Federal Aviation Administration

Performance Based Navigation (PBN)

Presented to: ICAO PBN Workshop for Air Traffic Controllers

Michael Watkins, Senior Air Traffic Representative – Asia/Pacific

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Overview

- Next Generation Air Transportation System (NextGen)
- Performance Based Navigation (PBN)
- Real World Examples
- Stakeholders in the PBN Procedure Development Process
- Aircraft Equipage
- Area Navigation (RNAV) Departures (SID)
- Optimized Profile Descents (OPD)
- Flight Management Systems (FMS)
- PBN/RNAV Reference Materials

Next Generation Air Transportation System - NextGen

Integrates new and existing technologies, policies and procedures to enhance safety, save fuel, and reduce delays to deliver a more reliable travel experience.

ENHANCES SAFETY

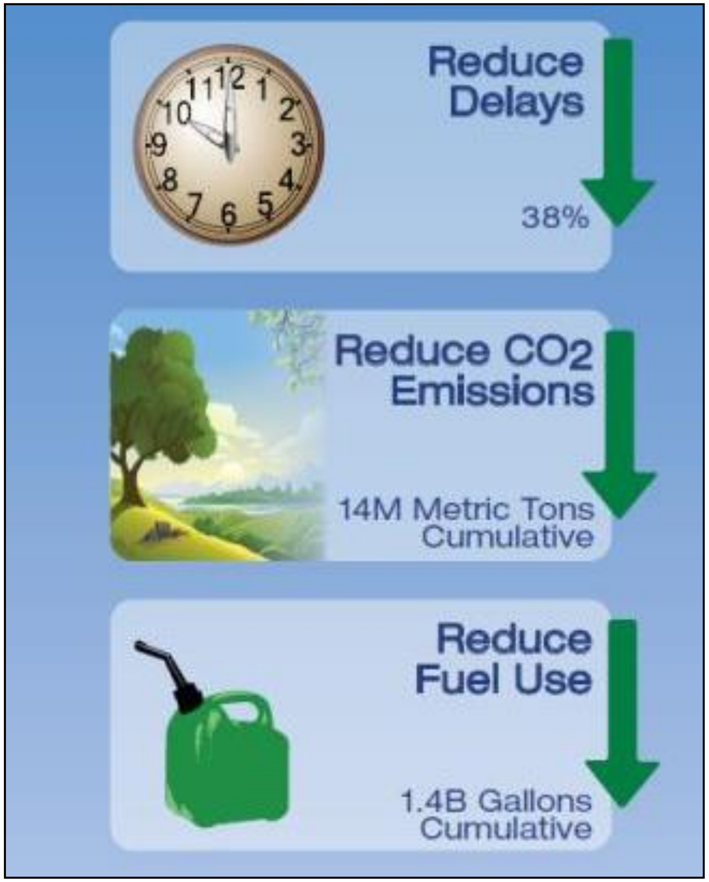
SAVES FUEL

REDUCES DELAYS

NextGen Benefits

Reduced Environmental Impact

NextGen will reduce aviation's environmental footprint through a combination of enhanced air traffic procedures, and other measures to make continual improvements. The efficiencies that reduce delays also save fuel and reduce emissions.



A key component of NextGen is Performance Based Navigation (PBN)

Performance Based Navigation (PBN)

History of PBN

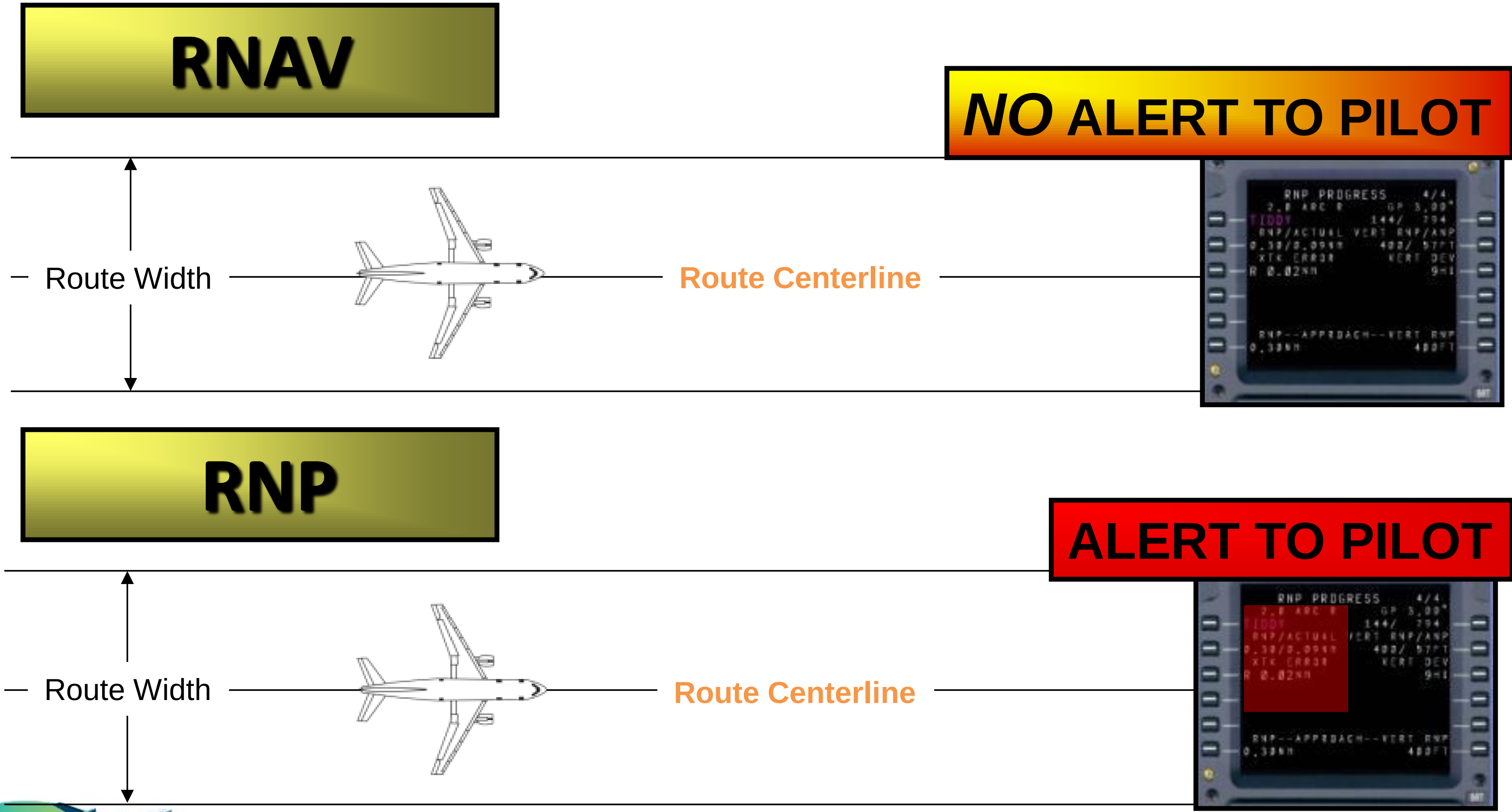
- Industry requests the establishment of an RNAV/RNP Program at FAA-RTCA Spring Forum 2002
- FAA Administrator issued a policy statement committing FAA to aggressively pursue the implementation of RNAV and RNP in the National Airspace System - July 22, 2002
- Roadmap initiatives incorporated into NextGen Implementation Plan and FAA Enterprise Architecture - 2008/2009
- NextGen Implementation Plan – March 2012

Performance Based Navigation (PBN)

- Navigation based on specified system performance requirements for aircraft operating on an air traffic route, instrument approach procedure, or in a designated airspace.
- Potential for aircraft to demonstrate requirements compliance through a mix of capabilities, rather than only specific equipment.

PBN makes key distinctions between *RNAV* and *RNP*

RNAV vs RNP


RNAV
NO ALERT TO PILOT
Route Width
Route Centerline
RNP
ALERT TO PILOT
Route Width
Route Centerline

RNAV/RNP Accuracy Values

(Not to be confused with separation standards)

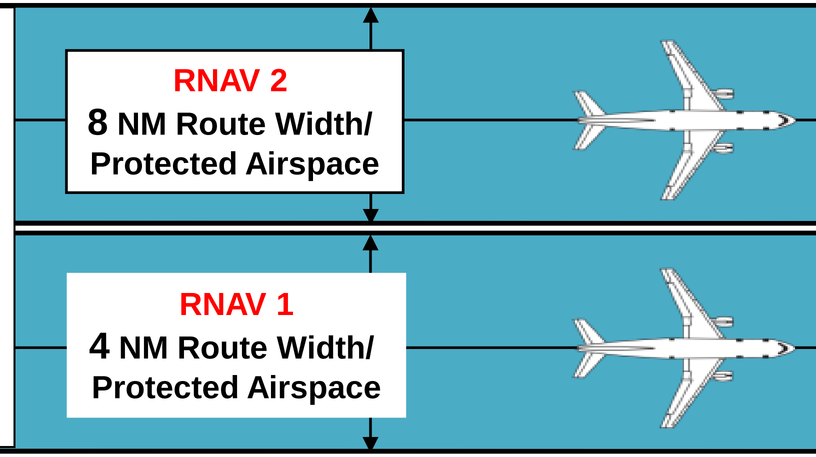
Oceanic and remote continental airspace is currently served by two navigation applications, RNAV 10 and RNP 4.

En-Route airspace in the U.S. is designated

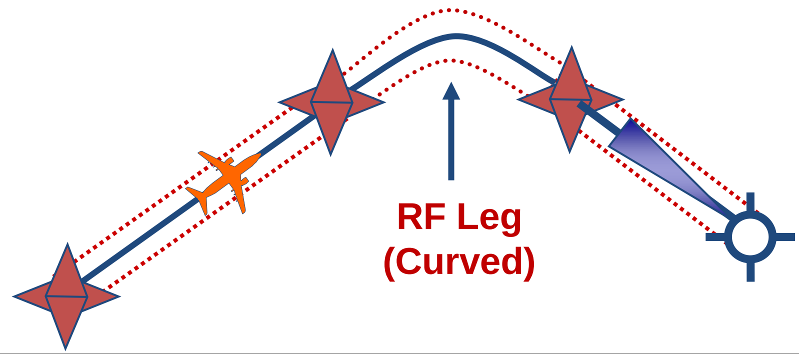
RNAV 2

Terminal airspace is designated

RNAV 1

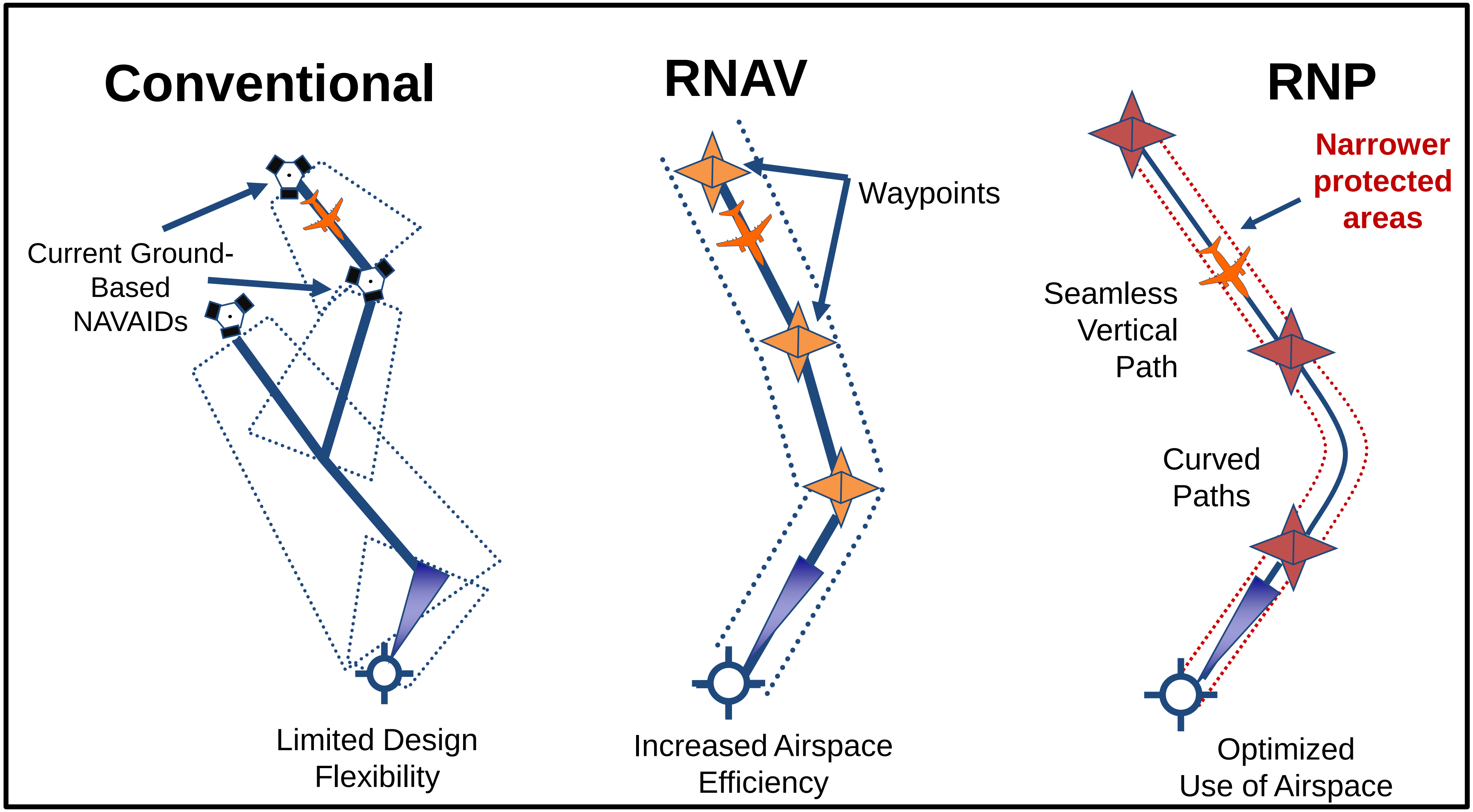


RNP Approach specifications require a standard navigation accuracy of RNP 1 in the *initial*, *intermediate* and *missed* segments and RNP 0.3 in the *final* segment.



Performance Based Navigation:

A Key Building Block of NextGen

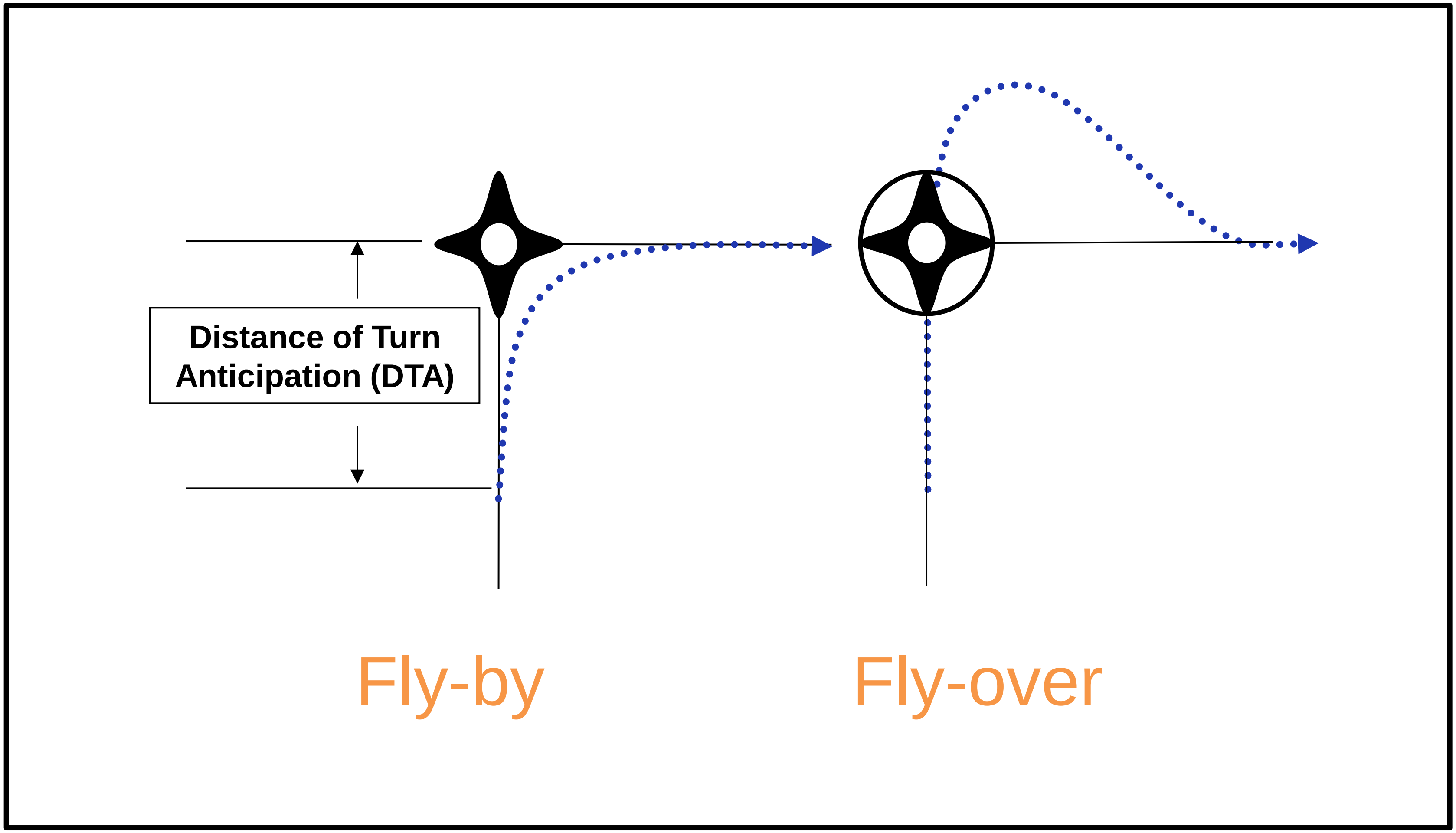


What Do Waypoints Do?

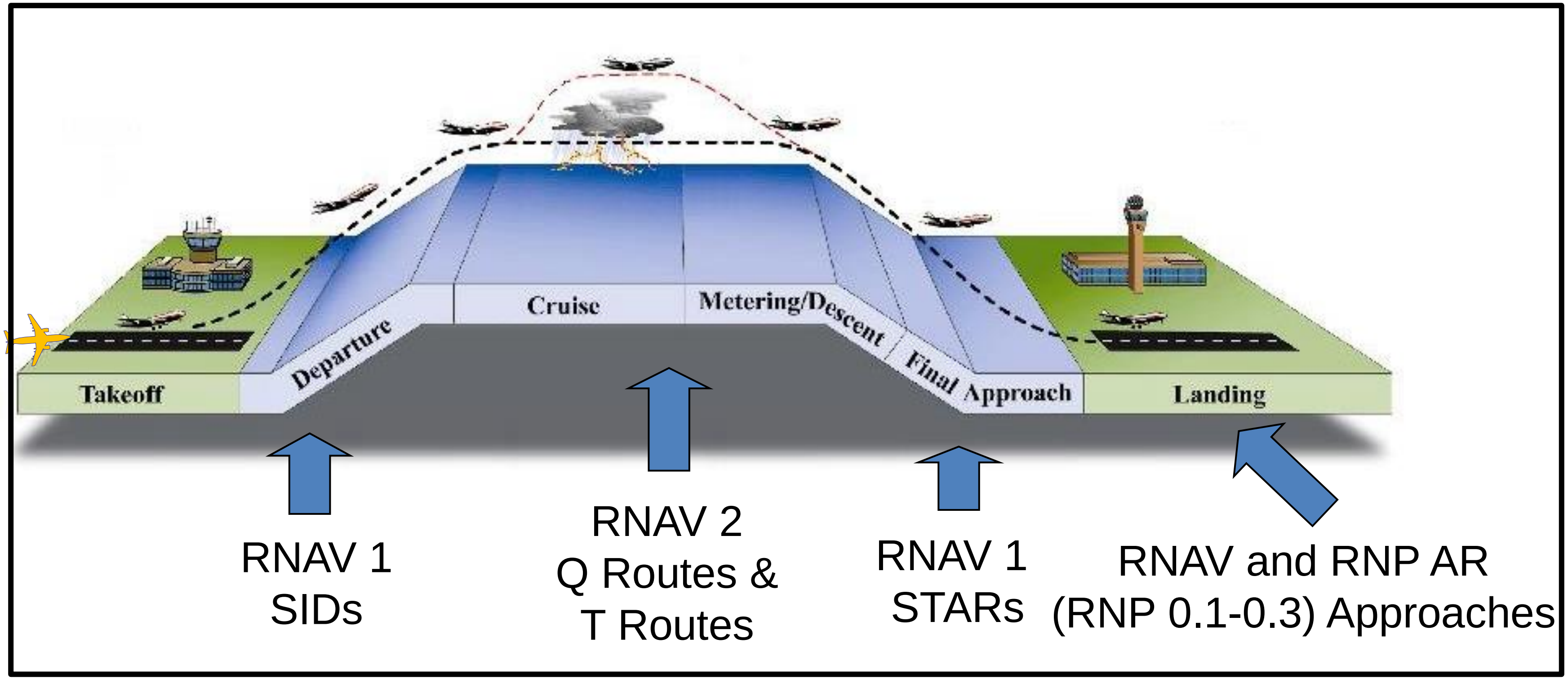
- Waypoints specify a geographic location in terms of latitude and longitude used for route definition, or as a reporting point.

- A waypoint may be used to indicate changes in:
  - Speed
  - Altitude
  - Direction

Types of Waypoints



PBN Implementation



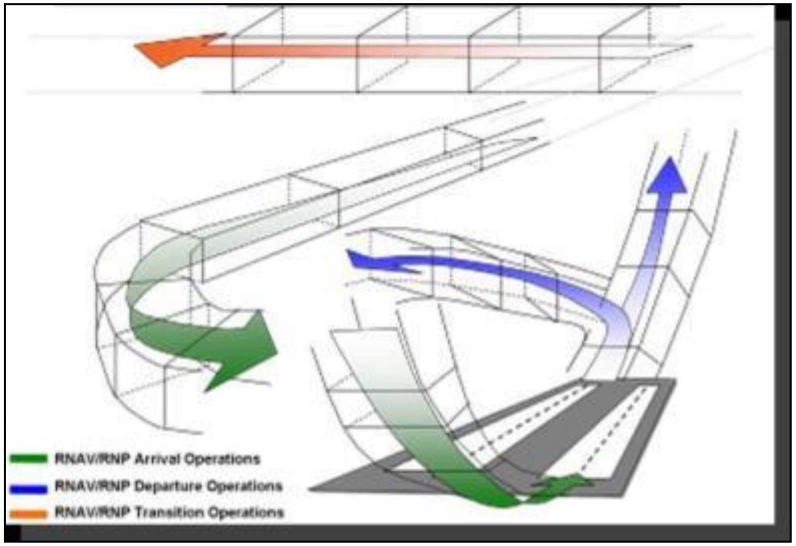
An integrated procedures concept will provide a framework for integration of PBN initiatives from departure to approach (including en route).

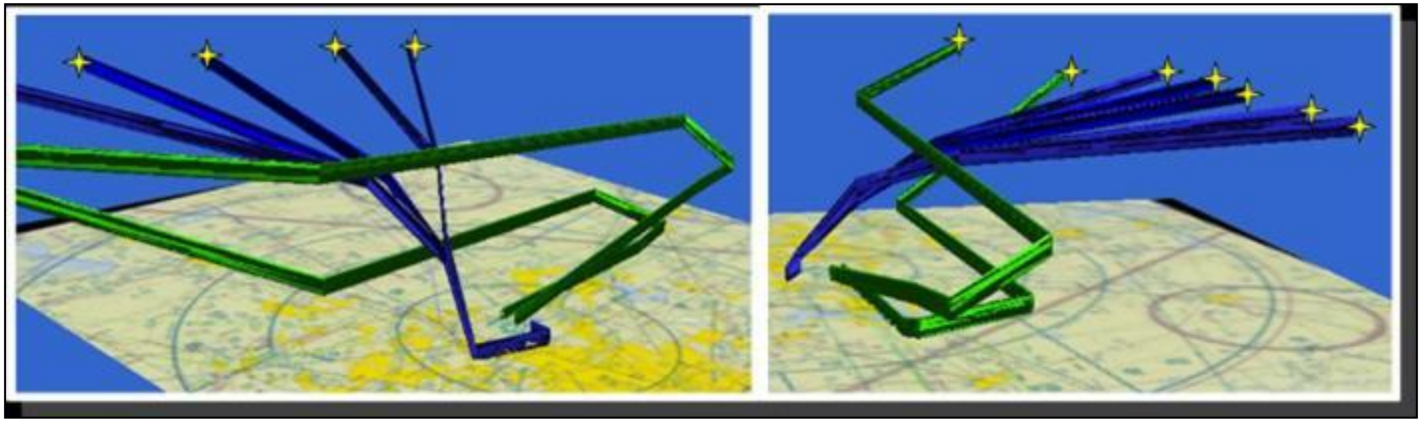
Integration of Procedures

Applications for De-confliction, Optimization and Benefits

Segregate traffic flows

- Between arrival/departure and transition operations
- Between primary and satellite airport operations
- Between city pairs





Benefits of PBN

RNAV or RNP procedure implementation can provide benefits in one or more of the following areas:

Safety | **Throughput** | **Efficiency** | **Access** | **Environment**

Benefits of PBN

Safety

- More accurate and reliable lateral and vertical paths.
- Enables reduced obstacle clearance criteria

  Allows new three-dimensional guided arrival, approach and departure procedures
- Enhances consistency of traffic flow.
- Reduces the risk of communication errors.

Benefits of PBN

Throughput

- Reduced delays at airports and in crowded airspace through:

  Procedurally de-conflicted arrival and departure routes

  Parallel routes

  Additional ingress/egress points around busy terminal areas

  Improved flight rerouting capabilities

  Development of closely spaced procedures for more efficient use of airspace

  De-conflicting adjacent airport flows

Benefits of PBN

Efficiency

- Enhanced reliability, repeatability, and predictability of operations increases air traffic throughput.
  - More precise arrival, approach, and departure procedures reduce track dispersion and facilitate smoother traffic flows
  - Less restrictive climb and descent gradients with shorter and more predictable ground tracks

Benefits of PBN

Access

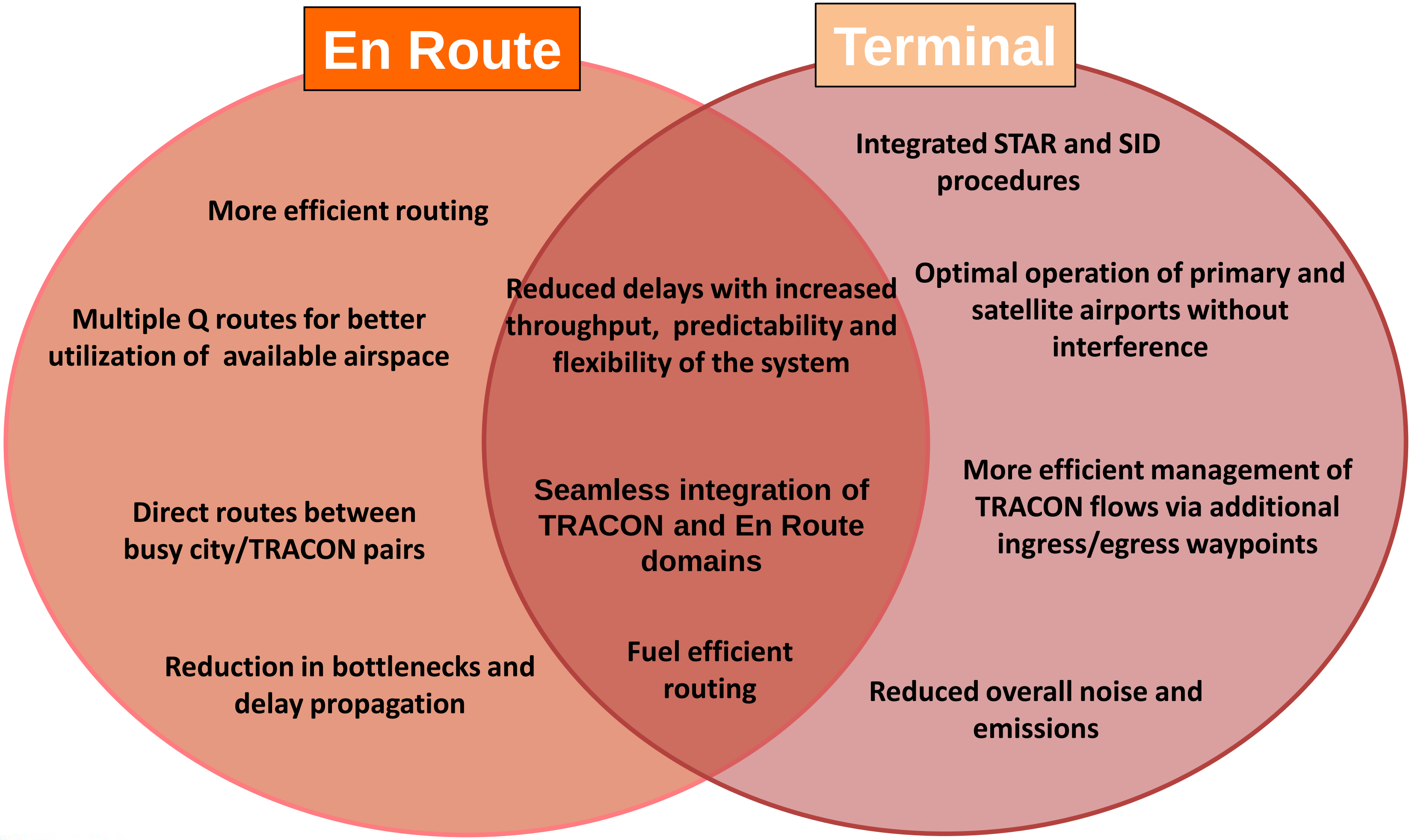
- Obstacle clearance and environmental constraints can be better accommodated through the application of optimized flight tracks.
- Reduced obstacle clearance criteria and more accurate path keeping can allow improved three-dimensional guided arrival, approach and departure procedures at airports (lower minima).

Benefits of PBN

Environment

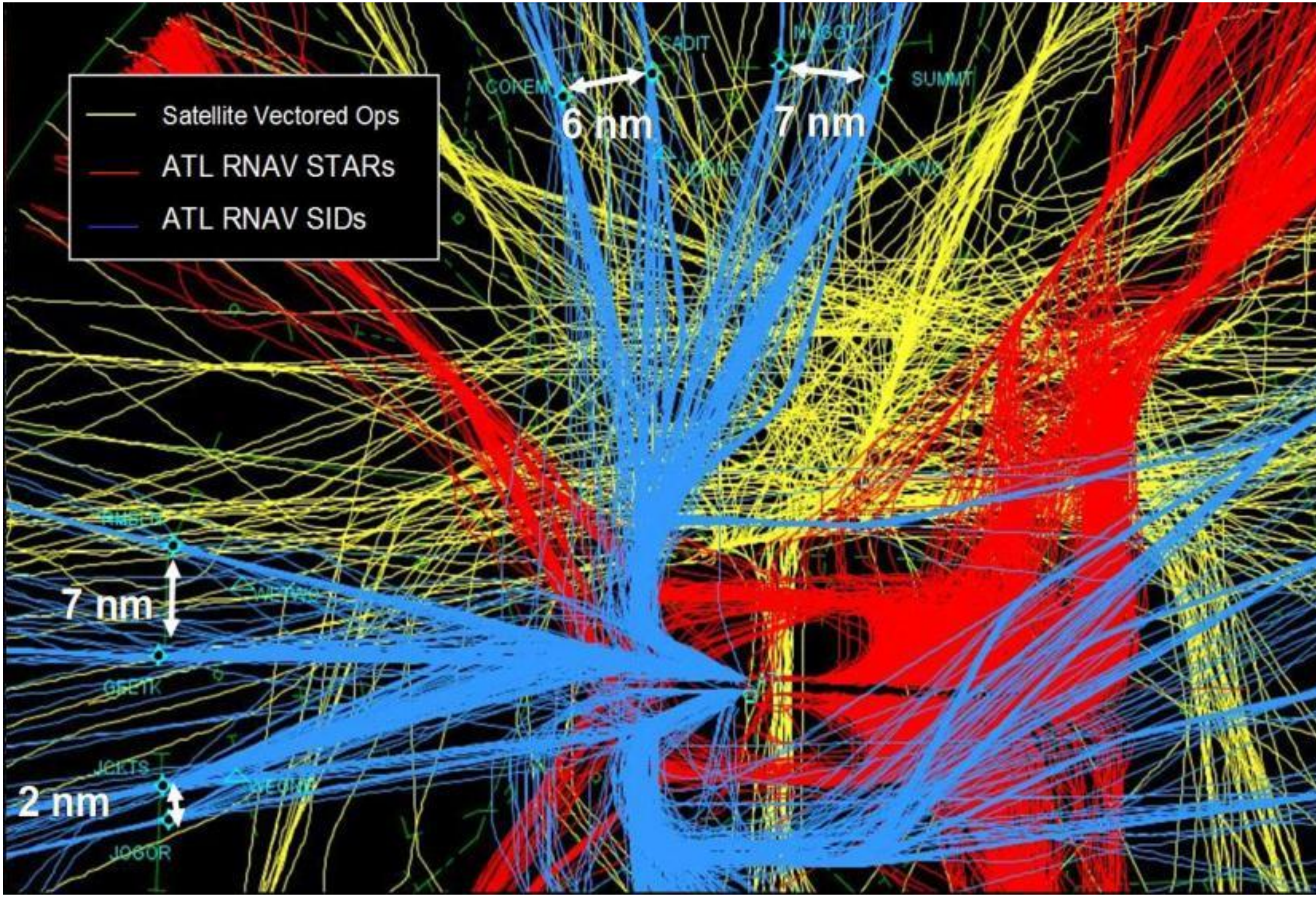
- Fuel efficiencies and reduced emissions can be achieved through:
  - Reduced ground delays resulting from the increased efficiency of departure flows
  - Improved flight profiles
- Flight tracks can be designed to avoid noise-sensitive areas.

Integrated Procedure Development



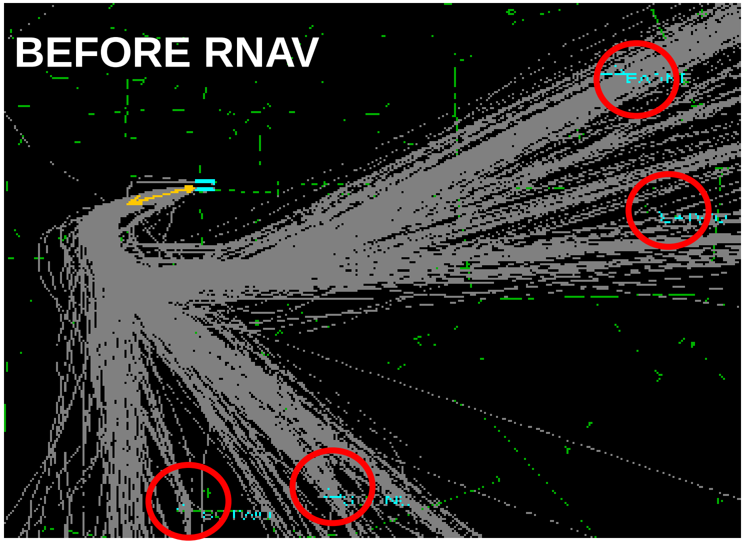
FAA
Air Traffic Organization

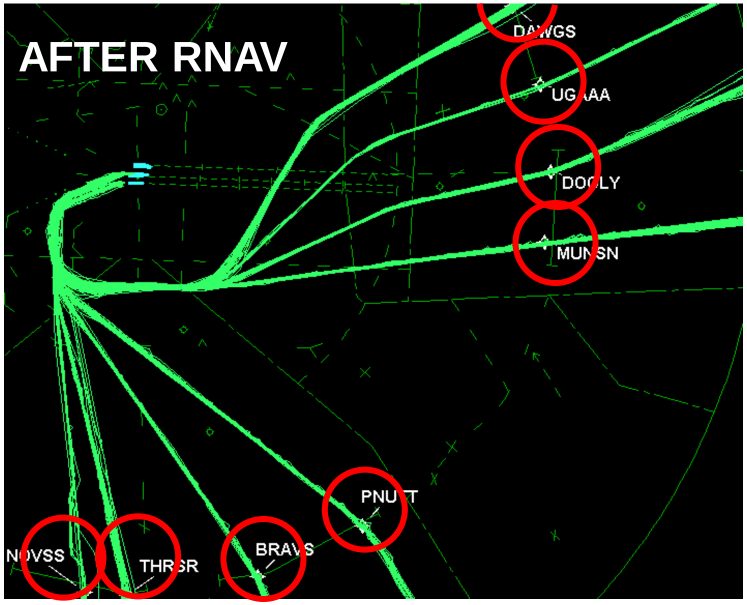
PBN Real World Examples


Satellite Vectored Ops
ATL RNAV STARs
ATL RNAV SIDs
COKEM
SADIT
SUMMT
6 nm
7 nm
7 nm
2 nm

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





Post-RNAV Implementation

ATL Communications Reduced up to:

- 40% for Departure Controller with RNAV SID
- 50% for Approach Controller with RNAV STARs

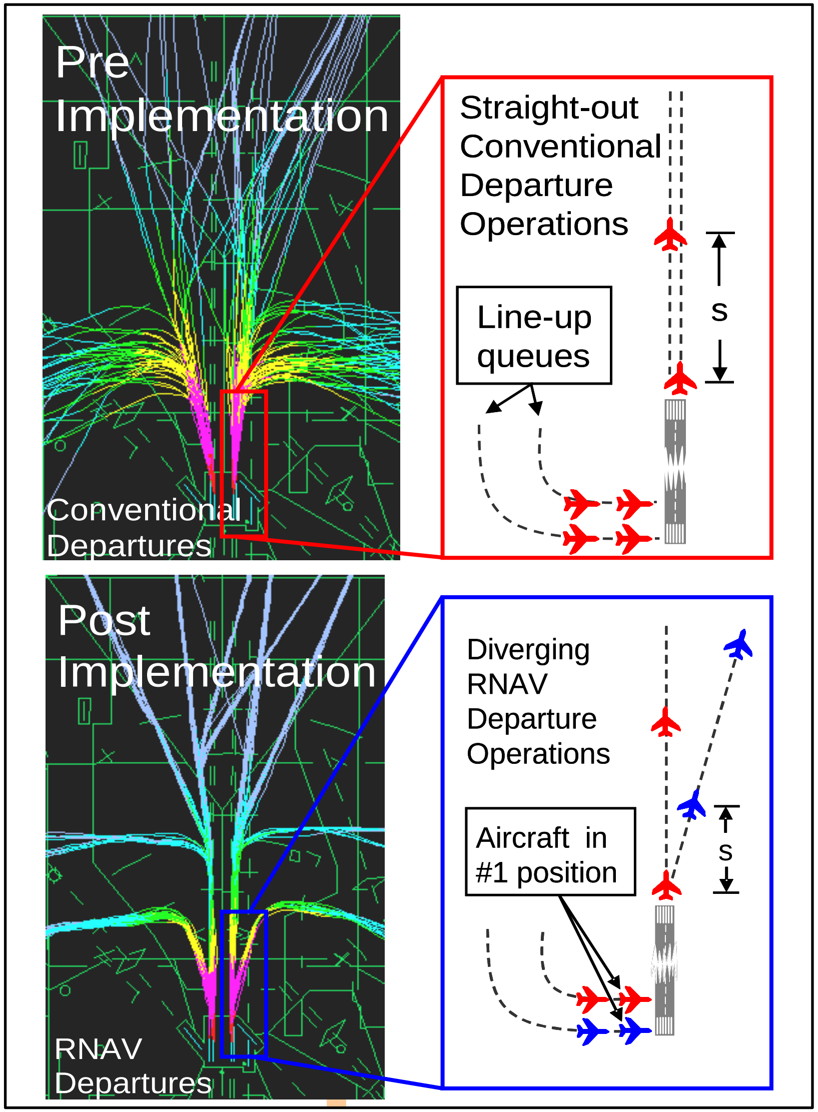
Dallas/Fort Worth International (DFW)

- RNAV enabled diverging departures at DFW.
- Diverging departures allow for the application of same runway separation standards reducing inter-departure times.
- Increase in departure capacity.

11 to 20 additional operations per hour

45% reduction in delay during peak demand

Increased departure capacity results in approximately $8.5M to $12.9M in delay savings per year.



Stakeholders in the PBN Procedure Development Process

- PBN Policy and Support Group
- Aviation System Standards
- Flight Standards
- Aircraft Certification
- Lead Operator
- ATC Facilities
- Service Center
  - Ops Support Group
  - Environmental Office
  - Safety Management Office
- Airport Authority

Procedure Proponents

- National Initiatives
- Lead Operators
- Airports and/or Air Traffic Facilities
- Industry User Groups

Aircraft Equipage


MODE CONTROL UNIT (MCU)
PRIMARY FLIGHT DISPLAY (PFD)
MULTI FUNC
Y (MFD)
CONTROL DISPLAY UNIT (CDU)

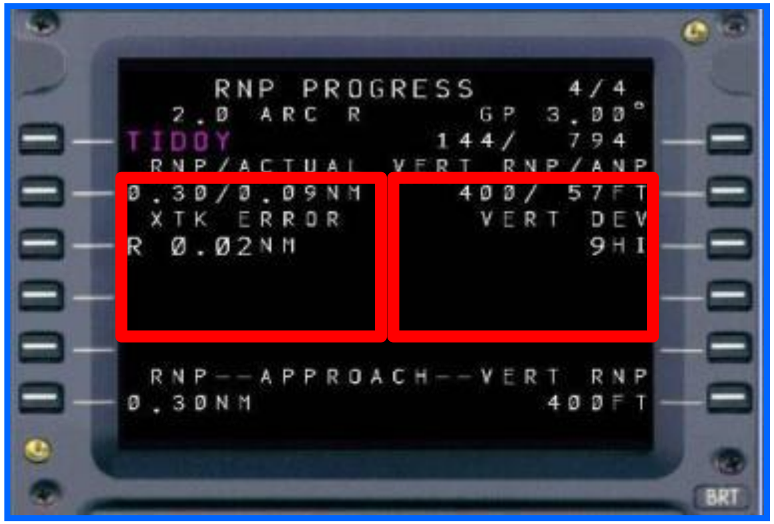
Airbus 380 Cockpit

Flight Management System (FMS)

- All FMS contain a navigation database, the elements from which the flight plan is constructed. These databases are defined via the ARINC 424 standard and are normally updated every 28 days.
- FMS capabilities are an integral part of RNAV/RNP procedures.

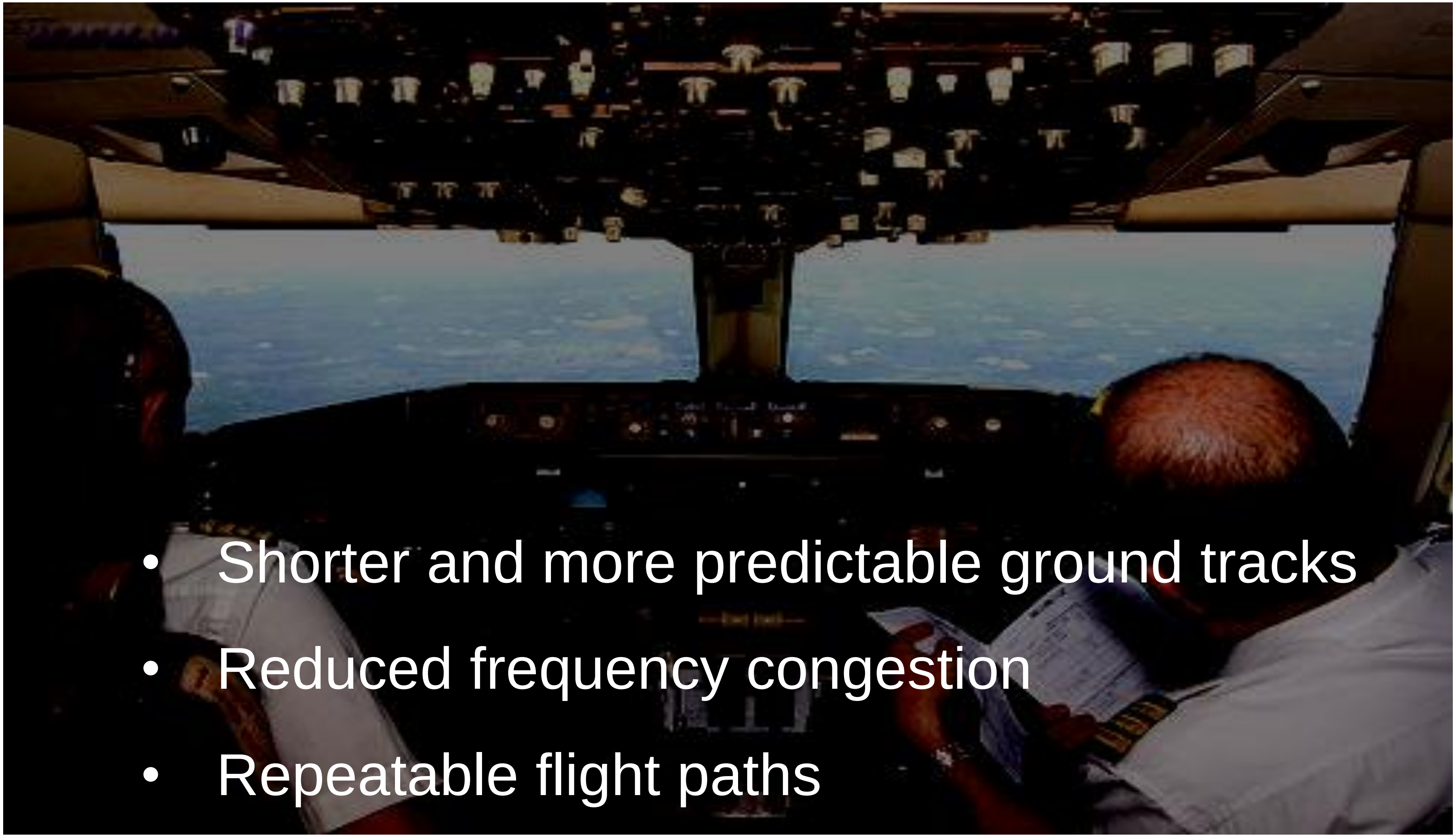
RNP

- A defining characteristic of RNP operations is the ability of the aircraft to monitor the navigation performance and inform the crew if the required aircraft performance is not met during an operation.
- This on-board monitoring and alerting capability enhances the pilot's situational awareness and can enable reduced obstacle clearance.



RNAV SID

RNAV SID Benefits



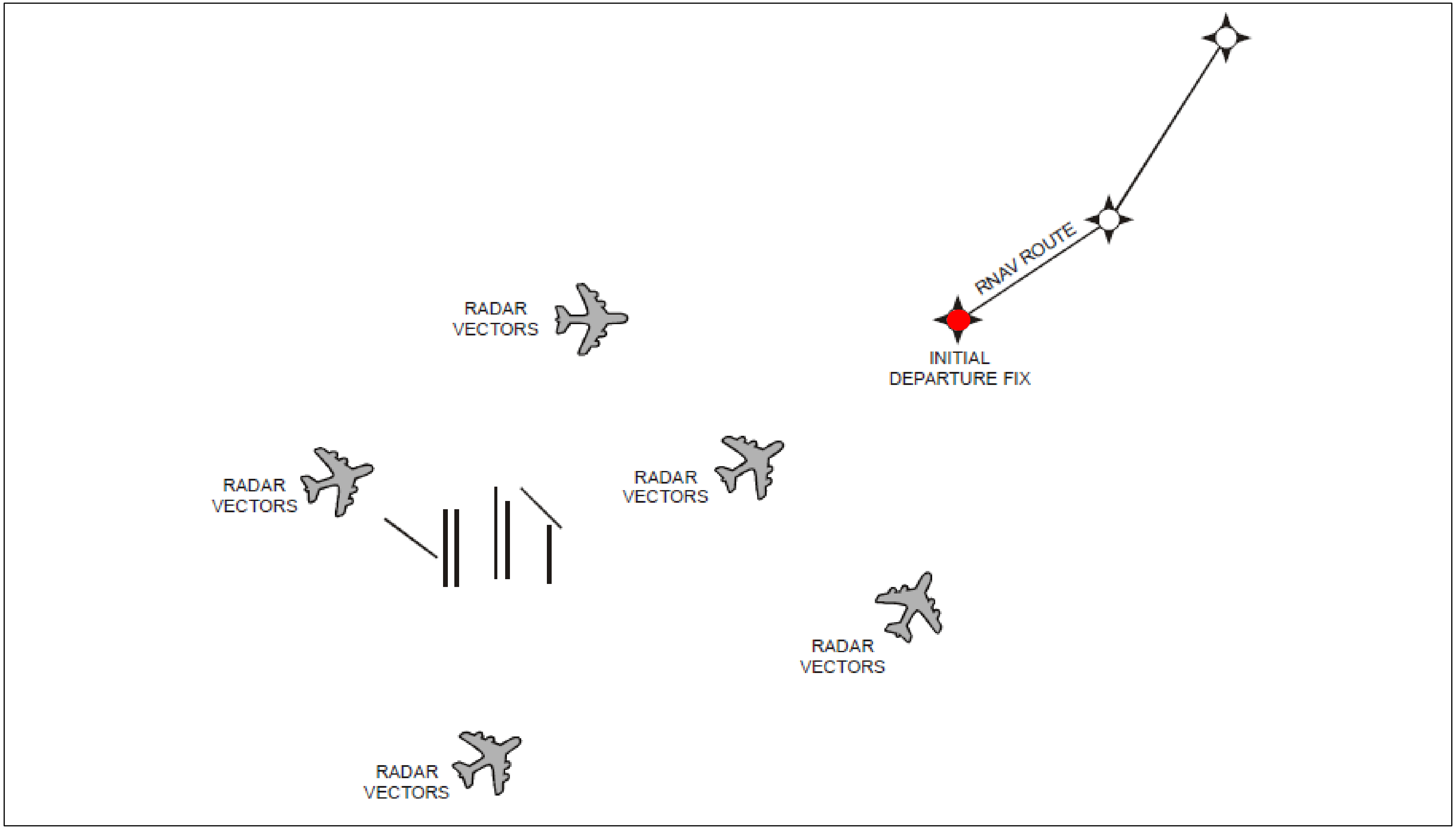
- Shorter and more predictable ground tracks
- Reduced frequency congestion
- Repeatable flight paths

Radar Vector SID

SIDs That Use Radar Vectors to Join RNAV Routes

- RNAV operations offer significant advantages in establishing routes for departures.
- Radar vectoring affords flexibility of routing and allows an aircraft to attain sufficient altitude/distance to achieve a satisfactory navigation solution prior to using RNAV.

Air Traffic (AT) may use radar vectors to pre-position departing aircraft prior to authorizing RNAV.



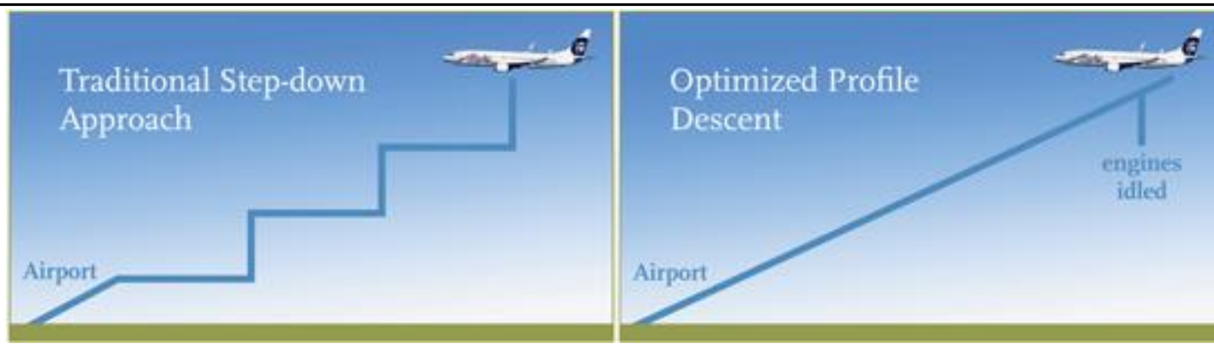
Optimized Profile Descent (OPD) RNAV STAR

Optimized Profile Descent (OPD)

- A descent profile procedure normally associated with a published STAR.
  - It starts at Top of Descent and, to the extent possible, comprises idle power descents that minimize thrust required to remain on the vertical path.
  - The termination point may be on an instrument approach procedure to allow for a continuous descent from the STAR to the runway, or at a point in space that allows for radar vectoring.
- OPDs are designed to allow use of aircraft automation and piloting techniques to maximize fuel efficiency and minimize environmental impact.

OPD

- Modern Flight Management Systems are capable of managing and optimizing descents along a predetermined path.

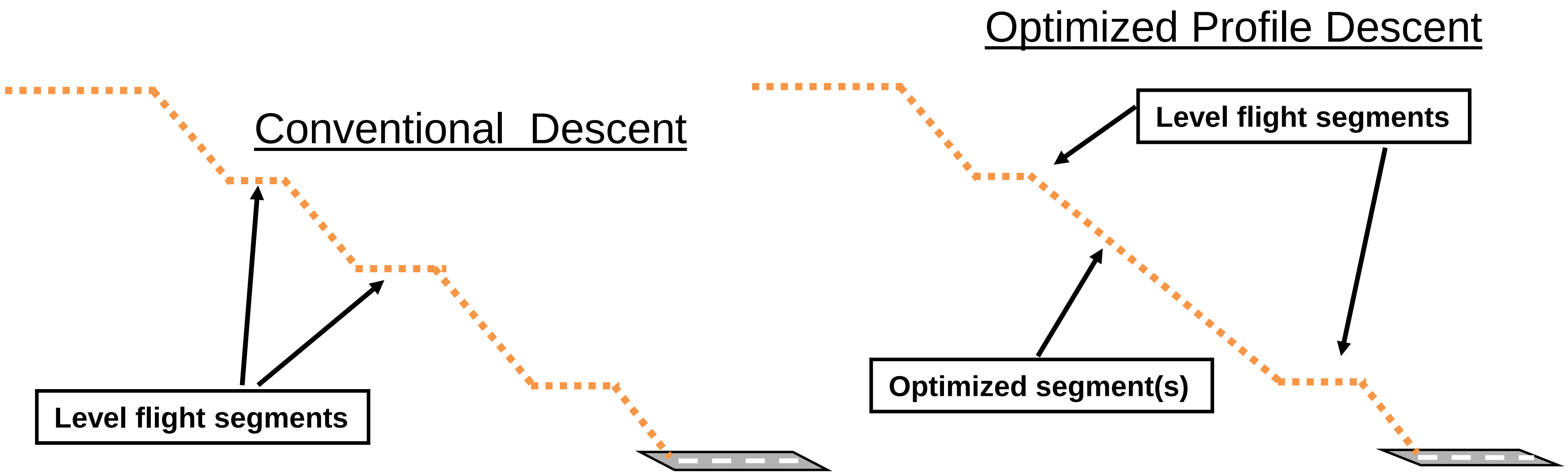


- OPD flight procedures use the capabilities of the aircraft FMS to fly a continuous descent profile minimizing level-off segments, based on the actual performance of the aircraft under current flight conditions along a fixed lateral path.

OPD Benefits

- Uses FMS capabilities to manage energy and has the potential to reduce cockpit workload
- Stabilized managed descent
- Reduced pilot/controller communications
- Reduced noise
- Fuel savings
- Reduced emissions

OPD vs Conventional Descent

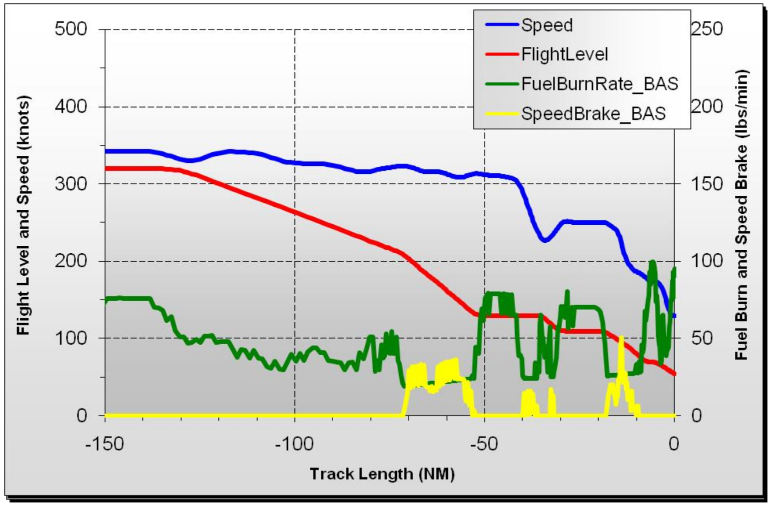


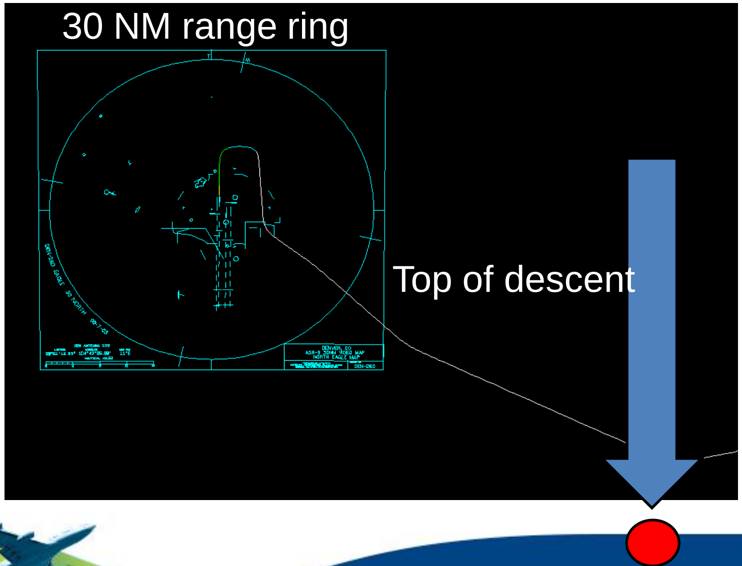
- Should be considered and incorporated into all RNAV STAR development.
- Reduces the amount of time spent in level flight on published arrival procedures (i.e., STARs).

Published procedures will principally consist of PBN procedures, though not exclusively.

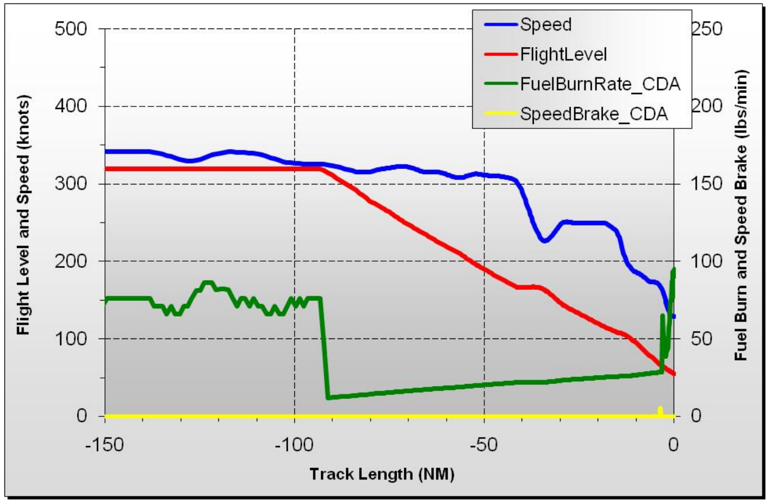
OPD Profile

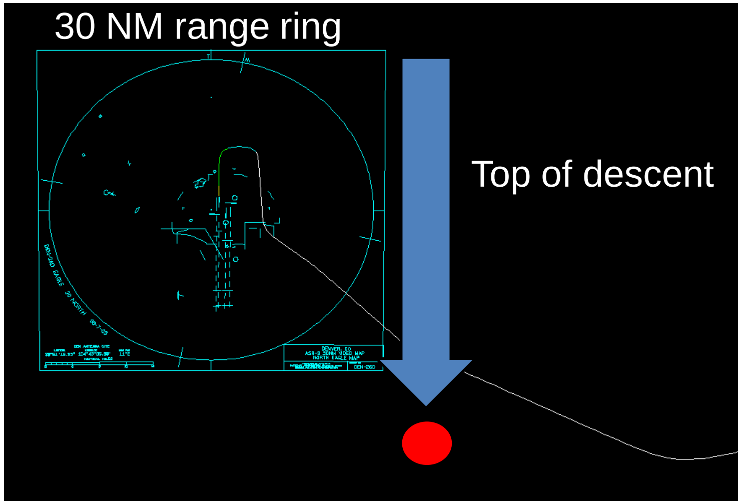
Prior to Optimization

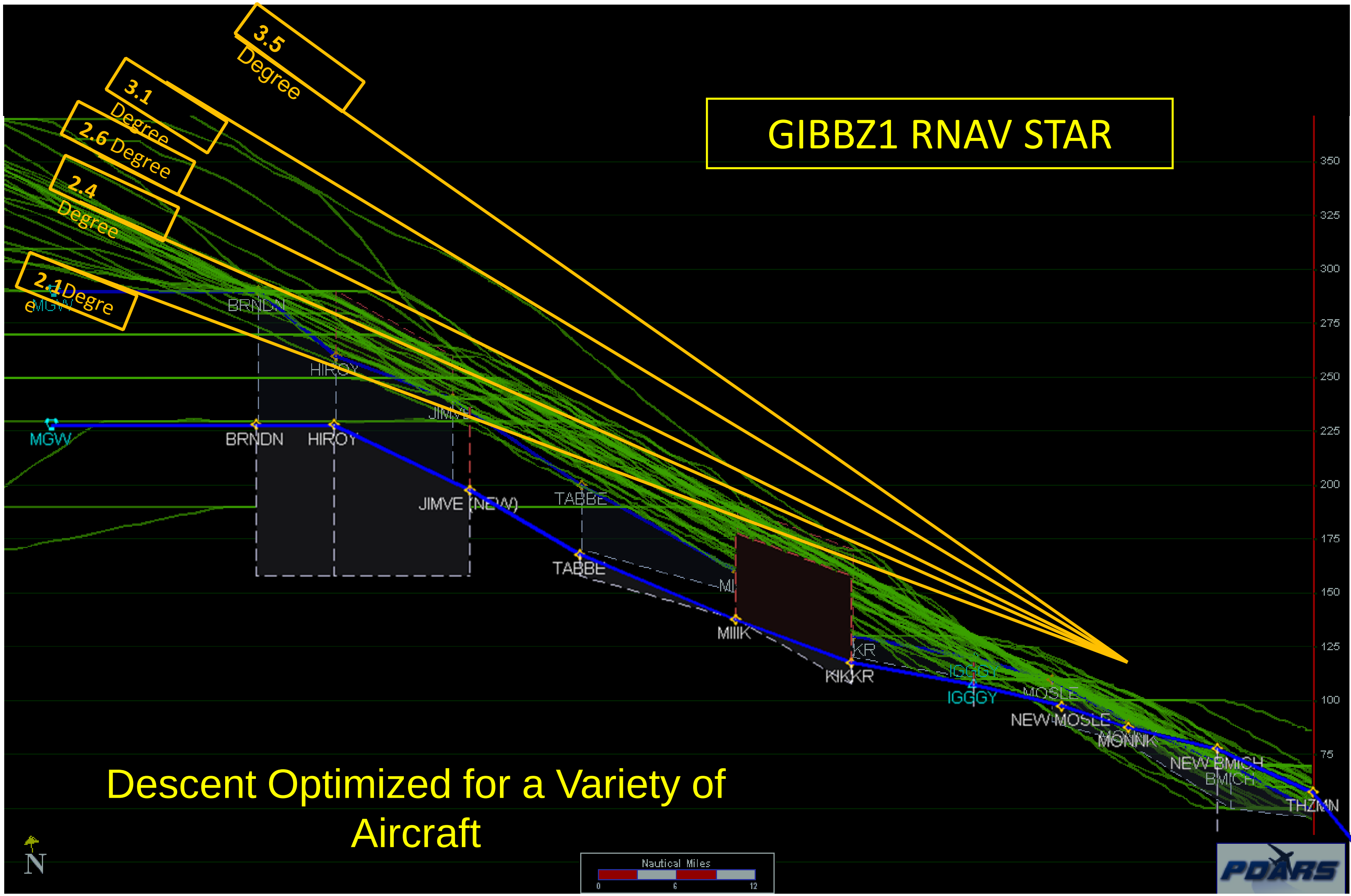


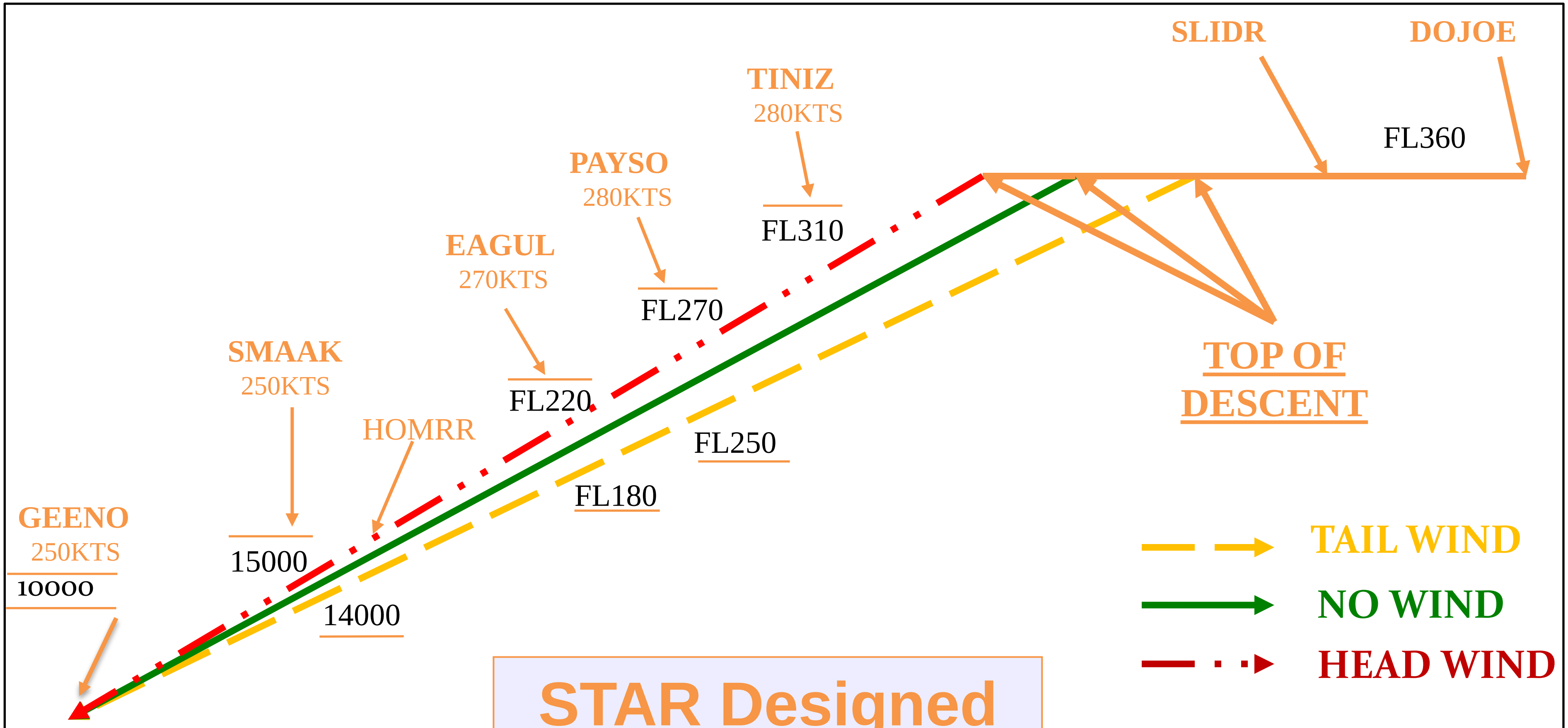


After Optimization



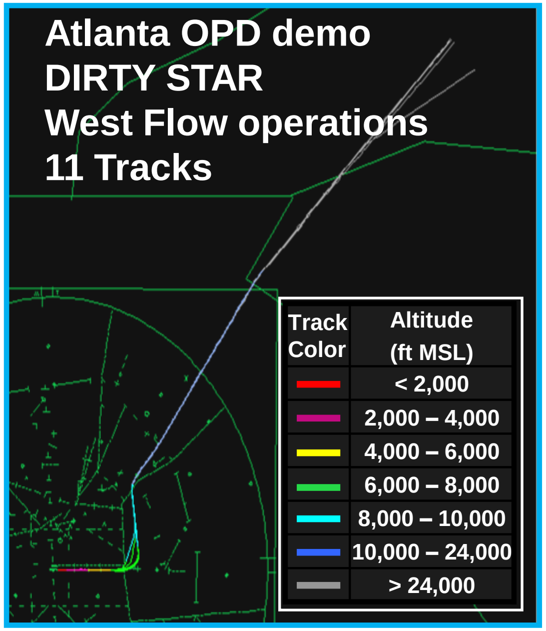


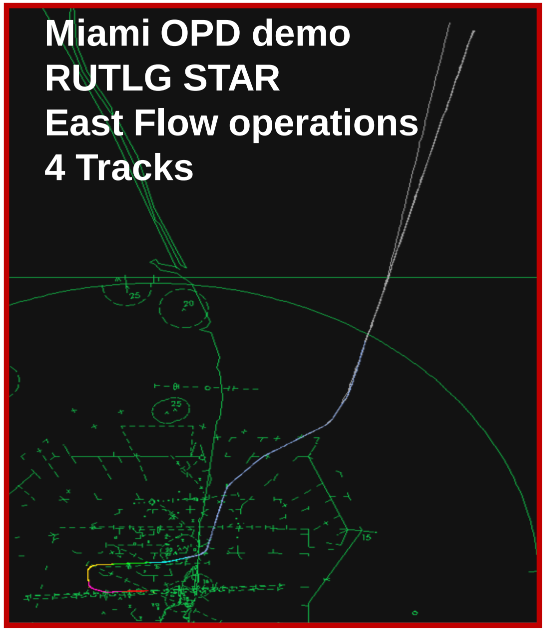

GIBBZ1 RNAV STAR
3.5 Degree
3.1 Degree
2.6 Degree
2.4 Degree
2.1 Degree
MGW
BRNDN
HIROY
JIMVE (NEW)
TABBE
MIIIK
KIKKR
IGGGY
NEW MOSLE
MONNK
NEW BMICH
BMICH
THZMN
350
325
300
275
250
225
200
175
150
125
100
75
Nautical Miles
0
6
12
N
PDARS
Descent Optimized for a Variety of Aircraft

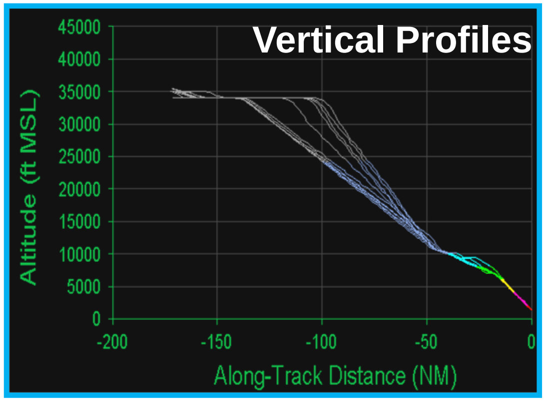


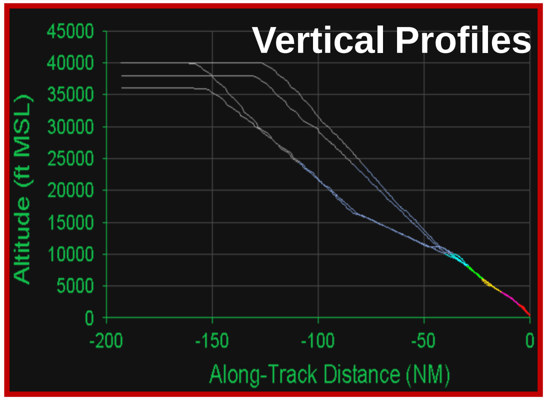
STAR Designed *with* an OPD

RNAV Arrivals with a OPD









- OPDs provide large benefits for fuel, emissions and flight time.
- May 2008 demos

  DIRTY STAR at Atlanta (ATL)

  - **360kg reduction in CO2 emissions per flight**

  RUTLG STAR at Miami (MIA)

  - **460-500kg reduction in CO2 emissions per flight**
- 600 OPD nighttime demos at ATL from August – November 2008

  VIKNN and NOTRE STARs

  380kg reduction in CO2 emissions per flight

Flight Management Systems

- Most FMSs interface with multiple aircraft subsystems for lateral and vertical navigation (LNAV & VNAV) and flight plan management capability.
- The core of an FMS consists of:
  - The Flight Management Computer (FMC)
  - Mode Control Panel (MCP)
  - Navigation Display (ND)
  - Electronic Flight Information System (EFIS)
  - Control Display Unit (CDU)

Photo Credit: DeltaPoints.com

Note: The FMC has no display and is controlled by the other components.

FMS Components

- The Mode Control Panel provides input for course, speed, heading, altitude, and vertical speed.
- Versions have been on aircraft since early autopilot systems (B707, B727, etc.).

- **The Navigation Display** (left) provides a visual course display.
- **The Electronic Flight Information System** (right) combines airspeed, course deviation, artificial horizon, altimeter, vertical speed, and heading readout, combining several analog instruments in one electronic display.

- The Control Display Unit is the principal flight plan interface with the Flight Management Computer.
- When controllers issue clearances to change the route of flight of an aircraft under their control, the pilots must spend time navigating the menus of this component.

  Sometimes, tasks that are easy to voice and enter into ATC Automation are much more time intensive in the cockpit.

What does this mean for you?

- When pilots check on your frequency, they will have flight plan data already entered into the FMS.
- Should you change their clearance or planned runway, they will have to amend that data.

  Vectors off course for traffic, then clearances to resume are relatively simple to program **<u>if</u>** you inform them where they can plan to resume the procedure or routes when the situation is resolved.

- If you do not tell them what to expect, they may guess and delete too many waypoints along the route.
- It may be a more complex task to get the FMS reprogrammed.

- Changes in runway assignment are a more complex task and involve:
  - Multiple CDU entries
  - Reviewing the new runway and procedure information
  - Redoing cockpit checklist briefings

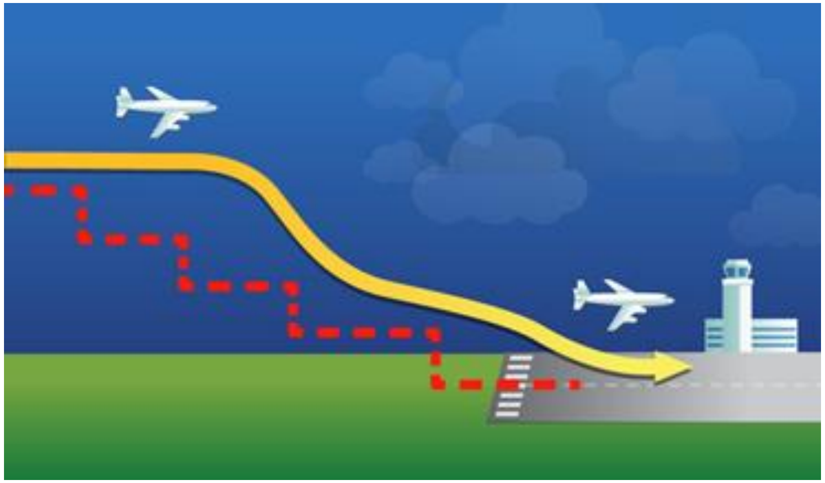
Benefit Examples

Established on Required Navigation Performance (RNP) -(EoR)

- With EoR, runway alignment occurs sooner, reducing passenger time, track miles, fuel burn, aircraft exhaust emissions, and noise.
- EoR doubled utilization of RNP AR visual approaches at DEN.
- Reduced flight time by approximately 275 hours annually.
- Investigating applications in independent dual and triple Instrument Landing System approaches.
- EoR will increase arrivals by over 6 percent.

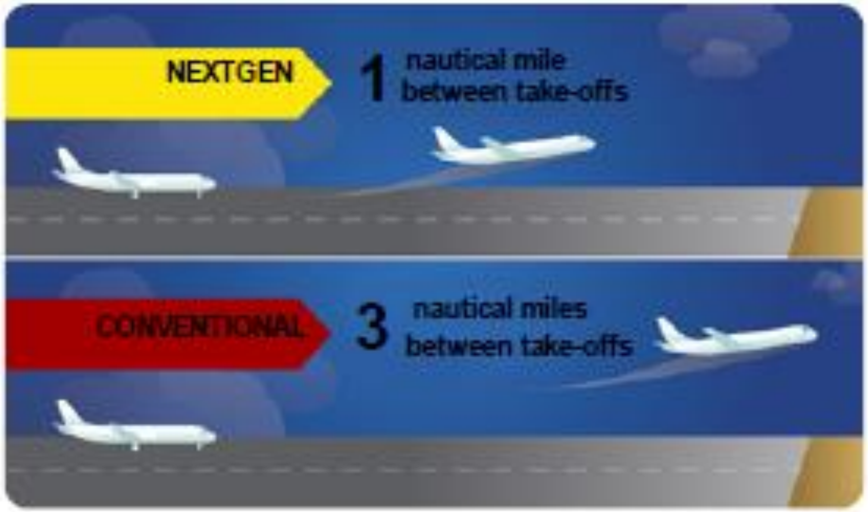
Optimized Profile Descent (OPD)

- The more accurate navigation, along with other NextGen procedures
  - Reduced fuel burn by 6 million Kg
  - Decreased carbon emissions by 15.7 thousand metric tons,
- Arrivals are three times more likely to execute continuous descents beginning at about 13 nautical miles and 2 minutes closer to IAH and HOU.
- Arrivals from SAT experience an average distance and time savings of 3 nm and 41 seconds.



Off the Ground and into the Air Faster at DFW

- At DFW, the RNAV off the ground procedure enables a 15-20 percent increase in departures per hour.
- American Airlines is saving $10-$12 million in annual fuel costs at DFW off the ground.
- DFW has had a 40 percent decrease in pilot-controller verbal communications, reducing the risk for miscommunication.



A 'Win-Win' at Jackson Hole

- Aircraft flying the RNAV procedure at Jackson Hole Airport save over four minutes of flight time in flight, compared to the traditional approach.
- The procedure makes the approach to the airport safer and avoids noise-sensitive areas in the Grand Teton National Park.

Miles-Wide Success with NextGen Collaboration in Mile-High City

- New procedures at Denver, decreased the most common type of go-around by 35 percent
- United Airlines saves 90 Kg of fuel on each arrival
- The network of GNSS procedures save 10 million Kg of fuel annually

RNAV Saves the Day in Juneau