en route airspace
  - Capacity gain of 9-12 departures per hour
- Repeatable and predictable paths
- Benefits
  - Increased throughput
  - Reduced departure delays
  - $30M annual benefit (at 2007 demand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





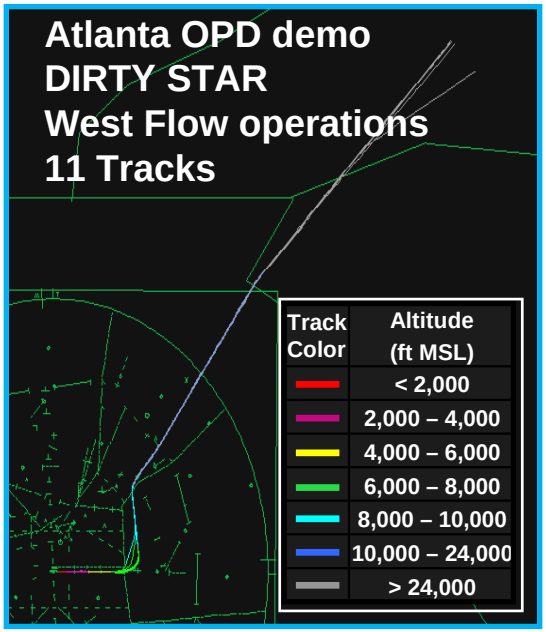
Dallas Fort Worth International (DFW)

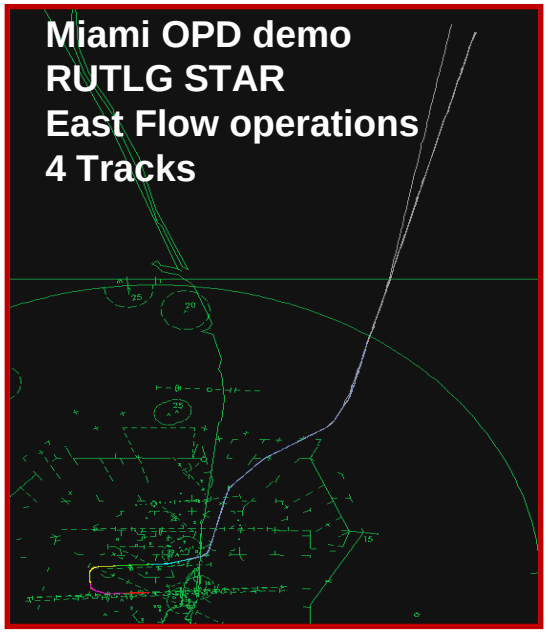
- RNAV enabled diverging departures at DFW
- Diverging departures allow for the application of same runway separation standards, reducing inter-departure times
- Reduction of inter-departure times yields an increase in departure capacity
  - 11 to 20 additional operations per hour
- Increased departure 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

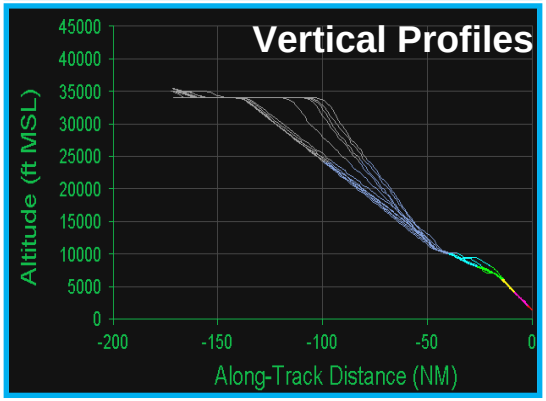


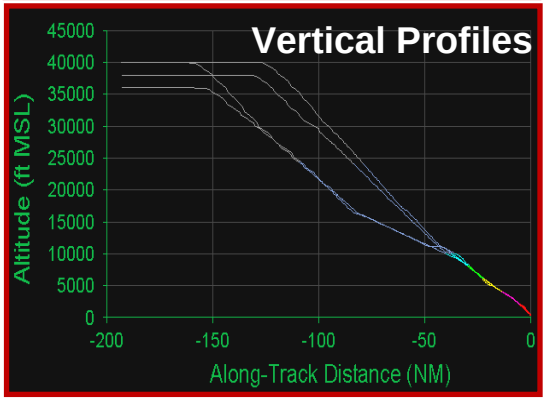
RNAV Arrivals

Optimized Profile Descent (OPD) Arrivals





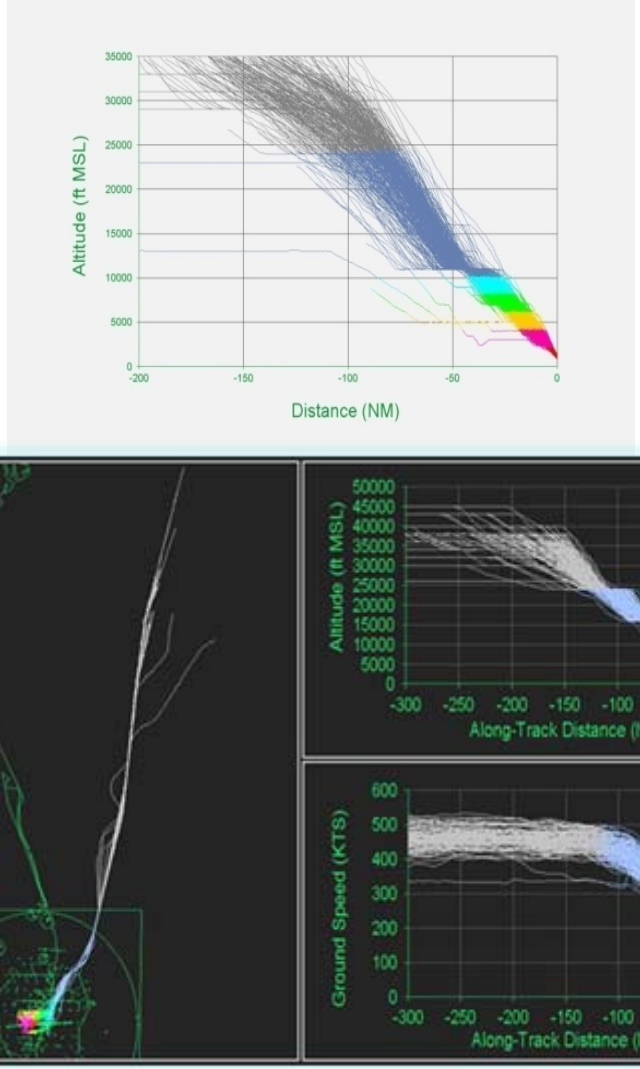




- **OPDs provide large benefits for fuel, emissions, and flight time**
- **May 2008 Demos**
  - **DIRTY STAR at Atlanta (ATL)**
    - **38 gallons of fuel savings and 360kg reduction in CO_2 emissions per flight**
  - **RUTLG STAR at Miami (MIA)**
    - **48-52 gallons of fuel savings and 460-500kg reduction 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

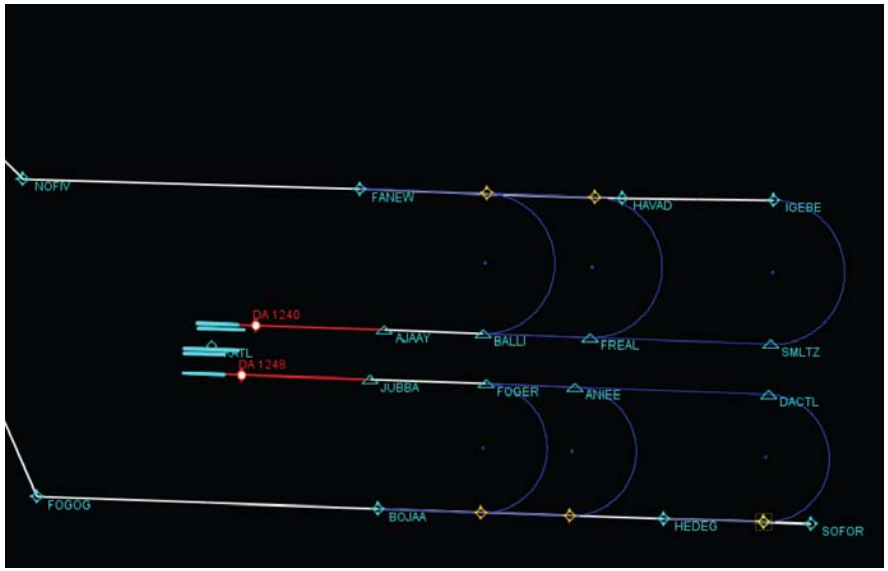
- Conducted a NAS-wide high-level analysis for prioritization of OPD implementation sites (Feb 09)
- Analyzed 4,000 flows at 1,800 airports and ranked by complexity of implementation, relative benefit, and resource readiness
  - **Complexity ranks sites by challenges to OPD implementation**
  - **Site 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**

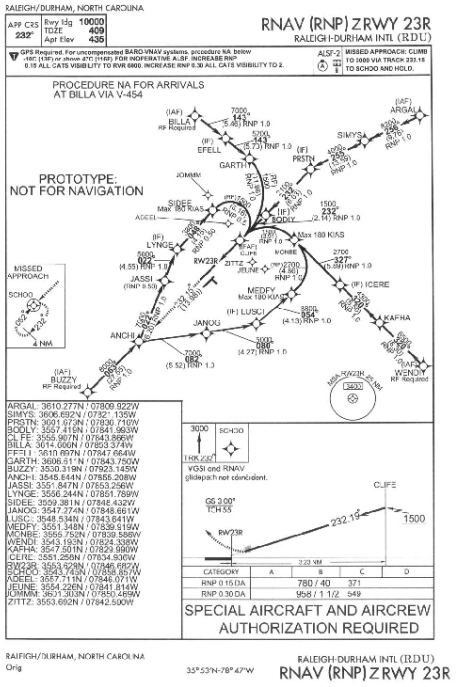
Proposed Design Concept



DELTA

Industry Collaboration Example- Southwest Airlines

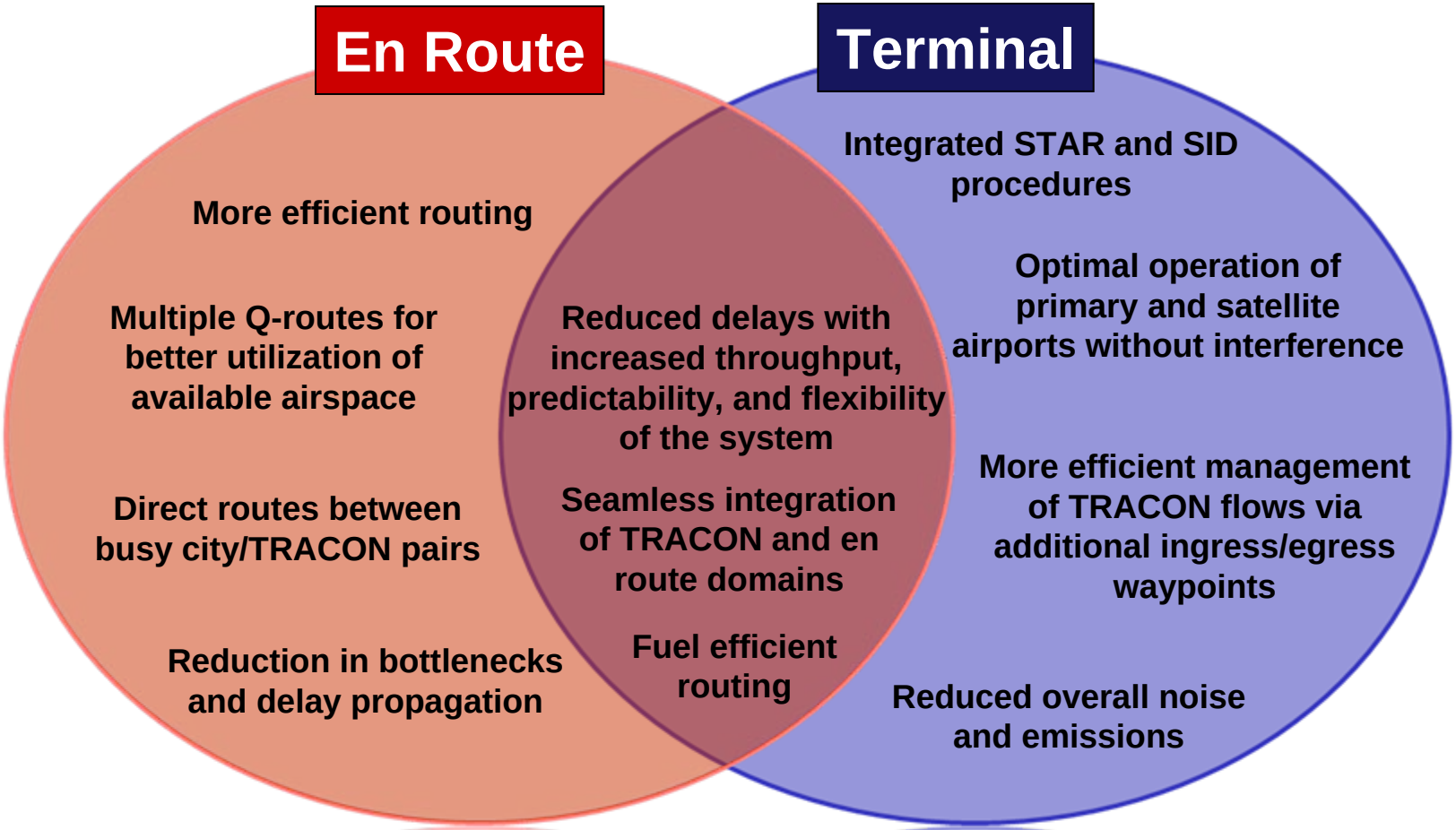
- **RNPs scheduled for publication on August 27, 2009**
  - **Raleigh Durham, NC (Curved Path)**
    - **RNAV (RNP) Z Rwy 5R**
    - **RNAV (RNP) Rwy 23L**
    - **RNAV (RNP Rwy 23R**
    - **RNAV (RNP) Z Rwy 5L**
  - **Boise, ID (Curved Path)**
    - **RNAV (RNP) Z Rwy 10R**
    - **RNAV (RNP) Rwy 10L**
    - **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

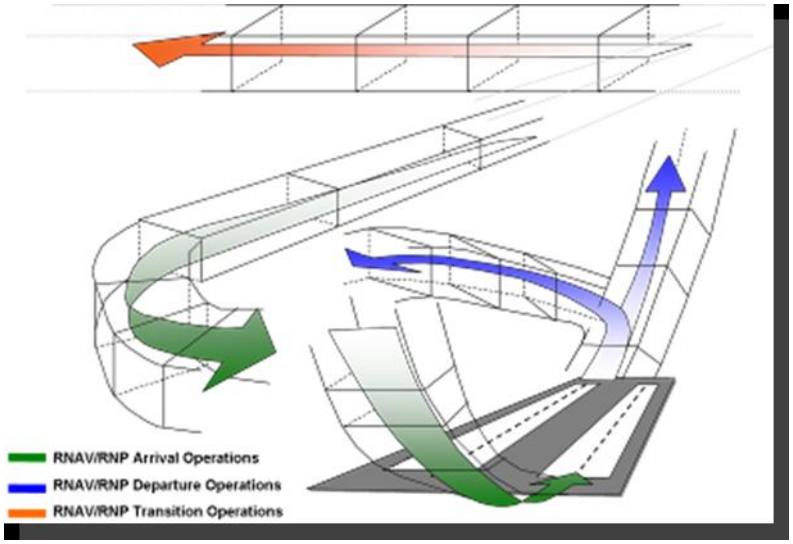
Integrated Procedure Development
Benefits

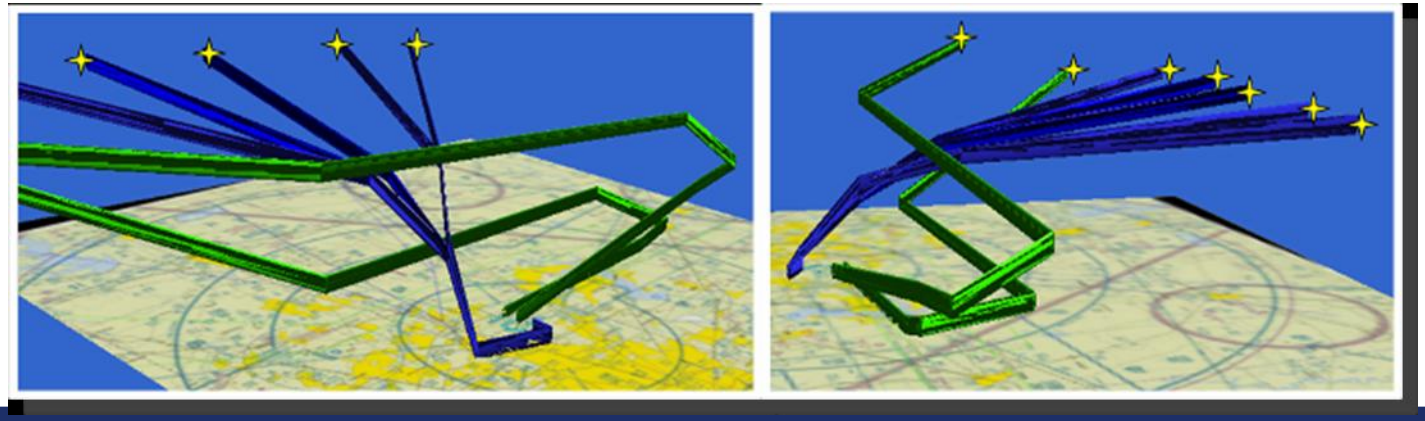


Integration of Procedures Example

Applications for De-confliction, Optimization, and Benefits

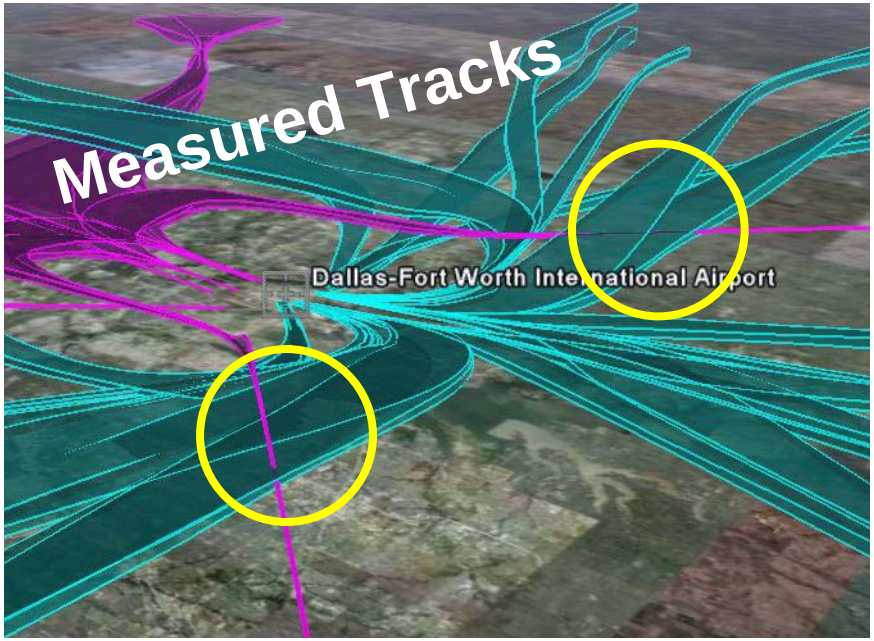
- Segregate traffic flows
  - Between arrival/departure and transitions operations
  - Between primary and satellite airport operations
  - Between city pairs

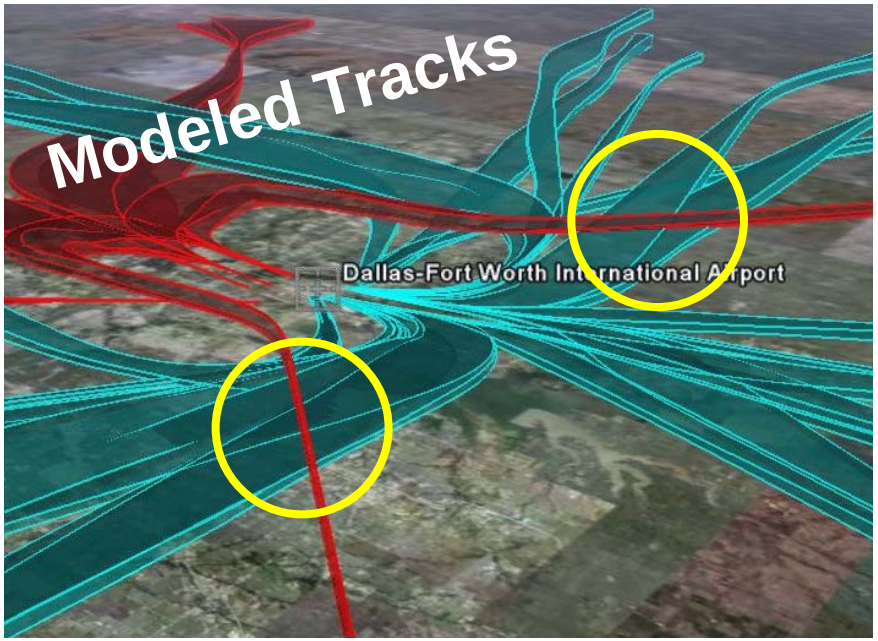




Integration of Procedures Example

Integrated Development of RNAV SIDs and STARs

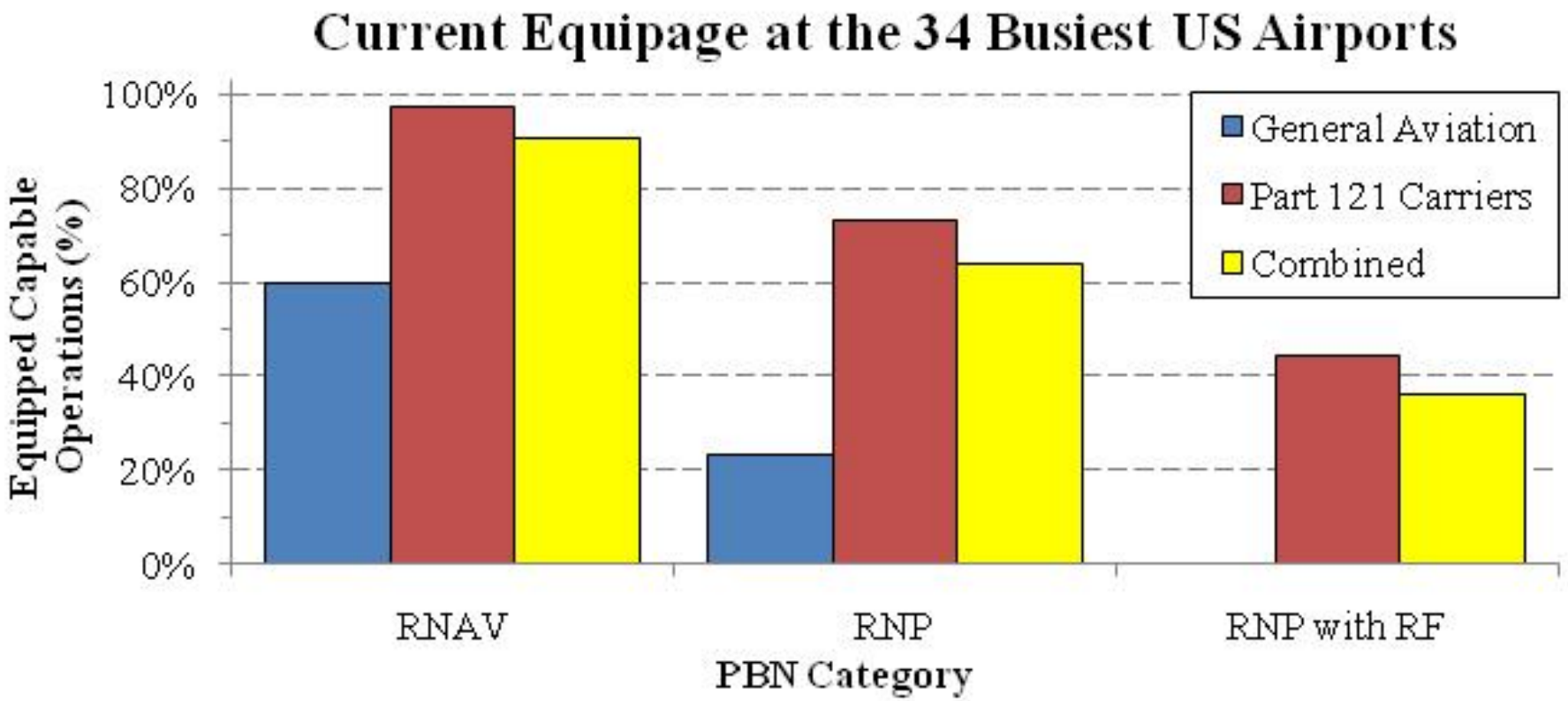




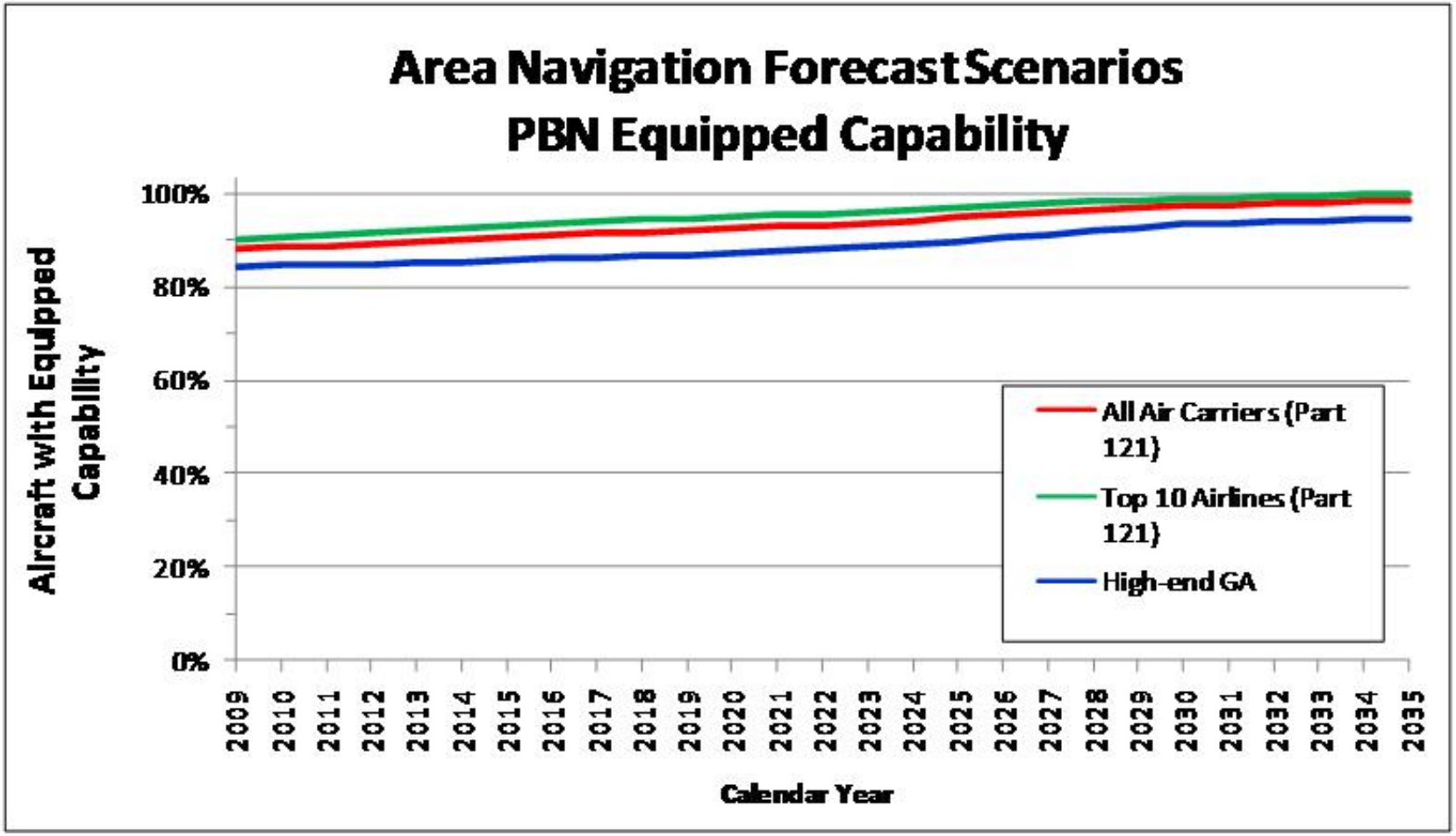
- Current STARs at Dallas-Fort Worth (DFW) are conflicting with departure flows
- The aircraft would cross vertically within 1,000 feet if the procedures were used at the same time
- Controllers are unable to use the two procedures simultaneously

- 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:

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

[1] Air carrier estimates are for US 14 CFR Part 121 fleet, estimated by Mitre.
[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.

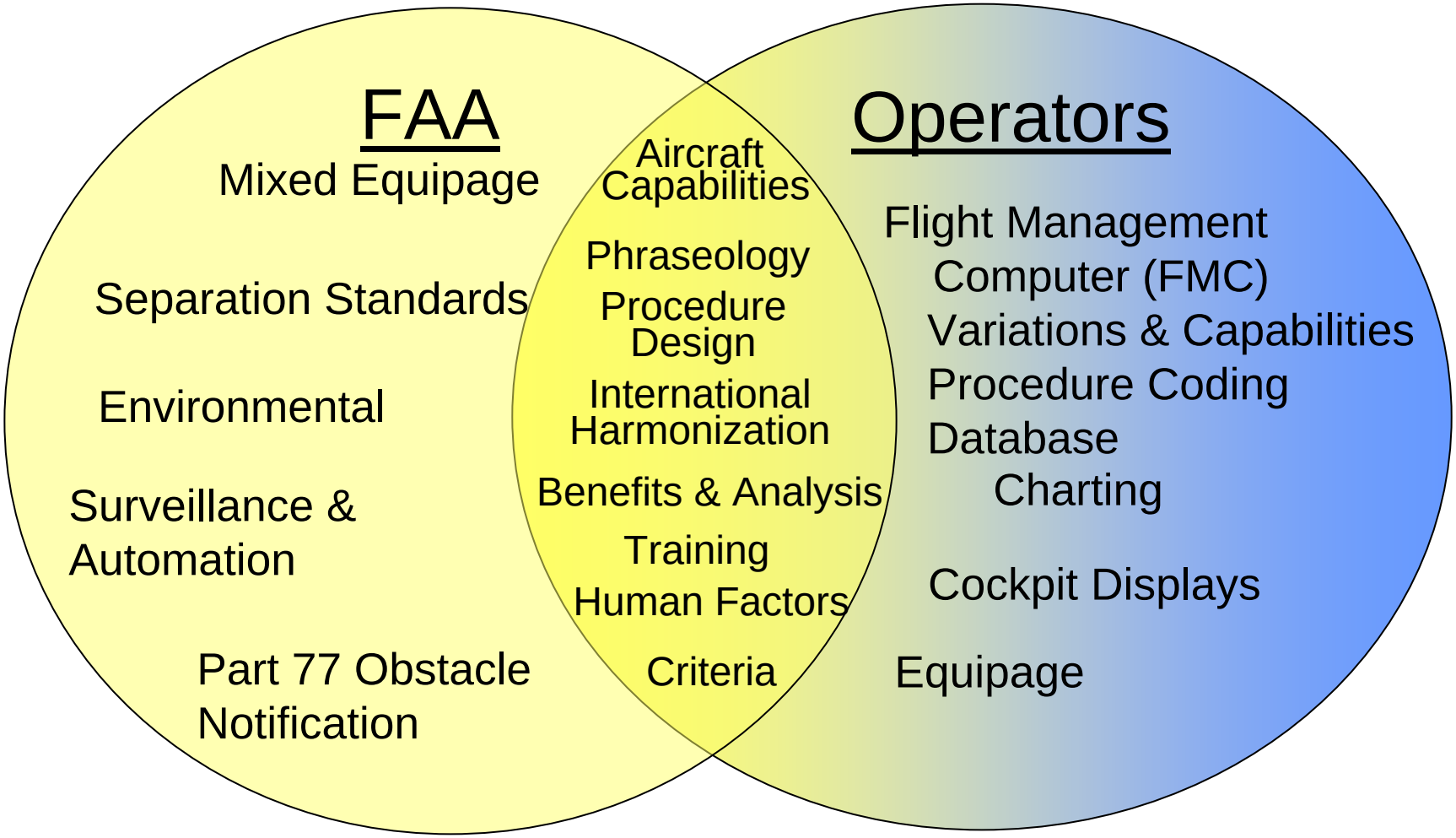
RNP SAAAR/RNP AR Operator Approvals

- 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
Aircraft Capabilities
Phraseology
Procedure Design
International Harmonization
Benefits & Analysis
Training
Human Factors
Criteria
Operators
Flight Management Computer (FMC)
Variations & Capabilities
Procedure Coding
Database
Charting
Cockpit Displays
Equipage

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

Questions?

B/U Slides

PBN Studies on Separation

Completed Since June 2008

- "Analysis of Area Navigation (RNAV/RNP-1) En Route Separation Along Adjacent Straight Segments With Radar Surveillance Including Impromptu Routes (Phase III)," DOT-FAA-AFS-450-50, March 2009
- "Analysis of Area Navigation (RNAV/RNP-1 and RNP-2) En Route Separation Along Adjacent Straight Segments Without Radar Surveillance Including Impromptu Routes (Phase IV)," DOT-FAA-AFS-450-51, March 2009
- "Analysis of Area Navigation (RNAV RNP-1 and RNP-2) En Route Separation Along Adjacent Segments With and Without Radar Surveillance and With Turns (Phase V)," DOT-FAA-AFS-450-52, March 2009
- "Analysis of Area Navigation (RNAV-2) En Route Separation With Conventional Routes Without Radar Surveillance Including Impromptu Routes, DOT-FAA-AFS-450-54," April 2009

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