Near Term Potential for System Capacity Gains from RNP and RNAV Procedures

By

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Purpose and Agenda

- **Briefly describe features and benefits of RNP and RNAV procedures**
- **Suggest ways we can leverage the recent successes of the RNP & RNAV programs to obtain earliest possible capacity benefits**

Attributes of a Successful Capacity Enhancement Initiative

- **Provides immediate benefits for early equippers as well as late equippers, and possibly even non-equippers**
- **Uses available, proven technologies**
- **Can be coupled with many other technologies**
  - **Long-term viability**
  - **Continuous improvement with anticipated advances in technologies**
- **Is part of virtually all future ATC modernization concepts and plans on the horizon**
  - **Basic building blocks of all future systems**

Build on Success of RNP & RNAV Procedures

- **RNP & RNAV meet these success criteria**
- **With continued development of beneficial RNP & RNAV procedures, how can we reach a "tipping point" where:**
  - **Sufficient aircraft will be equipped to enable significant increases in airport capacity**
  - **Equipping will become a competitive necessity for the airlines**
    - If you're not equipped, you can't compete

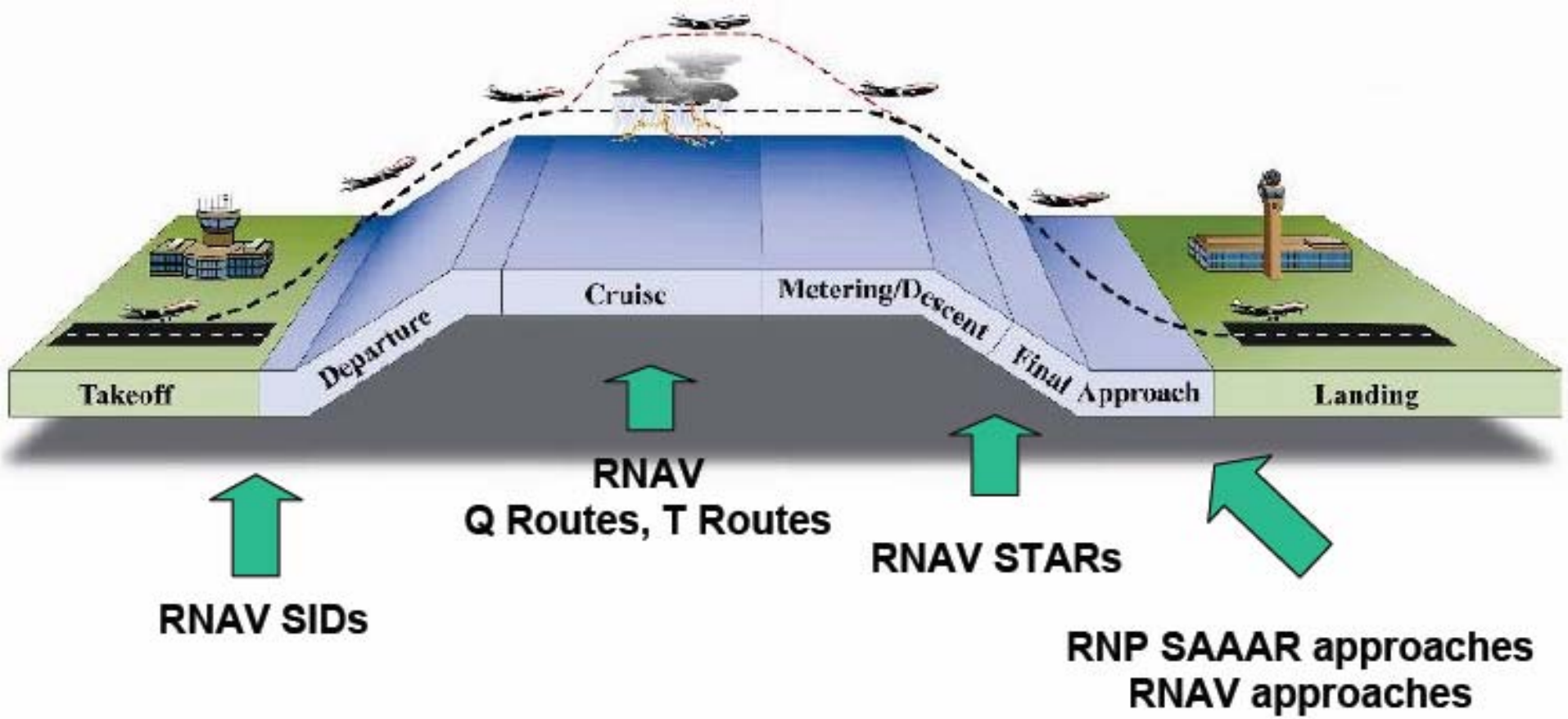
RNP & RNAV Background

- **Area Navigation (RNAV) -- Method of navigation that permits operation on any desired flight path, independent of ground-based navaid location**
- **Required Navigation Performance (RNP)**
  - **Statement of navigation performance accuracy necessary for operation within a defined airspace**
- **RNP is RNAV with on-board navigation monitoring and alerting**
  - **Dual flight management system computers**
  - **Monitor actual navigation performance (ANP)**
  - **Alerts when the RNP operational requirement cannot be met**

RNAV Definitions and Types

- **RNAV Q routes and T routes**
- **RNAV STARS**
- **RNAV SIDS**
- **RNAV approaches**
  - **RNAV (GPS)**
    - LPV (WAAS)
    - LNAV/VNAV
    - LNAV
  - **RNAV (RNP)**
- **RNAV Navigation Standards**
  - **Specify DME/DME/IRUor GPS; or an RNP value; or Type (A or B)**
  - **En route: RNP 5 (RNAV 5), Type A (RNAV 2)**
  - **Terminal: Type A (RNAV 2), Type B (RNAV 1)**

RNAV & RNP in all Phases of Flight



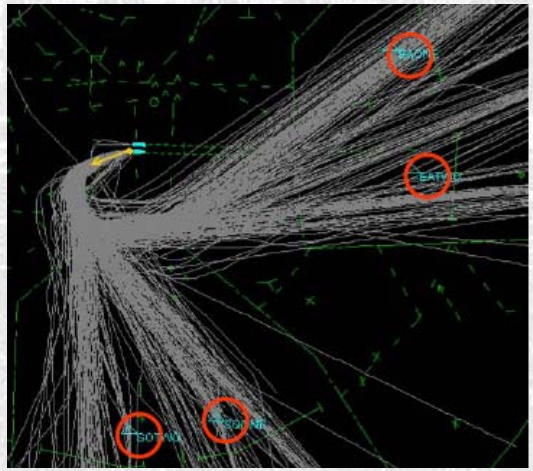
Source: RNAV/RNP Program Update, Federal Aviation Administration

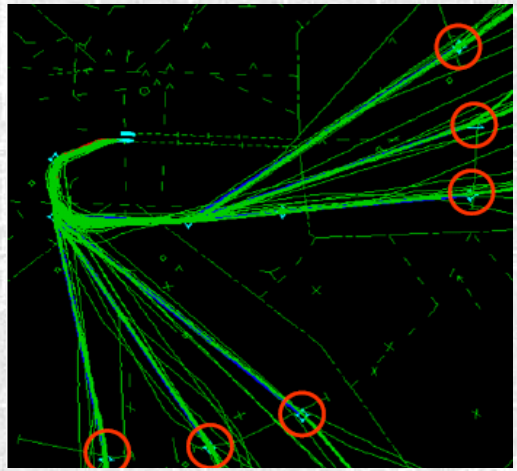
Las Vegas Example

- **First all-RNAV SIDS and STARS**
- **SIDS**
  - **Unique waypoints for each runway (at least initially)**
  - **RNAV 1**
- **STARS**
  - **All runways – expect vectors to final approach**
  - **Runway 25L – intercept localizer**
- **Ultimate goal – runway-specific STARS and SIDS**
  - **Coming from different directions**
  - **Tromboning issue**

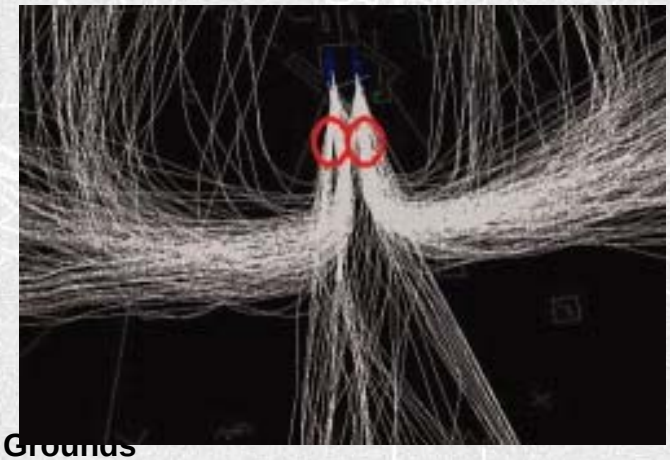
RNAV Standard Instrument Departures (SIDS) Radar Flight Tracks Before & After RNAV

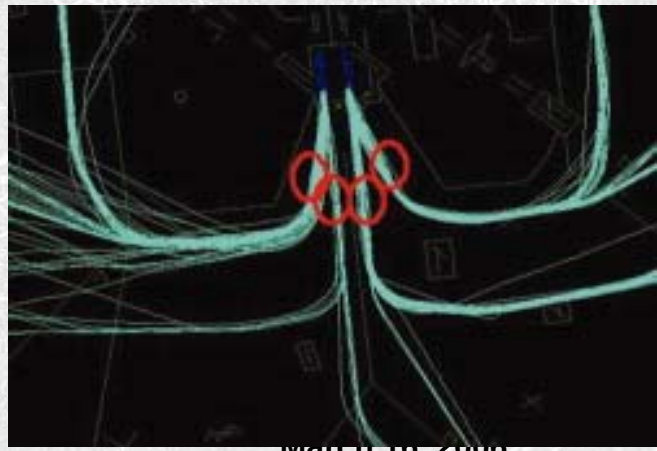
- **ATL RNAV Standard Instrument Departures**





- **DFW (AAL) RNAV Standard Instrument Departures**





Source: RNAV/RNP Program Update, Federal Aviation Administration

Departure Procedures- Before & After RNAV

BEFORE

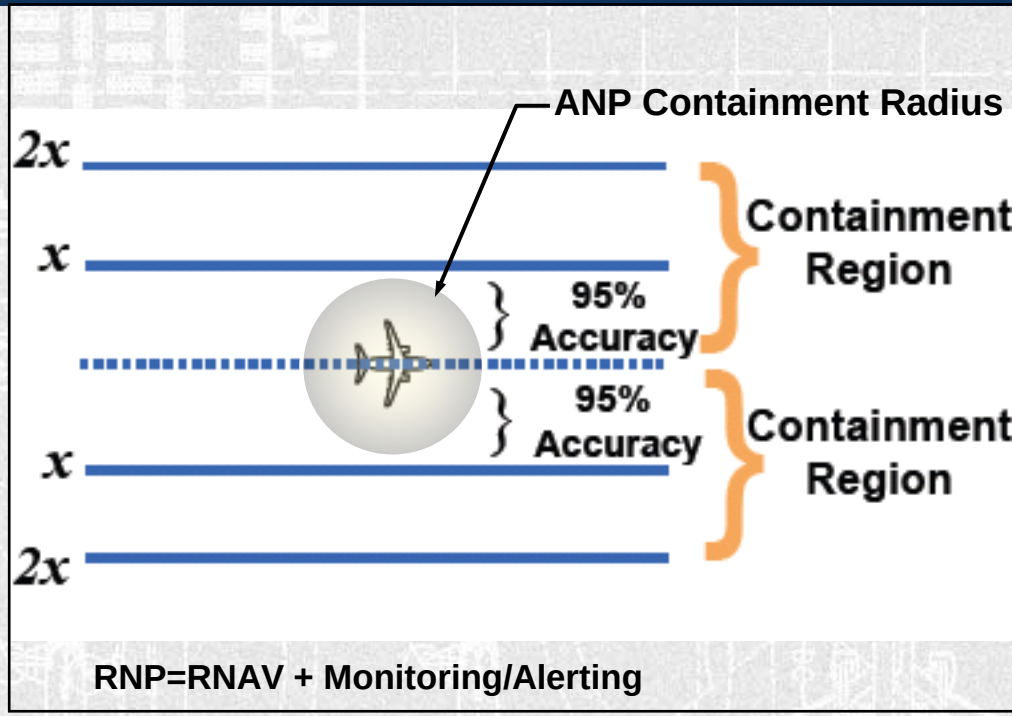
- **Departures are vectored**
  - **Headings, altitudes and speeds issued by controllers**
  - **Large number of voice transmissions required**
- **Significant dispersion**
  - **Tracks are inconsistent and inefficient**
- **Limited exit points**

AFTER

- **Departures fly RNAV tracks (not vectored)**
  - **Headings, altitudes and speeds are automated (via avionics)**
  - **Voice transmissions reduced (30-50%)**
- **Dispersions reduced**
  - **Tracks are more consistent and more efficient**
- **Additional exit points available**
- **Improved vertical profiles**
- **More time to focus on unequipped aircraft**

RNP Definitions

- Onboard avionics keep aircraft within a tightly specified airspace corridor
- RNP-x is aircraft path conformance (with accuracy x (nm) or better, 95% of time)
- RNP Containment Region is an area 2 x RNP-x on either side
- 99.999% probability that aircraft is within containment region



Source: RNAV/RNP Program Update, Federal Aviation Administration

RNP Background – Alaska Airlines

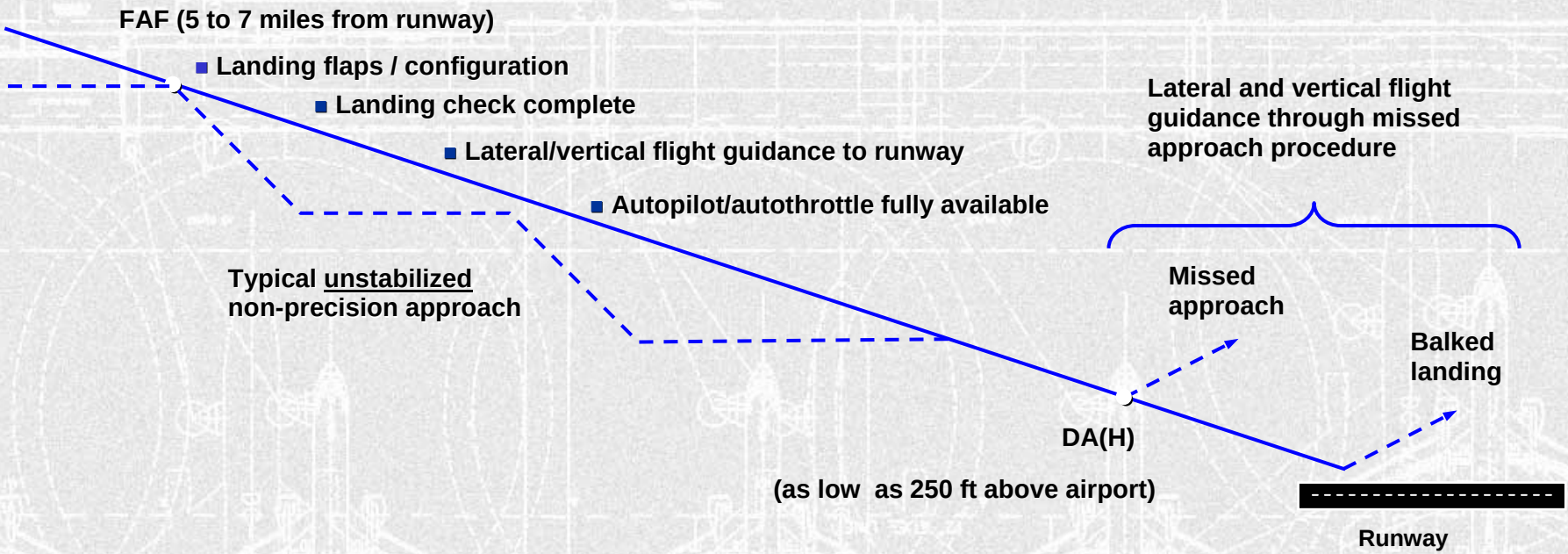
- **Pioneered RNP in Alaska**
  - –To serve "terrain-challenged" airports in remote areas (e.g., Juneau-Gastineau Channel)
  - –Exploit advanced avionics on its Boeing 737-400+'s
  - –Now using 17 RNP approaches and 12 RNP departures in Alaska
- **System-wide, flying 6,000 RNP approaches or departures per year**
  - –858 "saves" in 2005
  - –Saves airline up to $8 million per year

Source: Alaska Airlines

Source: Alaska Airlines

Asilomar Conference Grounds

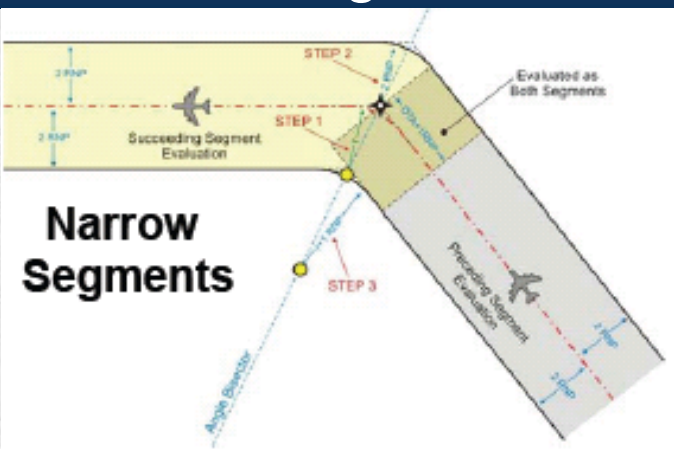
RNP & RNAV Enables Stabilized Approaches



- **Barometric vertical navigation (VNAV)**
- **Eliminates Dive and Drive (Non-Precision) approaches**
- **Provided a Stabilized Approach with LNAV/VNAV guidance to runway threshold**

Source: Alaska Airlines

Public RNP SAAAR Approach Criteria Enabling Features (Source: FAA)



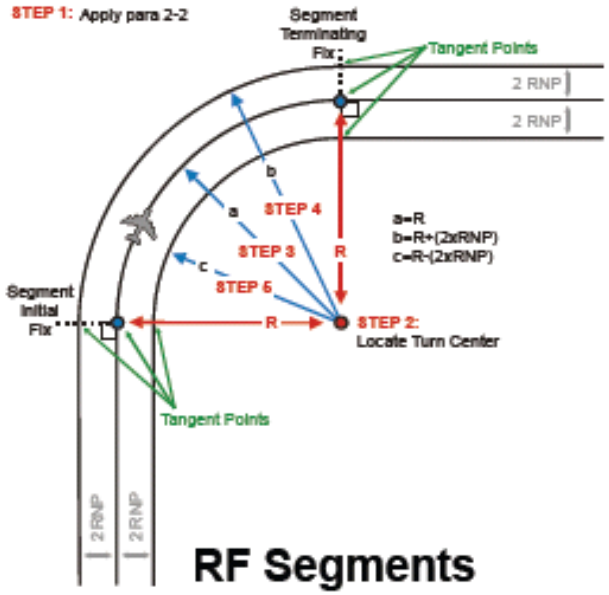
Narrow Segments

Narrow lateral linear segments
(RNP-0.3 or less with no secondary buffers)

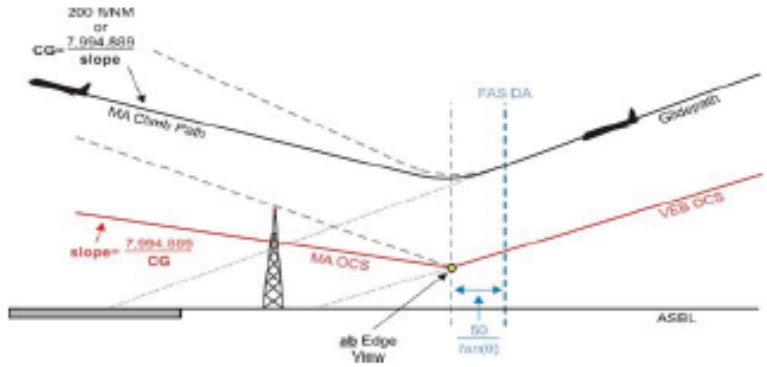
Curved segments anywhere along the approach
(Radius-to-fix legs with shorter leg lengths)

Guided, narrower turns on missed approaches
(Radius-to-fix legs, and RNP-1 or less)

Performance-based Vertical Buffers
(Vertical Error Budget)



RF Segments



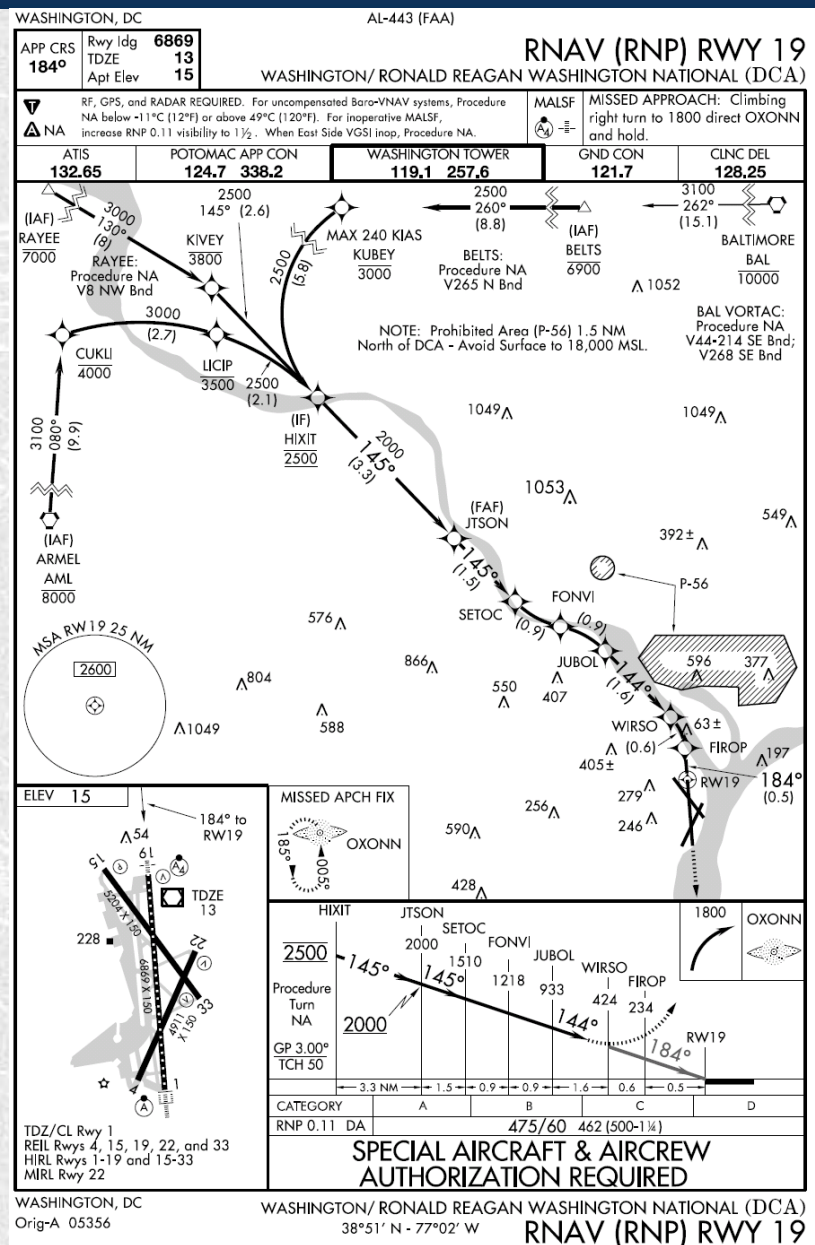
VEB & Missed Approach

Source: RNAV/RNP Program Update, Federal Aviation Administration

Asilomar Conference Grounds **March 16, 2006**

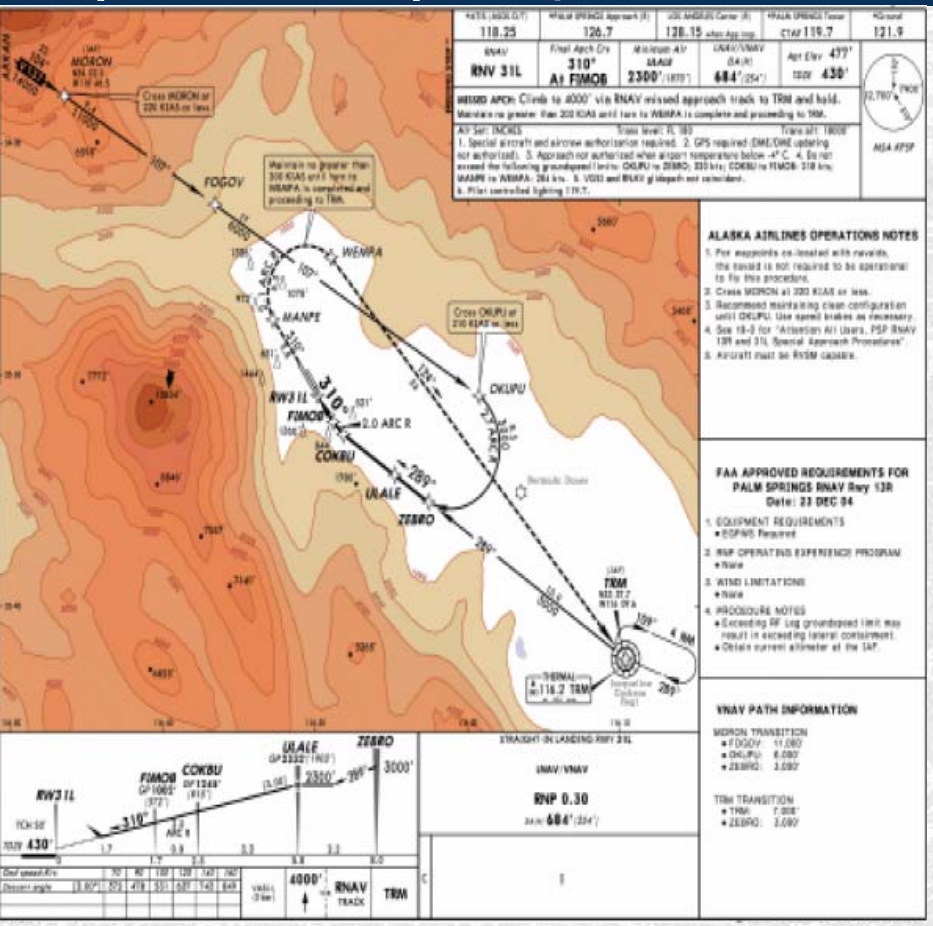
First Certified Public RNP SAAAR Approach to Runway 19 at DCA

- **Established 9/28/05, RNP 0.11**
- **LDA approach requires**
  - **720-ft. decision altitude**
  - **2 & 1/4 mi. visibility**
- **RNP approach requires**
  - **475 ft. decision altitude**
  - **1 & 1/4 mi. visibility**
- **Alaska has flown 10 of these approaches**
  - **Three have been "saves“ or avoided diversions**
  - **Diversions can cost airline $5,000-$10,000 each, and possibly more**



Source: RNAV/RNP Program Update, Federal Aviation Administration Asilomar Conference Grounds

Palm Springs Public RNP SAAAR* Approaches (31L, 13R) Expected February 2006



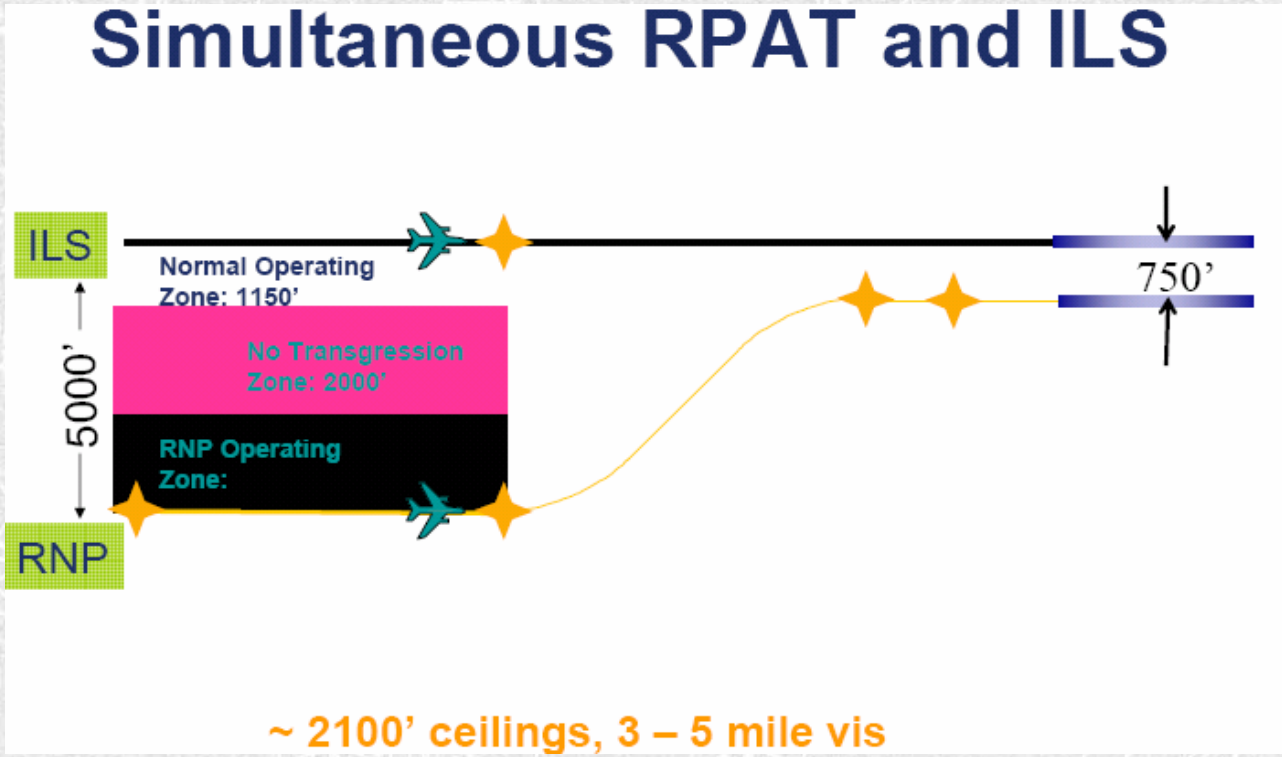
*** Special Aircraft & Aircrew Authorization Required (SAAAR)**

Source: RNAV/RNP Program Update, Federal Aviation Administration

- **RNP 0.3**
- **VOR/GPS-B minima of 1,823’ & 3 mi.**
- **Alaska Airlines “Special” RNP**
  - **Minima as low as 250’ and 3/4 mi.**
  - **Initiated in January 2005**
  - **24 flights diverted/cancelled in 6 weeks before implementation**
  - **20 “SAVES” since implementation**
- **Public RNP SAAAR Approach**
  - **Existing RNAV (RNP) Y Approaches**
    - 409’ and 1.5 mi. to Runway 13R
    - 304’ and 1 mi. to Runway 31L
  - **Future Public SAAAR minima of 254’ & 1 mi.**
  - **Expected March 2006**

RNP Parallel Approach Transition (RPAT)

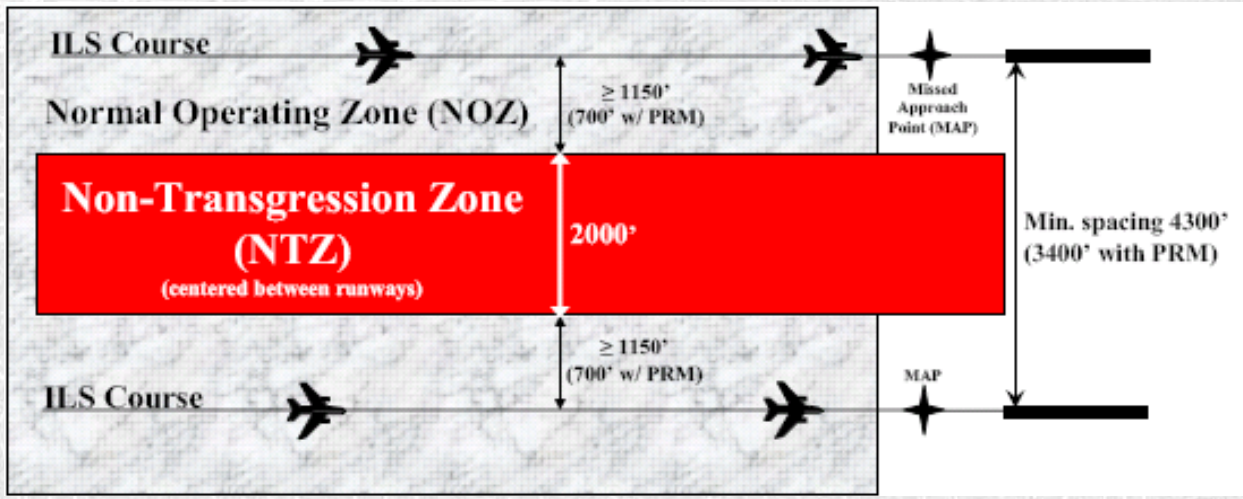
- **Provides up to 60% greater capacity over single runway**
  - **Applicable to parallel runways spaced as close as 750 feet**
  - **Provides ILS approach to accommodate mixed equipage**
  - **Maintains second arrival stream if one ILS is out of service**



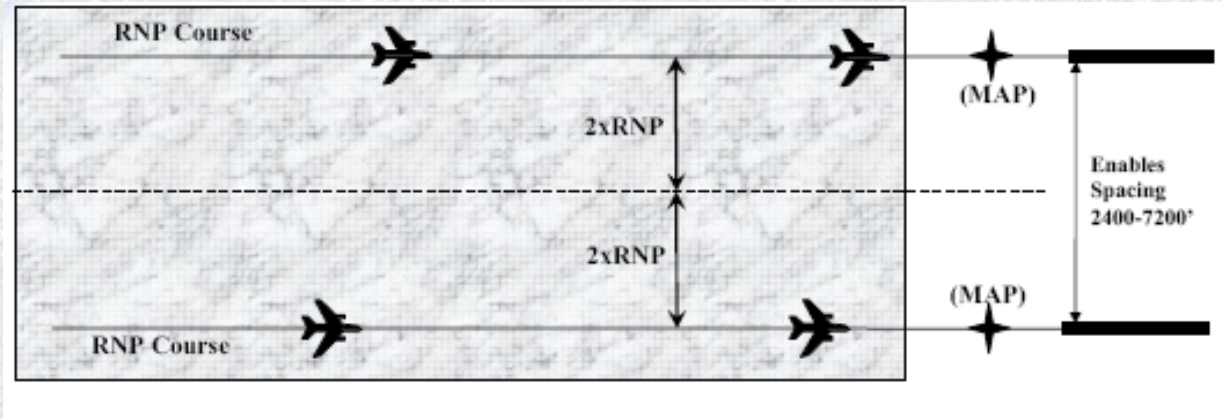
Source: FAA and MITRE CAASD

Multiple RNP Approach Procedures

- **Current Requirements for Simultaneous Independent ILS Approaches in IMC**



- **Future RPA Concept**



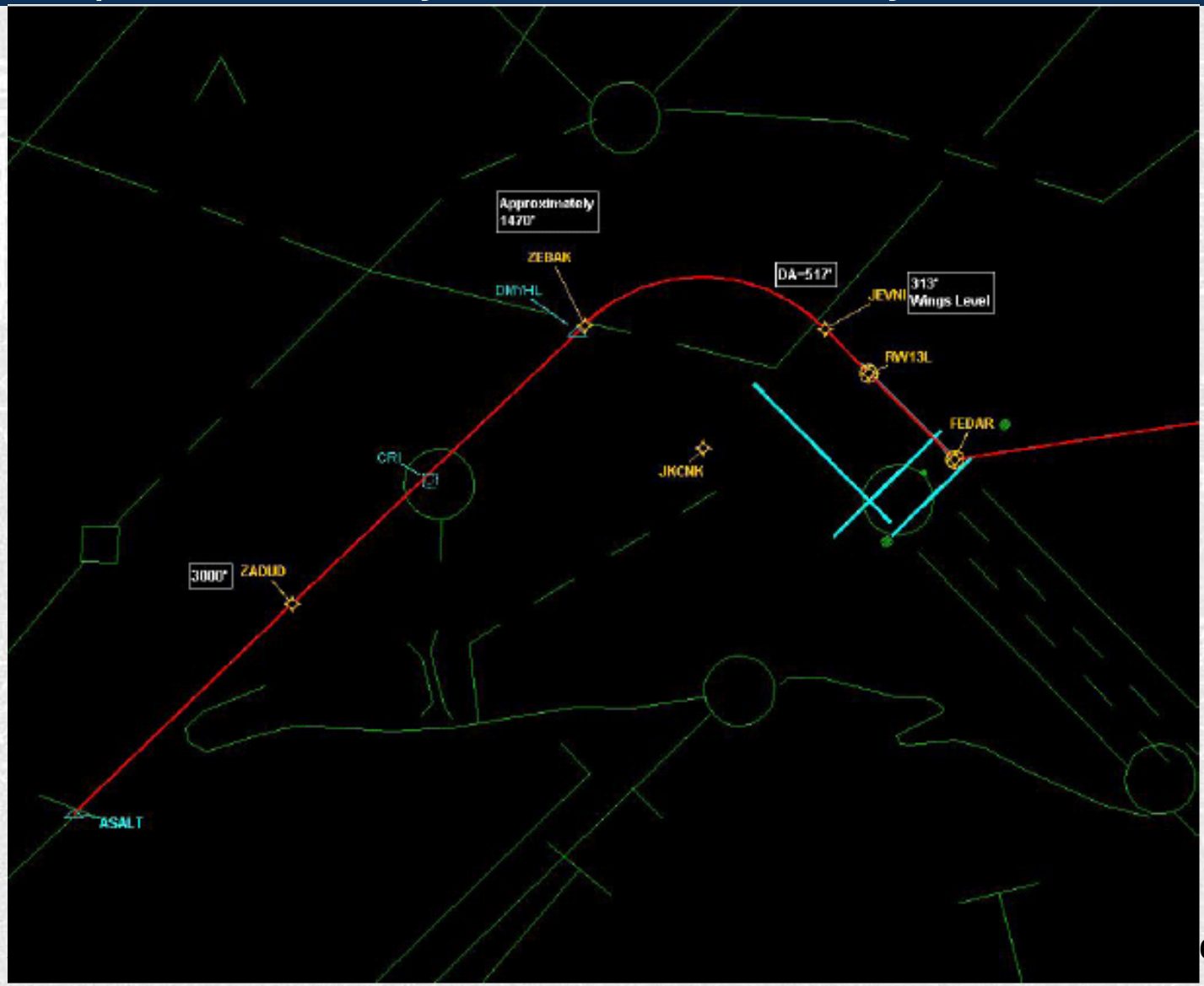
Source: RNAV/RNP Program Update, Federal Aviation Administration

Potential Benefits of RNP

- **IAP's where none possible before & backup procedures**
- **Reduced landing minimums**
- **Reduced voice communications and radar vectoring**
- **Precise navigation accuracy throughout terminal area**
  - **Curved or segmented procedures**
  - **More efficient vertical profiles and reduced fuel consumption**
  - **Predictable, repeatable tracks (potential noise abatement tool)**
- **Reduced separation and obstacle-clearance standards**
  - **More simultaneous operations**
  - **Increased arrival/departure throughput**
  - **Reduced delays, flying times, cancellations, and diversions**
- **More stable visual procedures**
- **Improved situational awareness and safety enhancement**
- **Most importantly -- immediate benefits to early equippers**

ILS Approaches to JFK Runway 13L and ILS Approaches to LGA Runways 4 and 22

Planned RNP SAAAR Approach to JFK Runway 13L/R Sponsored by JetBlue Airways



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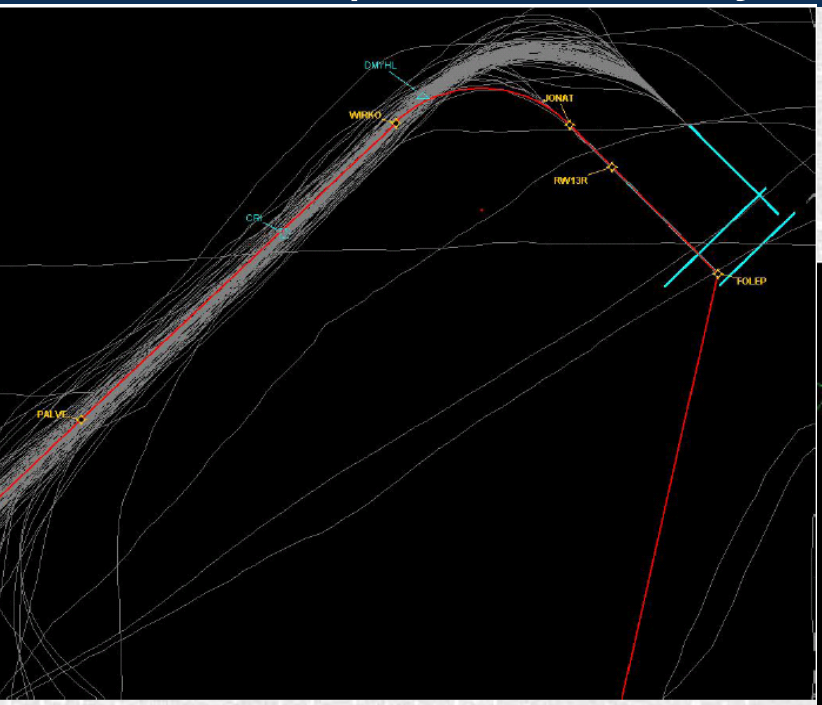
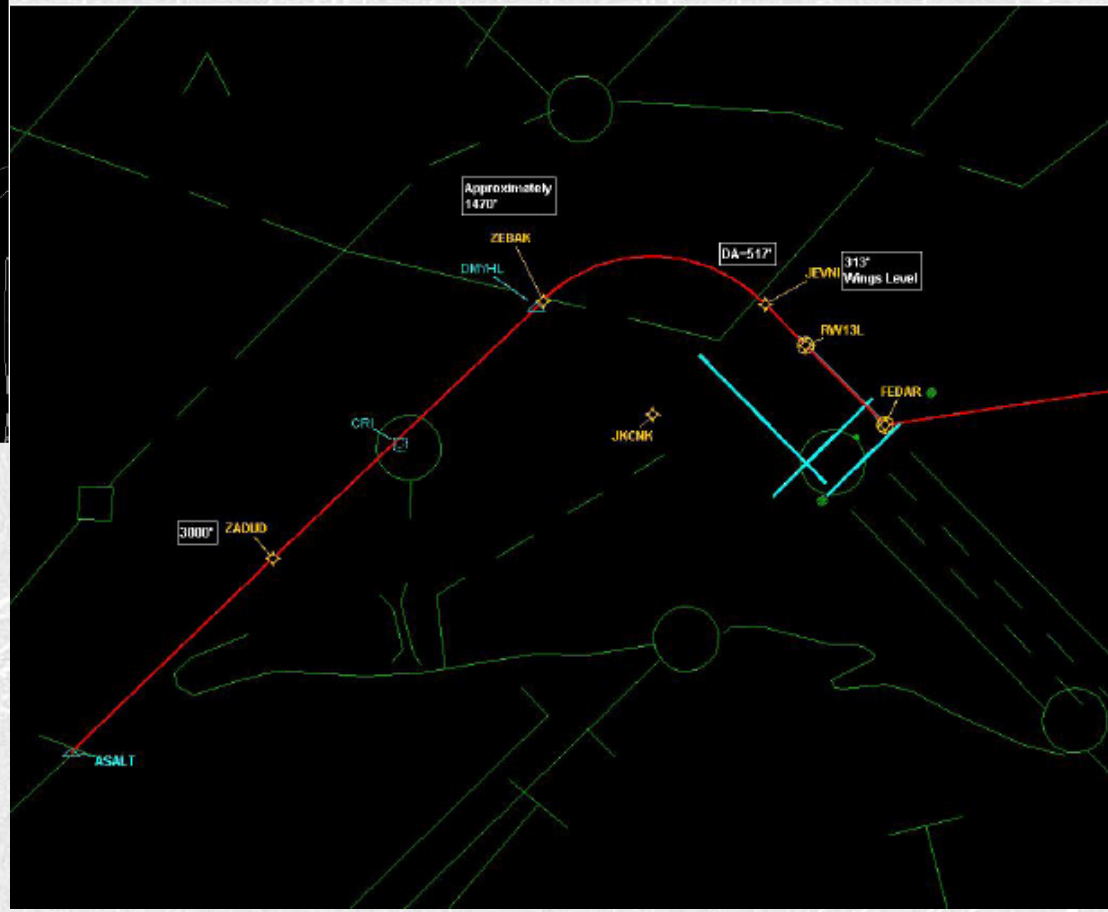
Planned RNP SAAAR Approach to JFK Runway 13L/R Sponsored by JetBlue Airways





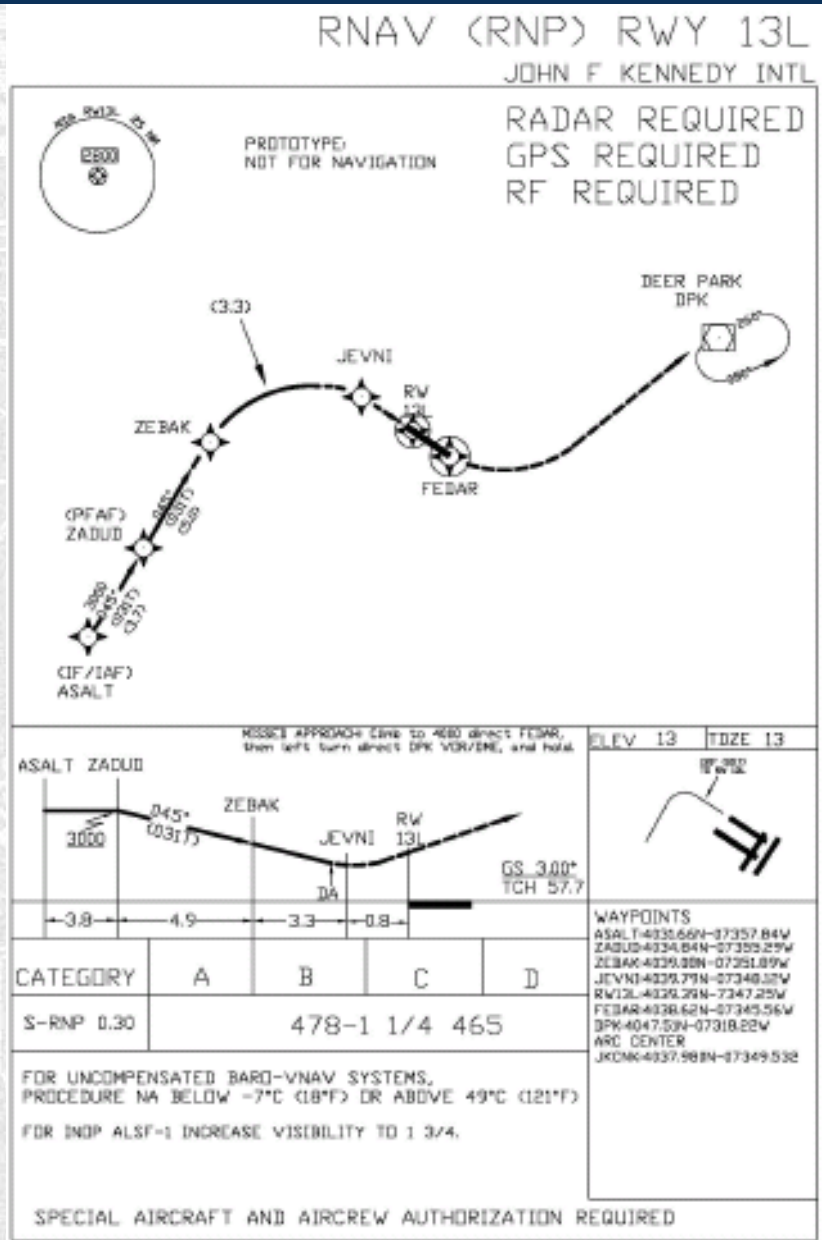
Asilomar Conference Grounds

Planned RNP SAAAR Approach to JFK Runway 13L/R Sponsored by JetBlue Airways

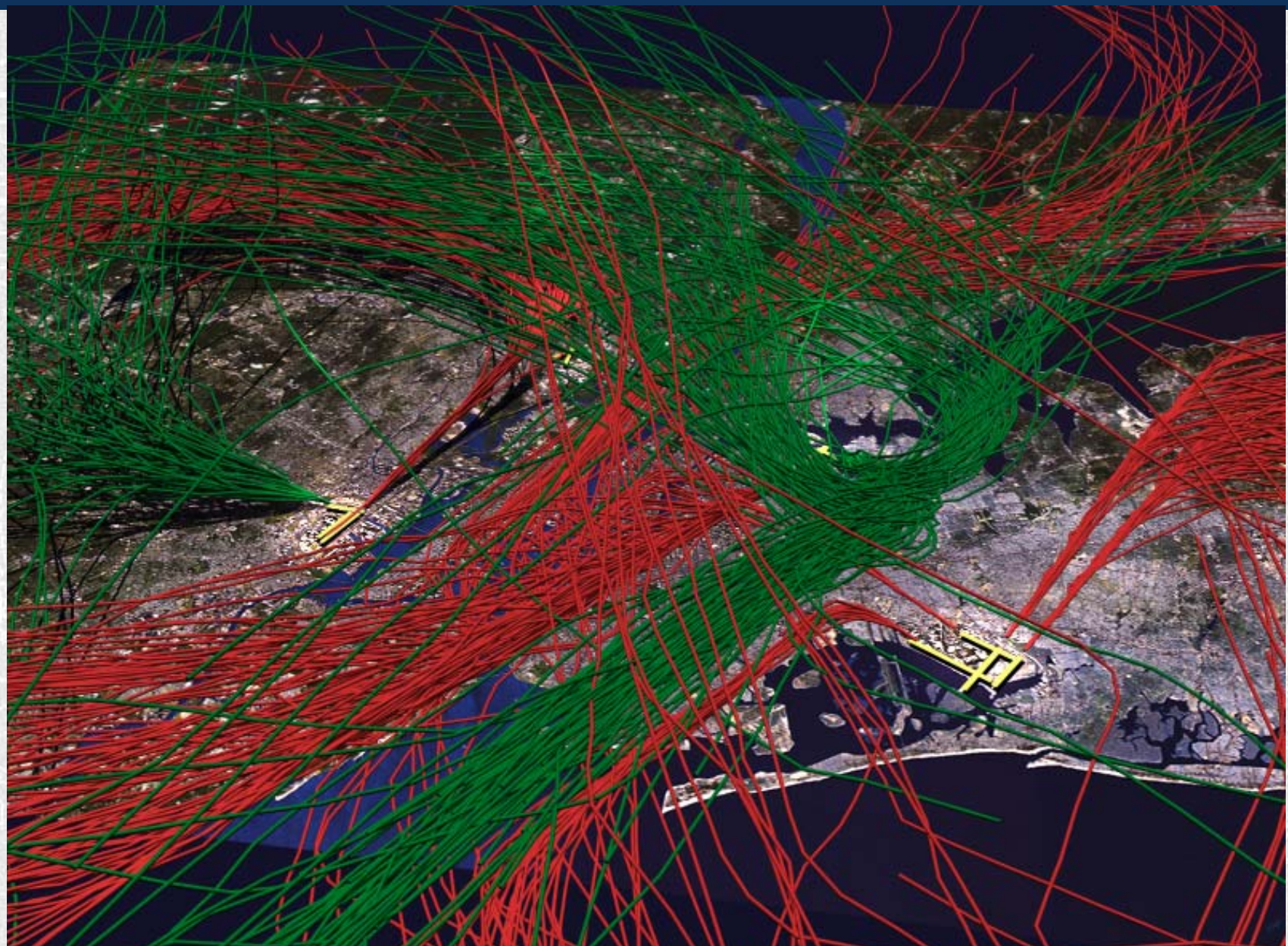
- **RNP value of 0.3 naut. mi.**
- **GPS & inertial are used for guidance**
- **Existing landing minimums 800’ & 2.5 mi.**

FMS CDU

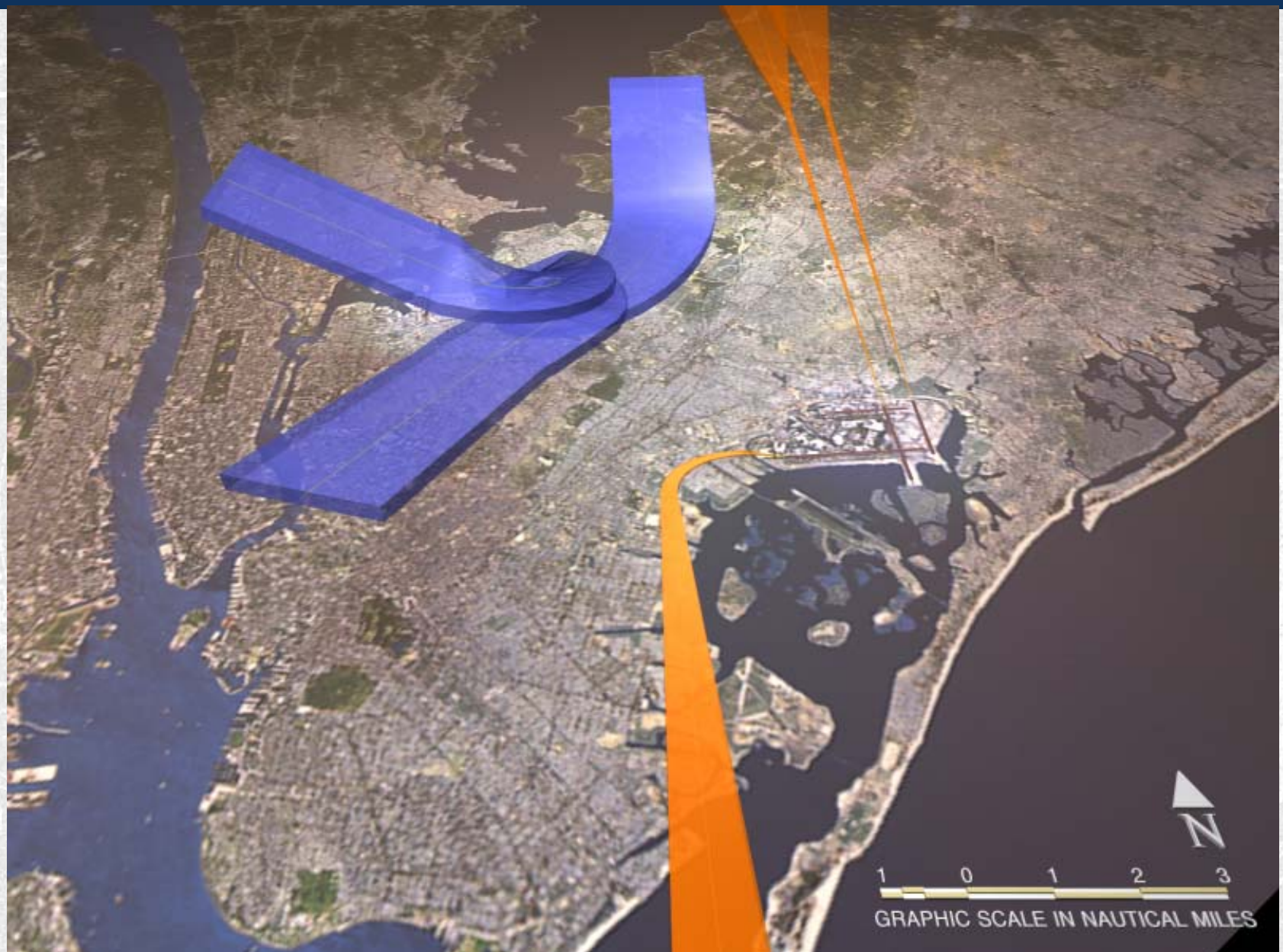
Source: Federal Aviation Administration



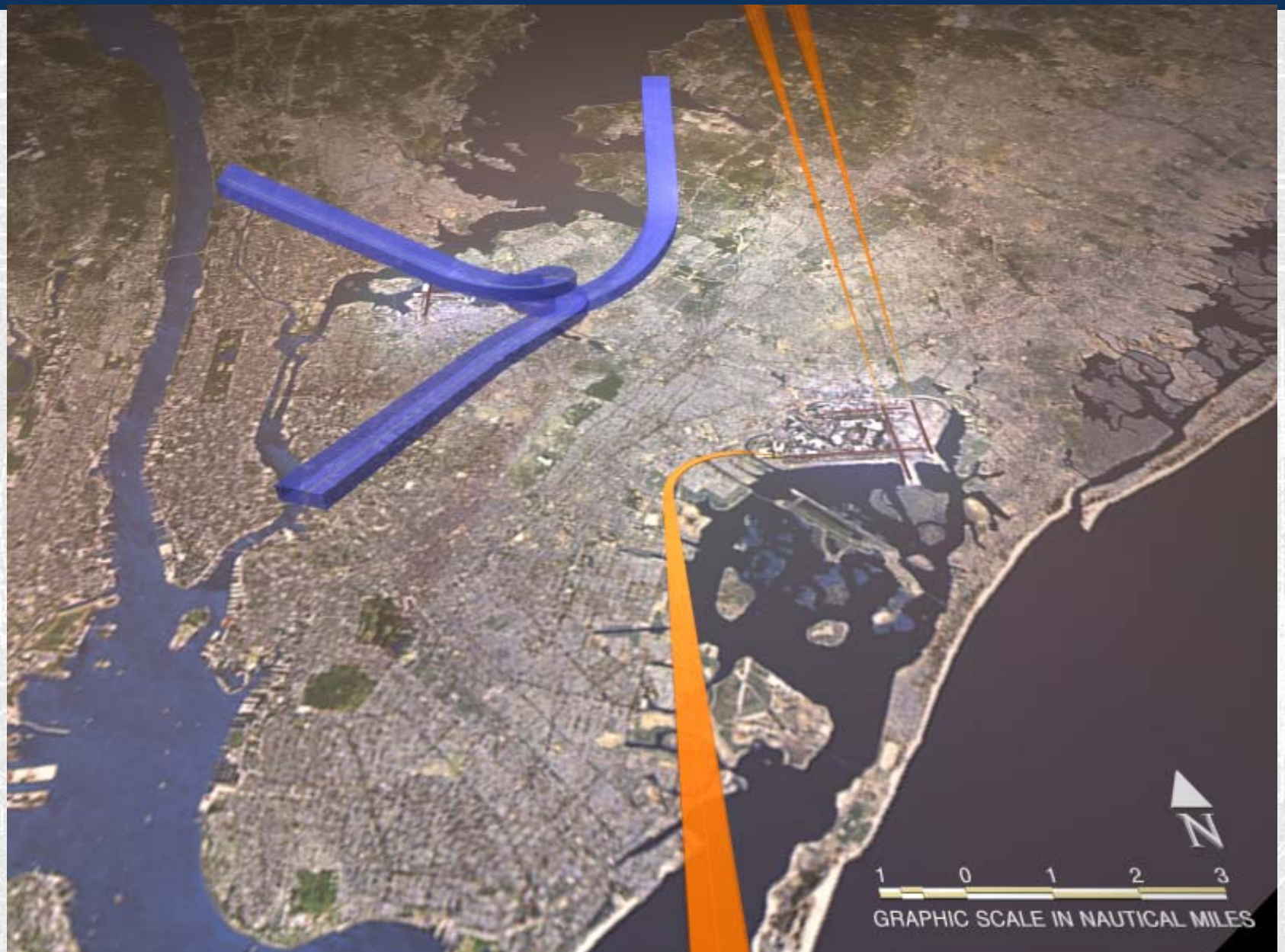
Radar Flight Tracks Showing Existing Interactions



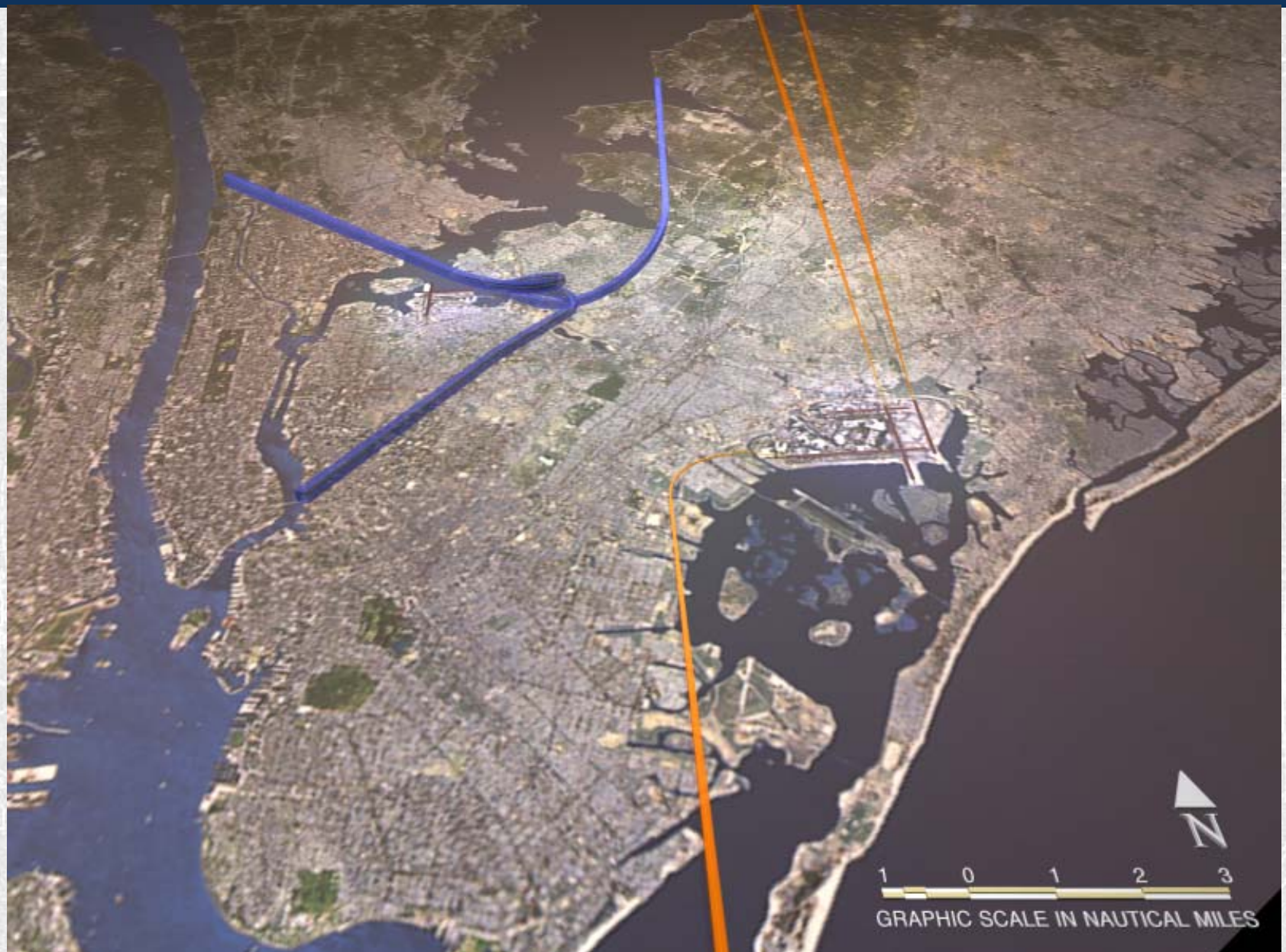
Radar Vectors: RNP about 1.0



RNAV with Current Sensors: RNP about 0.3



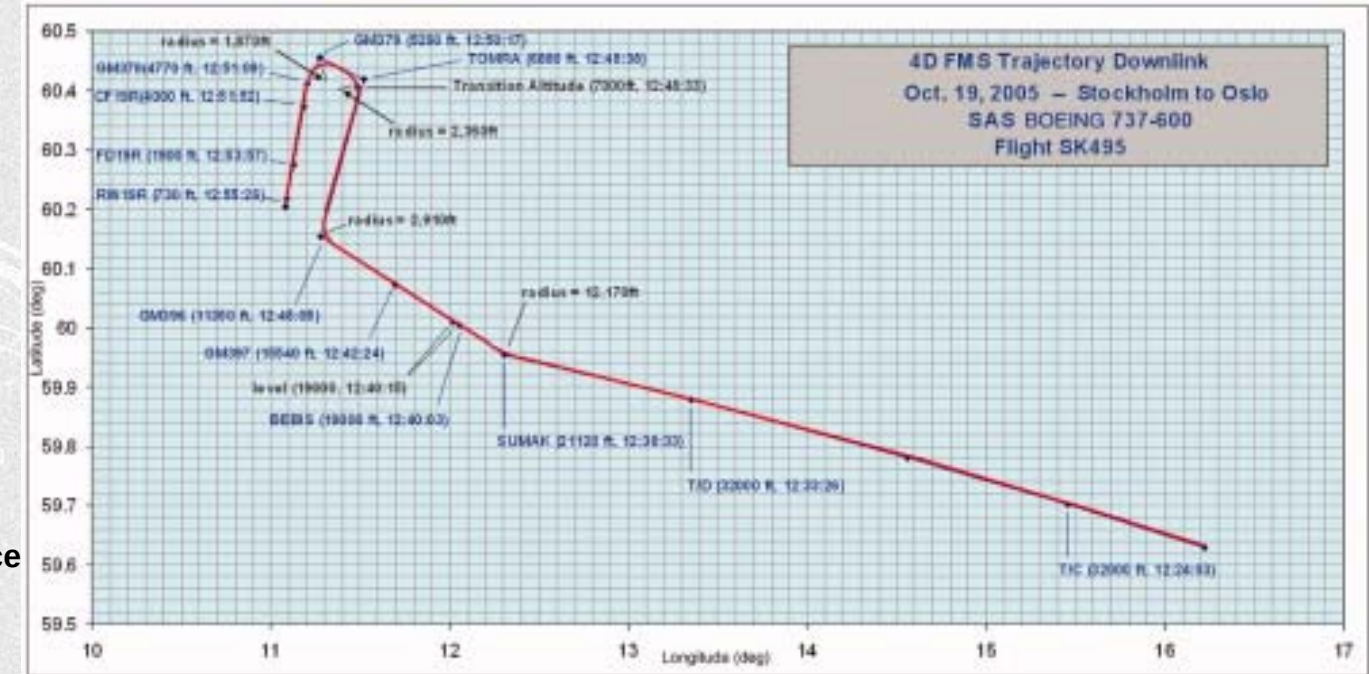
RNAV Enhanced with GPS: RNP about 0.1



Swedish Flight Trials of 4D Trajectories

- **SAS B-737-600 FMS updated for downlinking "4D" trajectories to the ground up to an hour in advance**
- **Will enable controllers to:**
  - **Establish a required time of arrival (RTA)**
  - **Call for speed adjustments to change spacing early in the arrival stream**
- **Will allow pilots to:**
  - **Cross threshold within ±10 sec. of RTA**
  - **Conduct continuous-descent approaches**
    - Conserves fuel while reducing noise and emissions
    - Could save 32 gal. of fuel per approach

Source: Aviation Week & Space Technology 11/07/2005, page 50



Aircraft Equipage

- About 90% of aircraft in U.S. airline fleet are ready to use RNAV procedures
- About 30% of airline aircraft in U.S. are currently equipped to use RNP < 1.0
- New aircraft are equipped with RNP-capable FMSs
  - All new airliners can meet RNP 0.3
  - Boeing has certified next-generation 737 for RNP 0.1
- Future projections of RNP equipage rate:
  - Without existing aircraft retrofit, expected to reach 60% by 2020
  - With retrofit, RNP equipage rate could reach 100% by 2017
  - Could this schedule be accelerated?

Air Traffic Control challenges

- **Ability to distinguish RNP-capable from other aircraft**
  - **Suffixes tell a good story but limited to one letter**
    - /E: Flight Management System (FMS) with DME/DME and IRU position updating
    - /G: Global Navigation Satellite System (GNSS), including GPS or WAAS, with en route and terminal capability
    - /R: Required Navigational Performance. The aircraft meets the RNP type prescribed for the route segment (s), route (s) and/or area concerned.
    - /W: RVSM
    - /J : /E with RVSM
    - /L: /G with RVSM
    - /Q: /R with RVSM
- **Sharing of responsibility for separation assurance**
- **Integration with existing and emerging surveillance and communication capabilities and radar-vectoring procedures**

Air Traffic Control challenges

- **Enhanced clearance procedures, phraseology, and training aids for controllers and pilots (already underway)**
  - **FAA Order 7110.65**
  - **AIM**
  - **Pilot/Controller Glossary**
- **Other challenges (for pilots and controllers)**
  - **Breaking out on a curved path**
  - **Leaving the autopilot coupled below the decision altitude (sy for a DA of 500 feet)**

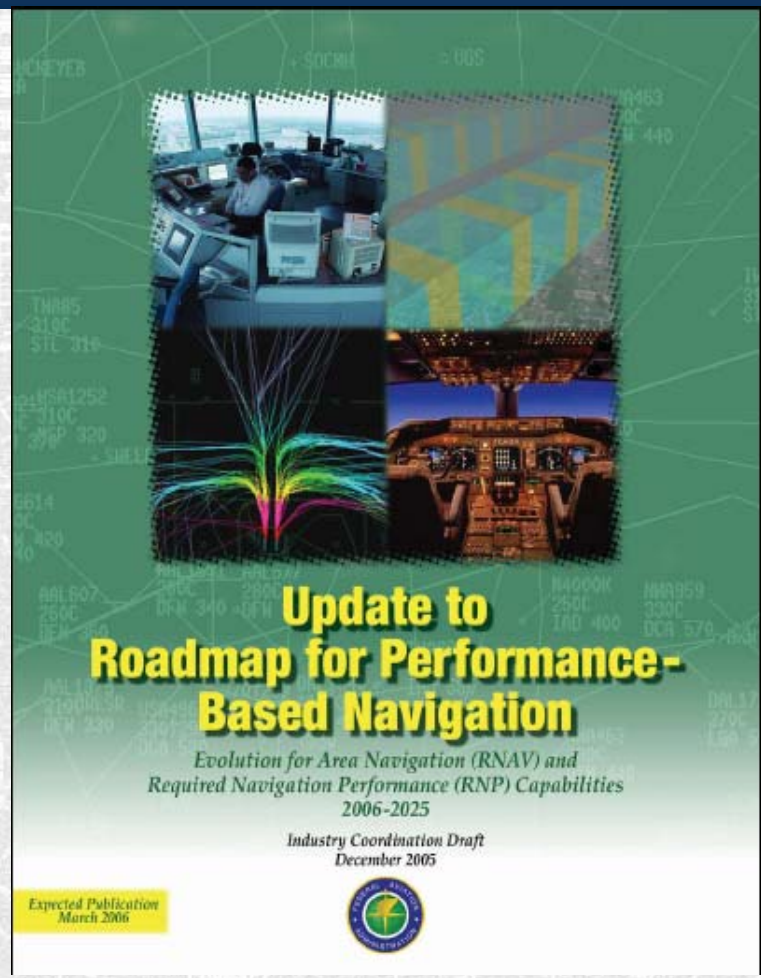
Status and Outlook for RNP

- **Airports where RNP approach procedures are being developed Include JFK, PDX, SFO, PSP, IAH, SUN, and DCA**
- **Airlines developing RNP approach procedures include Alaska, JetBlue, Continental, Delta, Southwest, WestJet, Quantas, and Air New Zealand**
- **All the RNP procedures developed so far are**
  - **Approach procedures**
  - **Require GNSS (unaugmented GPS)**
- **The FAA plans to implement 25 RNP SAAAR approaches per year**
  - **Priorities based on collaboration between FAA and industry**
  - **Performance Based Operations Aviation Rulemaking Committee (PARC)**

Recent FAA Publications

- **FAA Orders -- Procedures and Criteria**
  1. FAA Order 8260.52, *United States Standard for Required Navigation Performance (RNP) Approach Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR)*
  2. FAA Advisory Circular (AC) *90-RNP SAAAR*
  3. FAA Notice 8000.300, *Required Navigation Performance (RNP) Airworthiness Approval, Operational Approval, and Design Guidelines for Special Aircraft and Aircrew Authorization Required (SAAAR) Approach Procedures*
  4. FAA Order 8260.(RNP), *United States Standard for Required Navigation Performance (RNP) Approach Procedures (in development)*

http://www.faa.gov/ats/atp/rnp/rnav.htm



RNP Research Recommendations

- **Open up participation in RNP procedure development to wider range of stakeholders**
  - **Involve Airports**
  - **How can we find “win-win-win-win” situations for the “airlines-airports-FAA-communities”?**
- **Encourage and coordinate continued development of beneficial RNP approach and departure procedures**

RNAV & RNP Research Recommendations

- **Do the math**
  - **FAA cost to develop RNP procedure about $20,000, with annual M&O cost of $3,000**
  - **One "saved" diversion is worth about $30,000 - $50,000 to the airline**
    - AL says it's more like $5,000 - $10,000 per "save", considering 3 kinds of saves: reduce delay, avoid cancellation, and avoid diversion
  - **Main cost to airlines is for training and equipage**
- **Goal: Reach a "tipping point" where**
  - **Sufficient aircraft will be equipped to enable significant increases in airport capacity**
  - **Equipping will become a competitive necessity for the airlines**
    - If you're not equipped, you can't compete