NextGEN

Performance Based Navigation

Navigating in the 21st Century

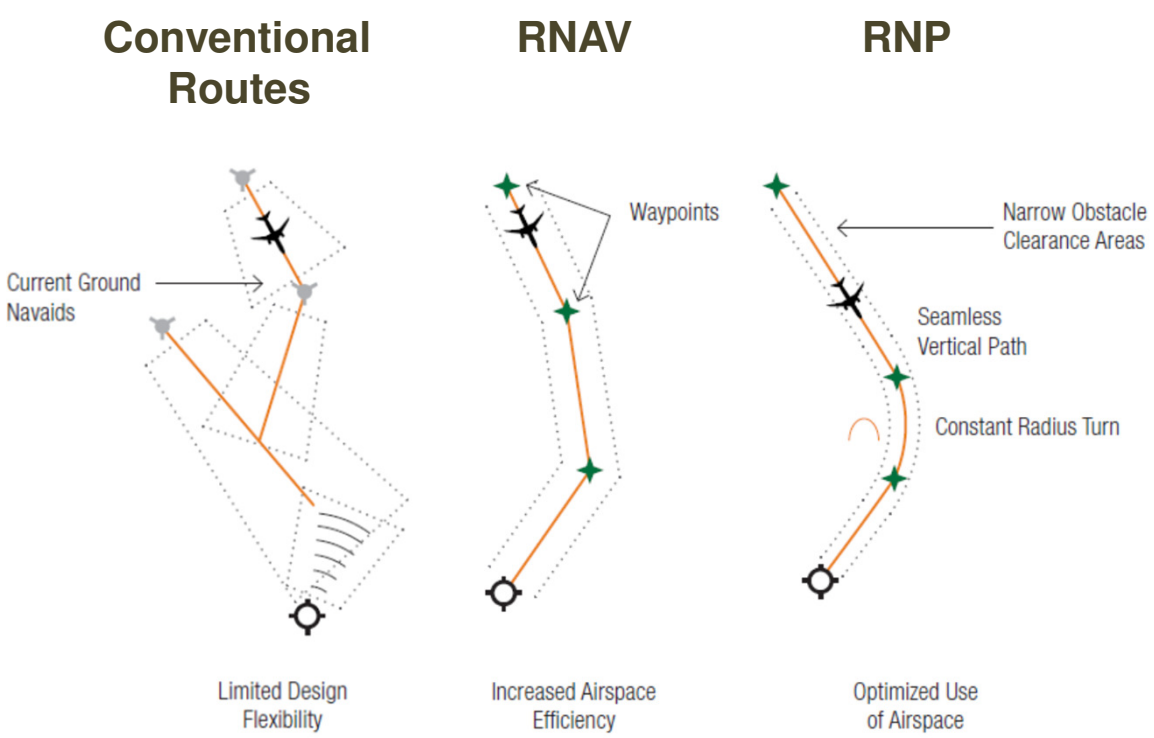
Joseph Post, Office of NAS Systems Engineering & Integration

March 2019

FAA


Safety
Policy
Comm
Weather
Navigation
NextGEN
Procedures
Surveillance
Airframes &
Engines
Fuels
Airspace
Automation

Performance Based Navigation (PBN)



Courtesy Boeing

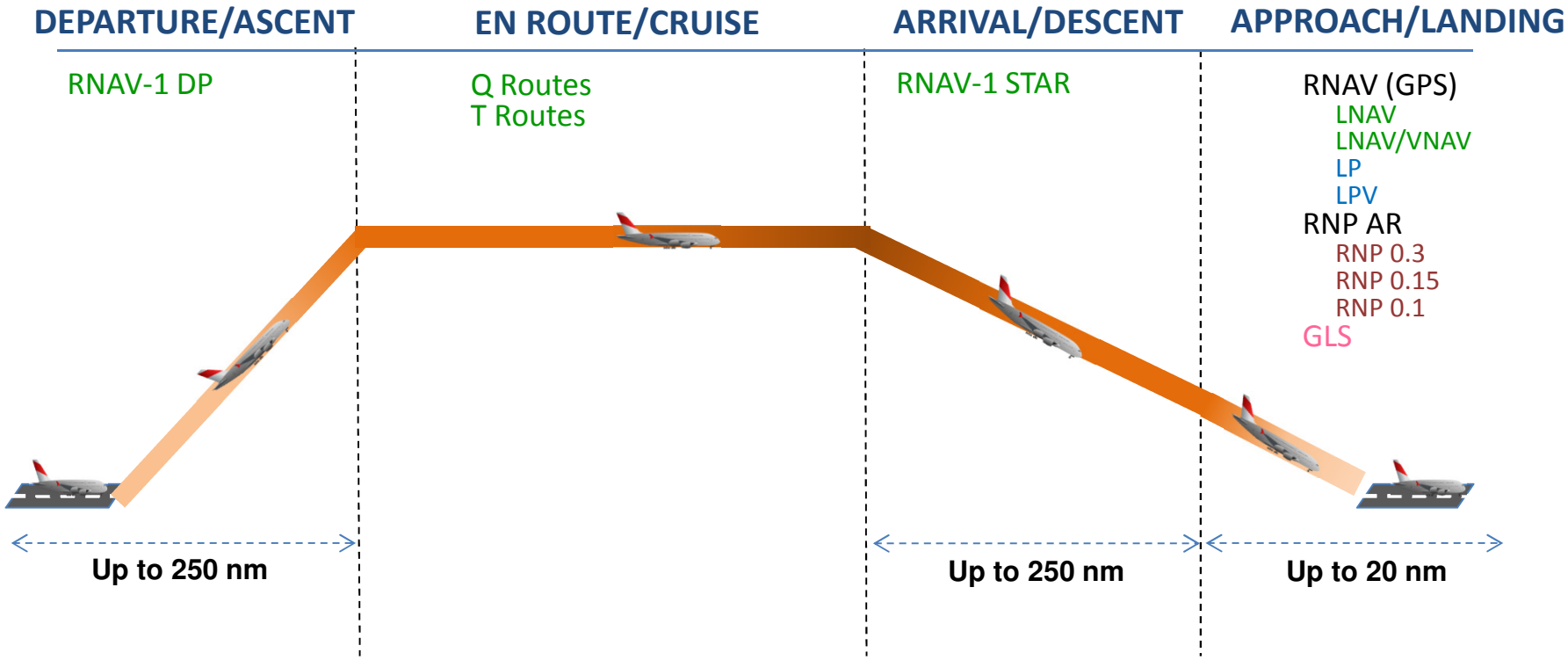
Benefits:

- Increased safety
- Improved flight efficiency
  - Lower emissions
  - Less total noise exposure
- Increased capacity
  - More route options
- Improved airport access in IMC
- Improved predictability
  - Trajectory Based Operations

Challenges:

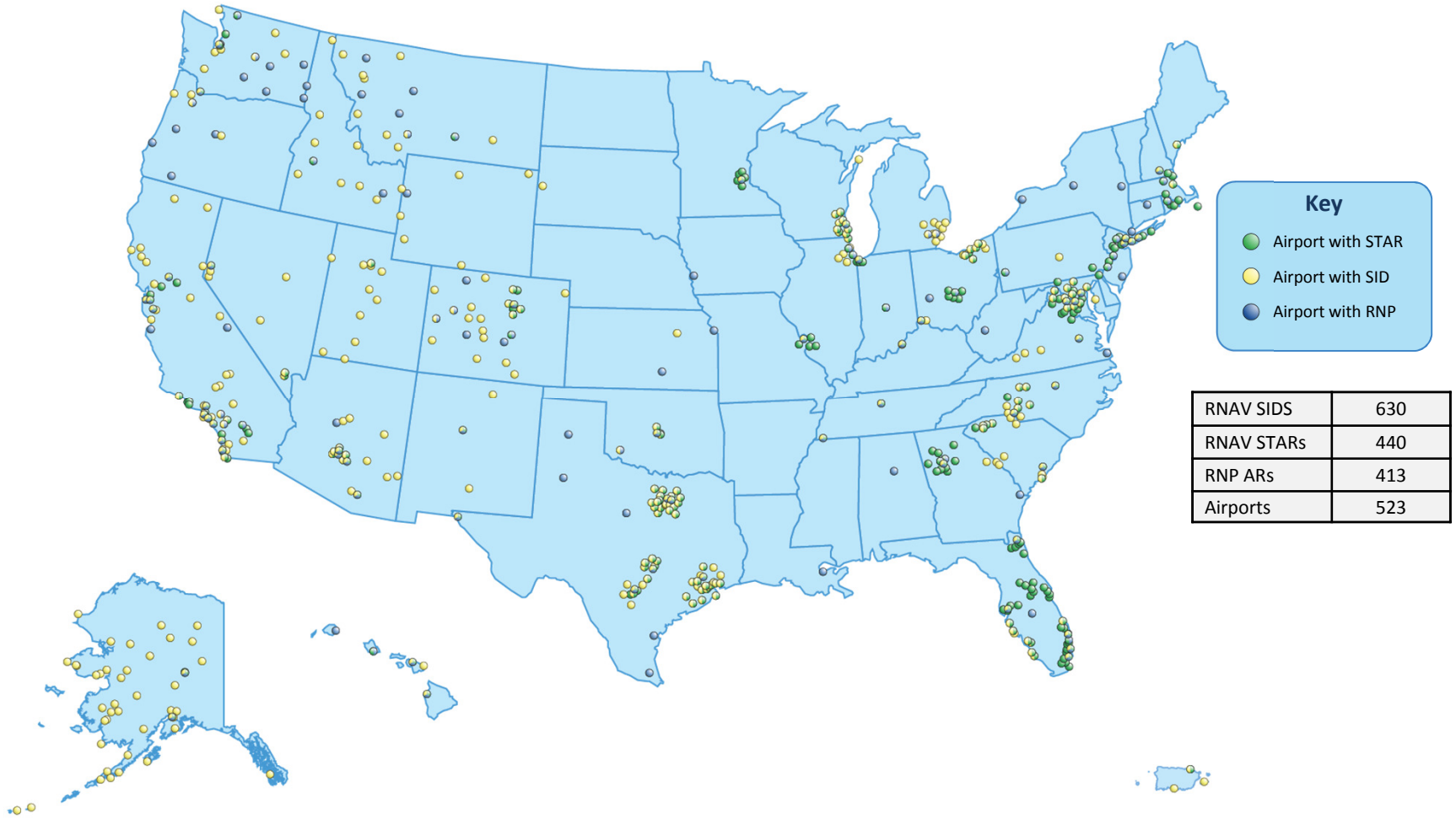
- Community concerns
  - Noise concentration
  - Noise transfer
- Aircraft equipage

PBN Procedures by Phase of Flight



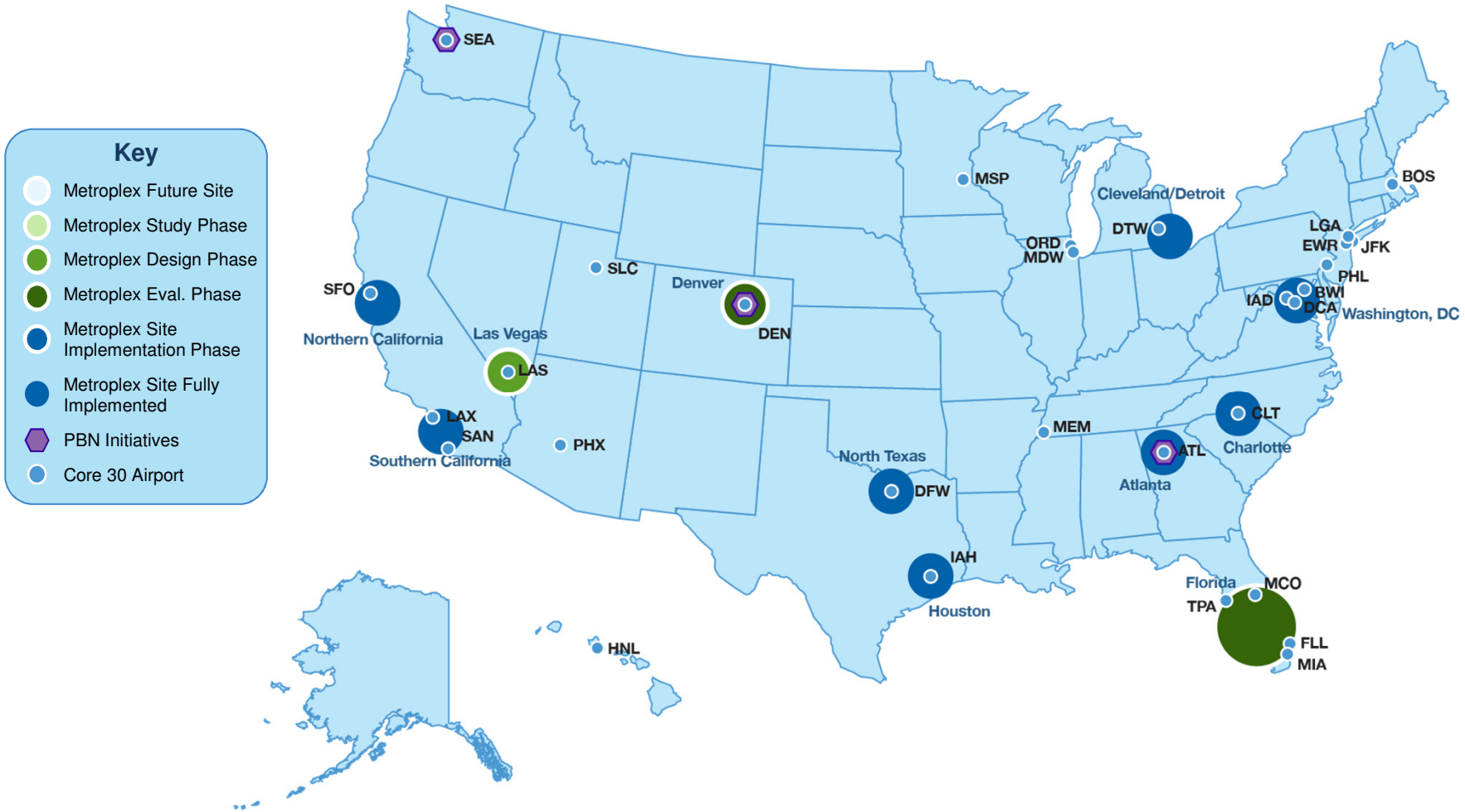
DP – Departure Procedures
GBAS – Ground-Based Augmentation System
GLS – GBAS Landing System
LNAV – Lateral Navigation
LP – Localizer Precision
LPV – Localizer Precision with Vertical Guidance
RNAV – Area Navigation
RNP – Required Navigation Performance
STAR – Standard Terminal Arrival Route
VNAV – Vertical Navigation

Performance Based Navigation (PBN)
As of: Nov. 2018



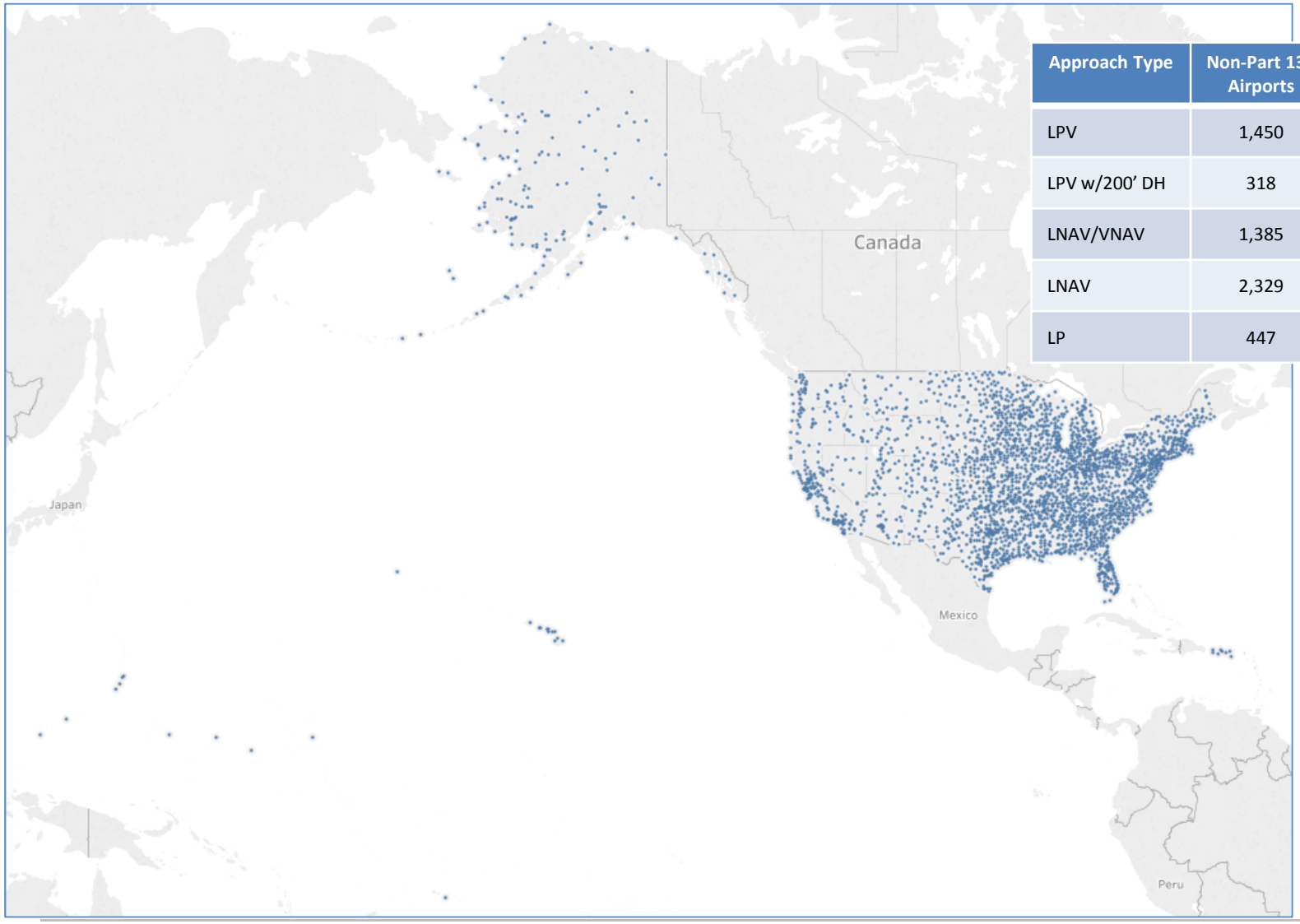
RNAV SIDS	630
RNAV STARs	440
RNP ARs	413
Airports	523

Metroplex Performance Based Navigation (PBN)
As of: Nov. 2018



Airports with RNAV (GPS) Approaches

As of: Jan. 2019



Approach Type	Non-Part 139 Airports	Part 139 Airports	Total
LPV	1,450	481	1,931
LPV w/200' DH	318	719	1,037
LNAV/VNAV	1,385	478	1,863
LNAV	2,329	535	2,864
LP	447	75	522

Required Navigational Performance (RNP)

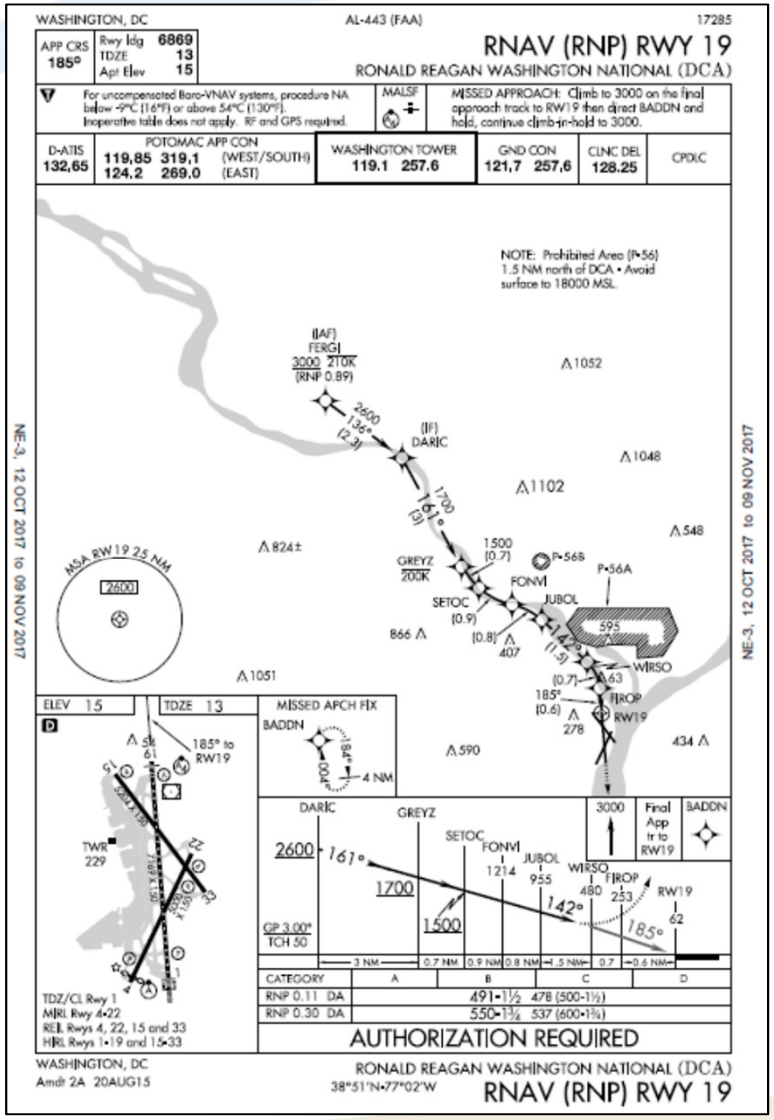
- RNP extends an aircraft's RNAV capability with on-board performance monitoring and alerting functions.
- RNP provides high confidence that an aircraft will precisely follow a desired path (i.e., procedure)
- Airspace planners can design RNP procedures with tight segments and complex curved paths.
- FAA is allowing reduced separation minima on approach, in certain specific circumstances, for aircraft using RNP Authorization Required (AR) approach procedures.

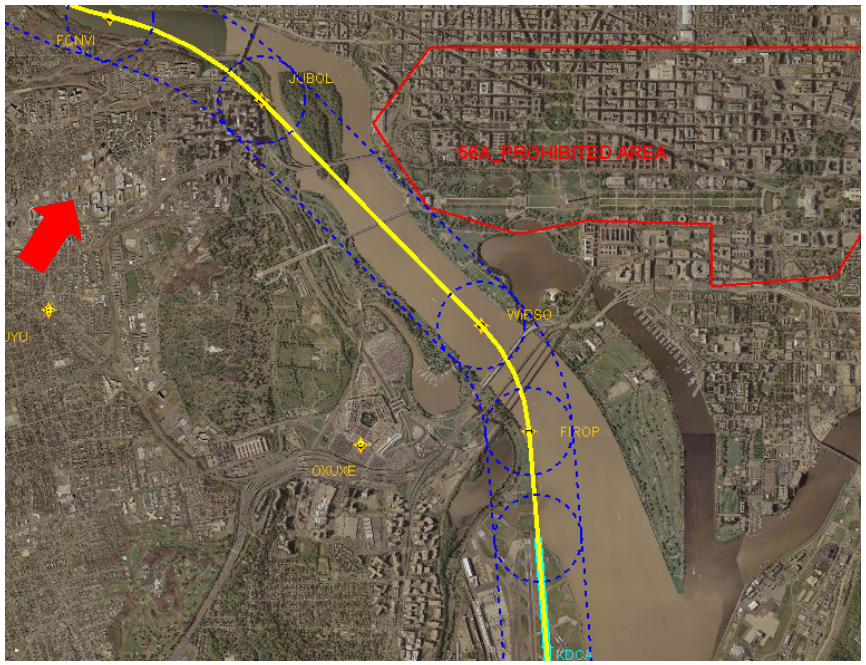
Total System Error = Path Definition + Flight Technical + Navigation System Errors

- For **RNP 0.3**,
  - TSE must remain ≤ 0.3 nmi for 95% of the flight time
  - P(TSE > 2 · 0.3 nmi w/o annunciation) < 10^{-5}
- **RNP AR** procedures require a TSE lower than for standard RNP procedures.
  - For RNP AR an aircraft typically requires:
    - Dual GNSS sensors
    - Dual FMS
    - Dual air data systems
    - Dual autopilots
    - Inertial Reference Unit (IRU)

RNP Approach Example

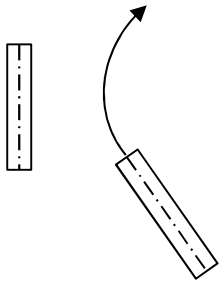
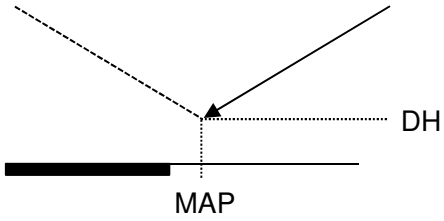
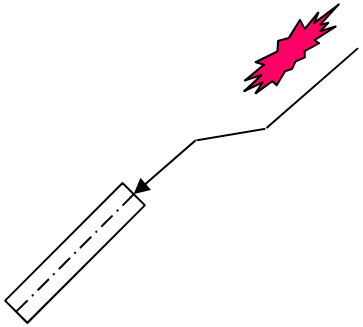
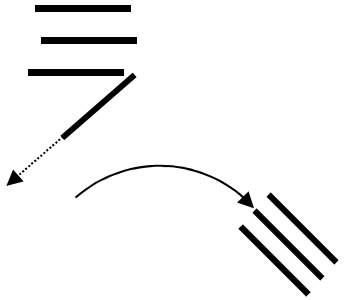
DCA 19 – Ronald Reagan Washington National Airport

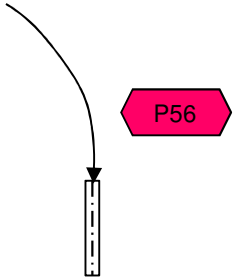
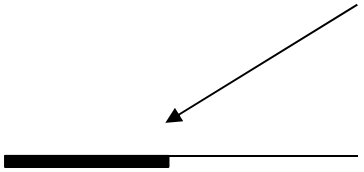
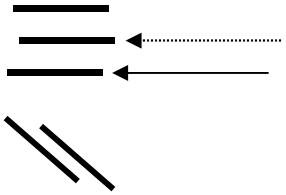
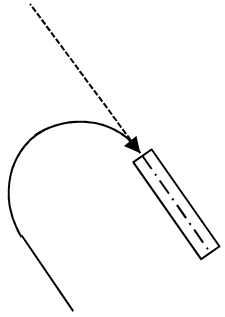




- Safety enhancement, with 3-D path to runway
- Provides a corridor which avoids restricted airspace
- RNP AR approach significantly improves availability of Runway 19 during low visibility conditions
  - There is no ILS for Runway 19

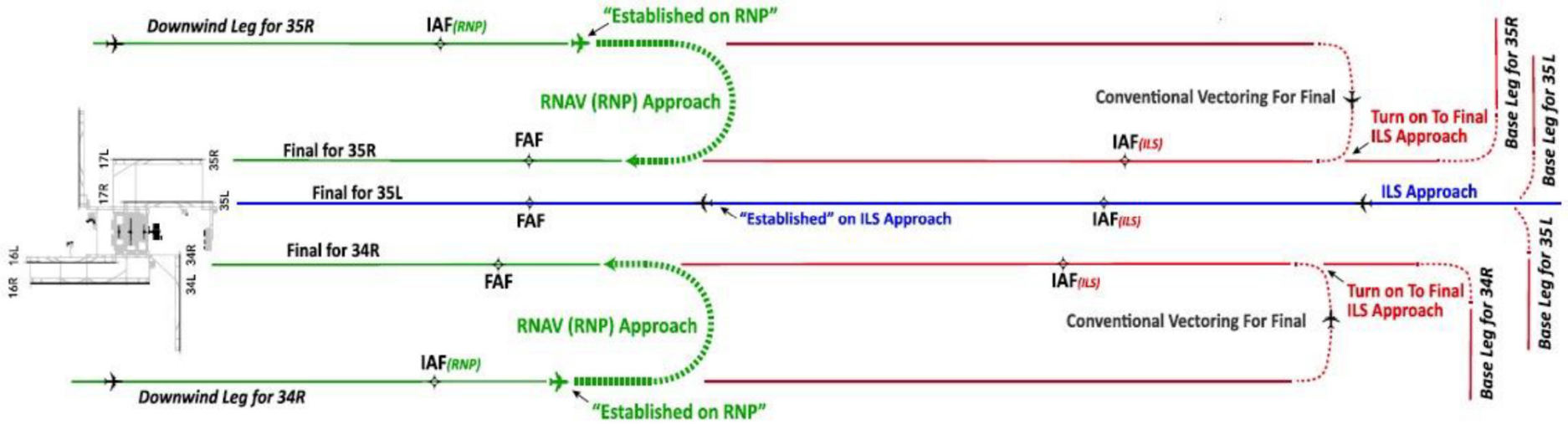
RNP Approach Benefits

Converging Approaches	Lower Minima	Noise Abatement	Airport De-Confliction
			
Early, guided turns on missed approach.	Lower Decision Height (DH)	Avoids noise-sensitive area	Allows proximate airports to maintain capacity

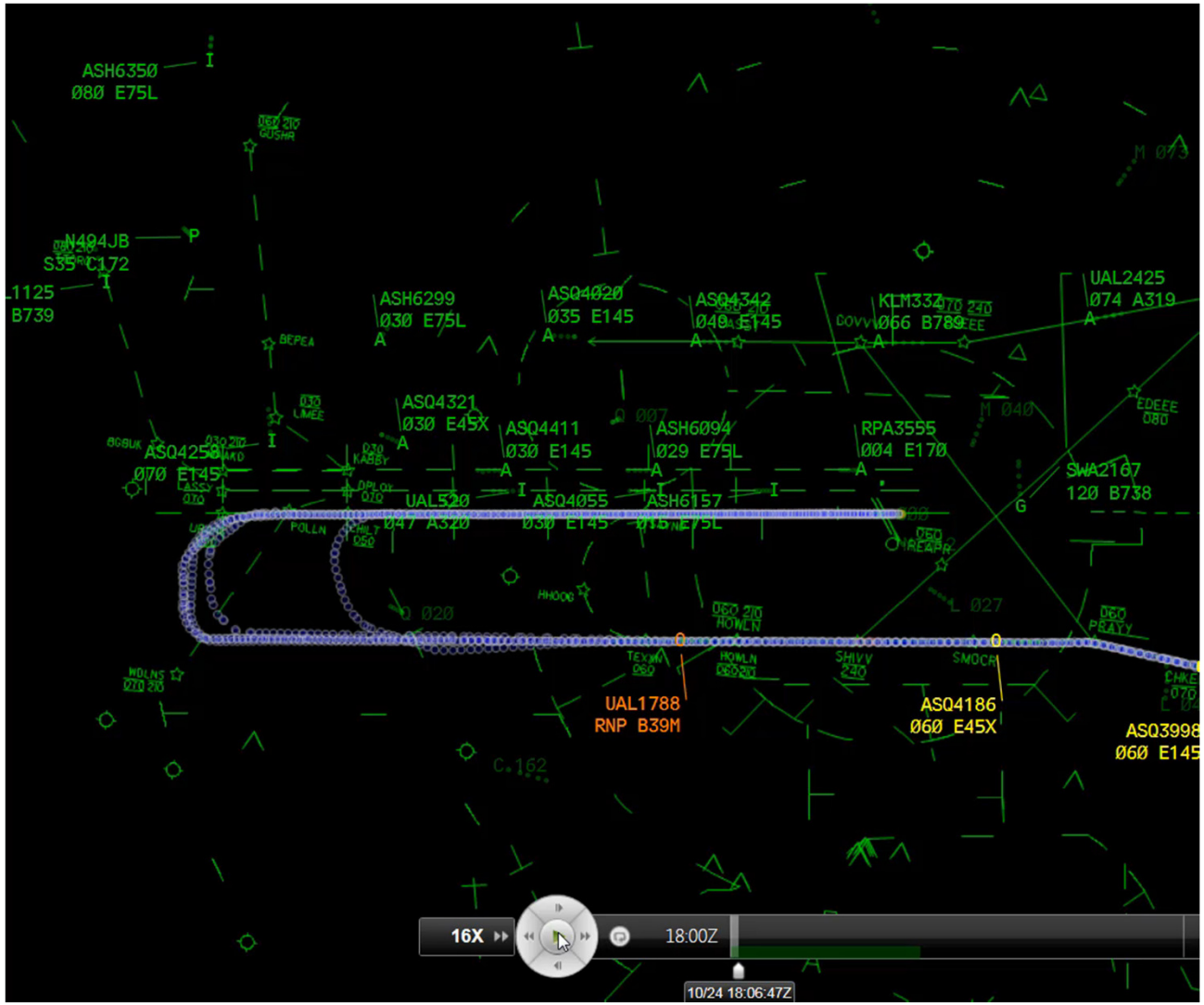
Geographic Mitigation	Improved Vertical Guidance	Improved Parallel Approaches	Defined Turn to Final
			
Avoids Special Activity Airspace or high terrain	Alt. restrictions removed, vert. guidance further from runway	Simultaneous approaches to parallel runways	Defined turn to final yields a shorter flight path

Established on RNP (EoR)

- Allows ATC to clear an aircraft on an RNP approach incorporating a turn to final without ensuring 1,000 ft. vertical / 3 mile horizontal separation from aircraft on parallel approaches
- Provides a shorter, repeatable, stabilized path to runway for RNP aircraft



EoR at IAH

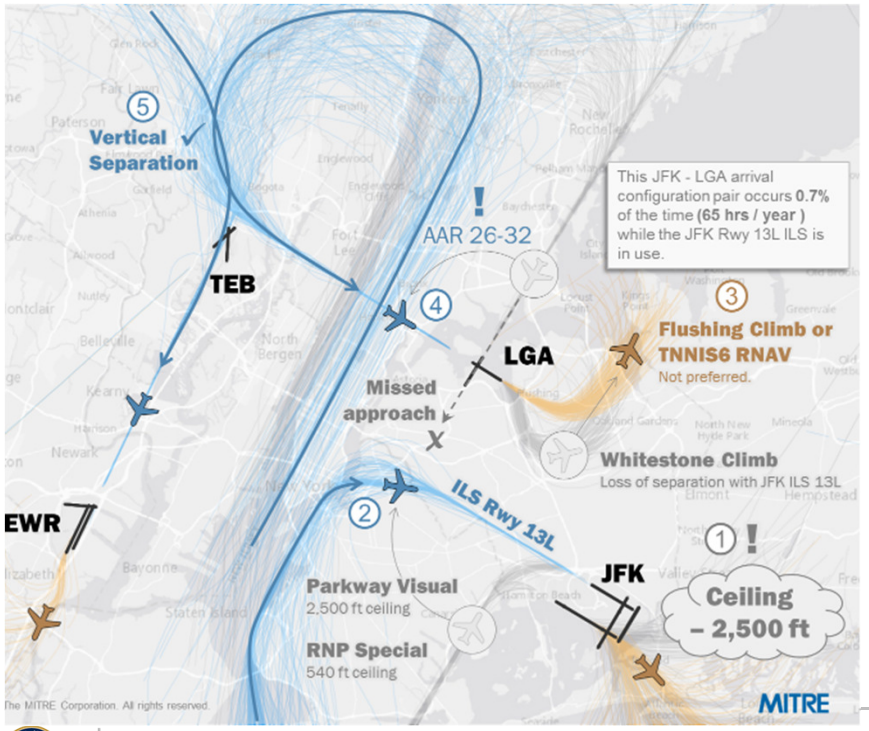

ASH6350
Ø80 E75L
N494JB
S35 C172
1125
B739
ASH6299
Ø30 E75L
ASQ4020
Ø35 E145
ASQ4342
Ø40 E145
KLM33Z
Ø66 B789
UAL2425
Ø74 A319
ASQ4321
Ø30 E45X
ASQ4411
Ø30 E145
ASH6094
Ø29 E75L
RPA3555
Ø04 E17Ø
ASQ4258
Ø7Ø E145
UAL520
047 A32Ø
ASQ4055
Ø5Ø E145
ASH6157
SWA2167
12Ø B738
UAL1788
RNP B39M
ASQ4186
Ø6Ø E45X
ASQ3998
Ø6Ø E145
16X
18:00Z
10/24 18:06:47Z

Multiple Airport Route Separation (MARS)

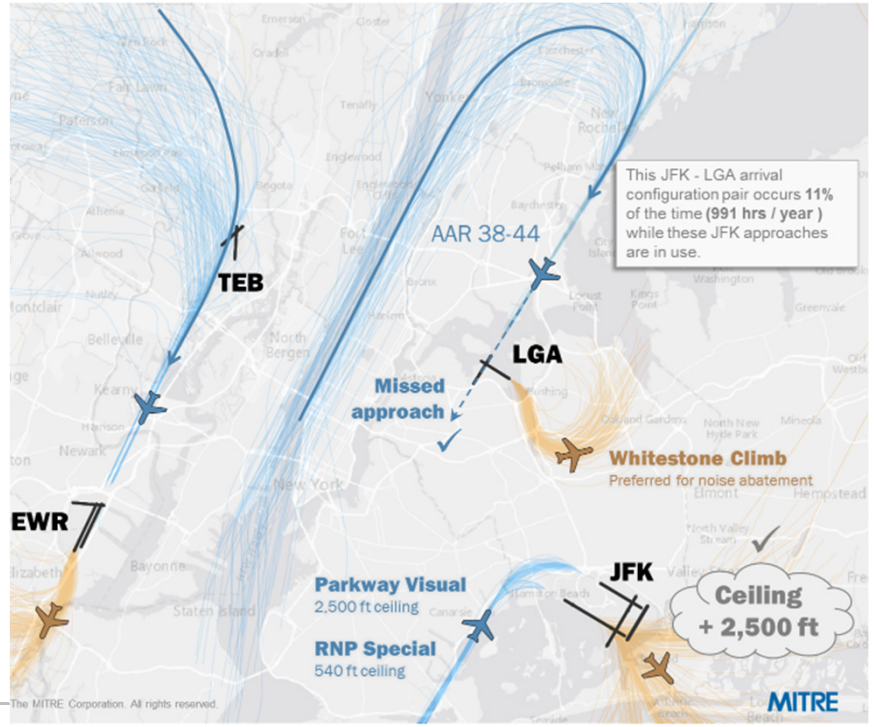
- Uses RNP and EoR concept to de-conflict traffic flows to separate airports
- Currently being explored for application in New York

Notional Example: JFK ILS 13L

Before



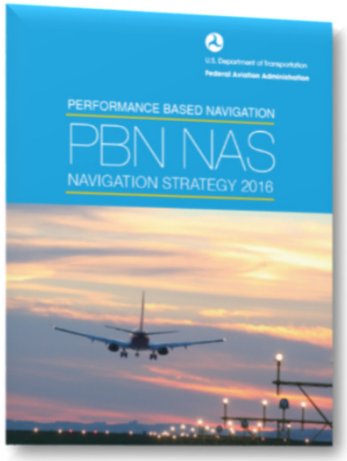
After

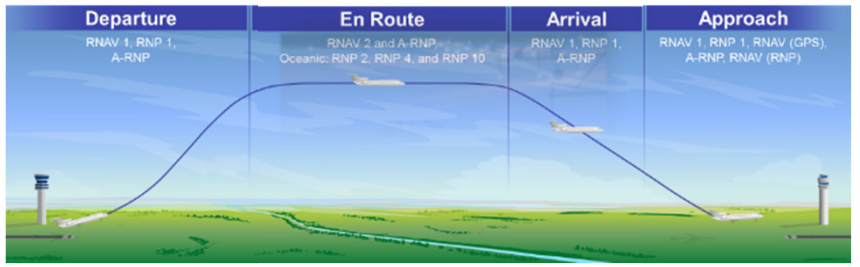


PBN NAS Navigation Strategy

Key Elements

- Clear vision of PBN as the basis for daily operations at all locations in the NAS
- Identification of the key navigation capabilities that will be available in the NAS over the next 15 years
- Defined Navigation Service Groups (NSG) for navigation capabilities
- Expectations for evolution of operator capabilities
- Emphasizes stakeholder/community engagement and collaboration





Near Term (2016–2020) Increase Utilization	Mid Term (2021–2025) Streamline Service Delivery	Far Term (2026–2030) A Streamlined NAS
Approach/Terminal ☐ Implement RNAV (GPS) with LPV and LNAV/VNAV approaches at qualifying runways meeting current Terminal Instrument Procedures (TERPS) criteria ☐ Criteria to increase the number of runways qualifying for vertically guided approaches ☐ Expand use of Established on RNP (EoR) at first site ☐ Expand use of Equivalent Lateral Spacing Operations (ELSO) at first two sites ☐ Criteria for low-visibility access with LPV	**Approach/Terminal** ☐ Implement Vertically guided RNAV (GPS) approaches at runways meeting new TERPS criteria ☐ Expand use of RNAV (GPS) approaches (with LPV and LNAV/VNAV) with RF ☐ Expand use of EoR at sites supported by cost-benefit analysis ☐ Expand use of ELSO at sites supported by cost-benefit analysis ☐ Leverage A-RNP at key sites	**Approach/Terminal** ☐ Vertically guided RNAV (GPS) approaches at qualifying airports with an IAP ☐ A-RNP procedures at sites supported by cost-benefit analysis ☐ Complete the transition to PBN procedures **Oceanic** ☐ Transition to dynamic UPRs where supported by operator capability

More PBN Structure
More Advanced Procedures

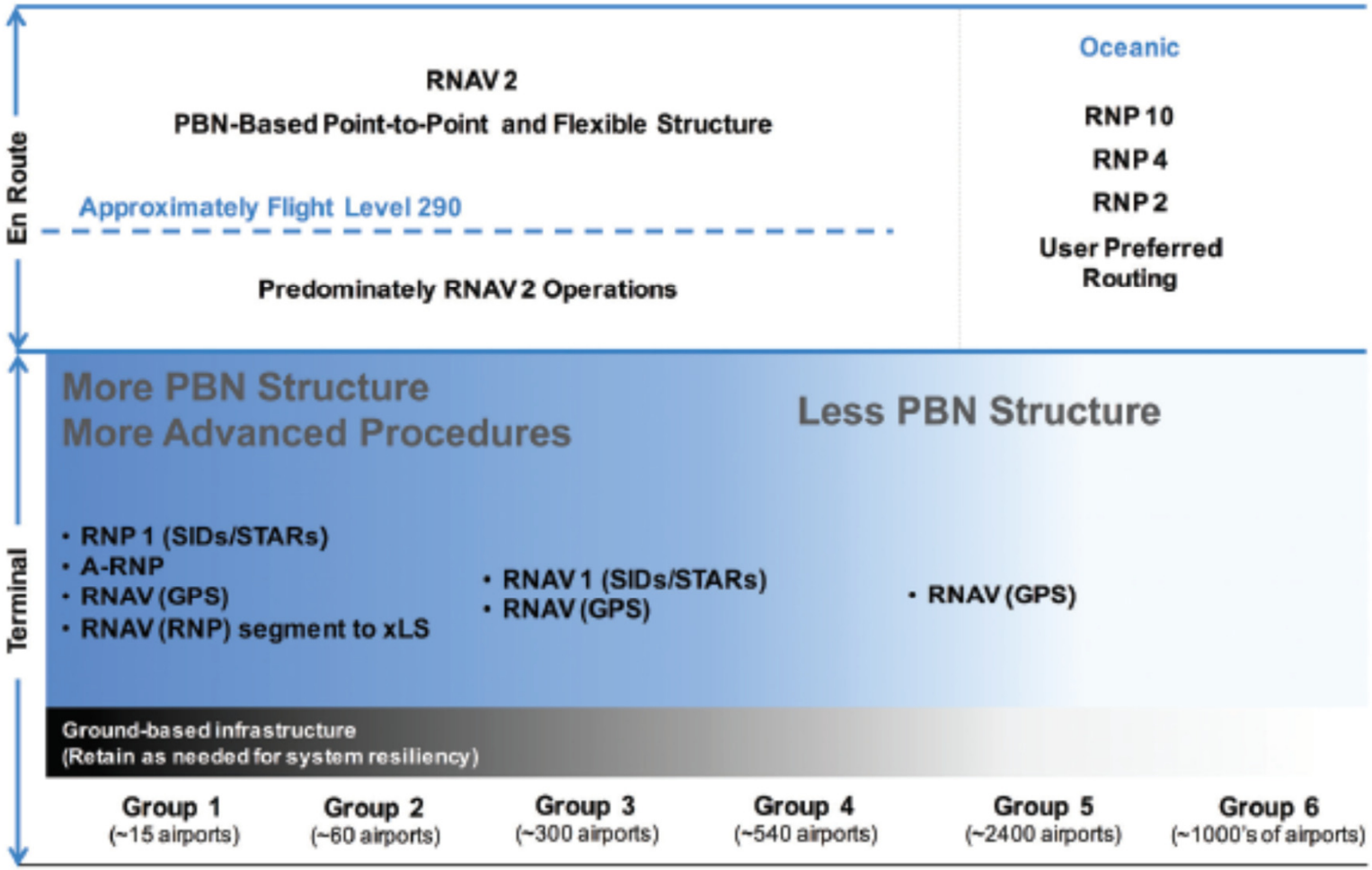
Less PBN Structure

Ground-based infrastructure
(Retain as needed for system resiliency)

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
(~15 airports)	(~60 airports)	(~300 airports)	(~540 airports)	(~2400 airports)	(~1000's of airports)

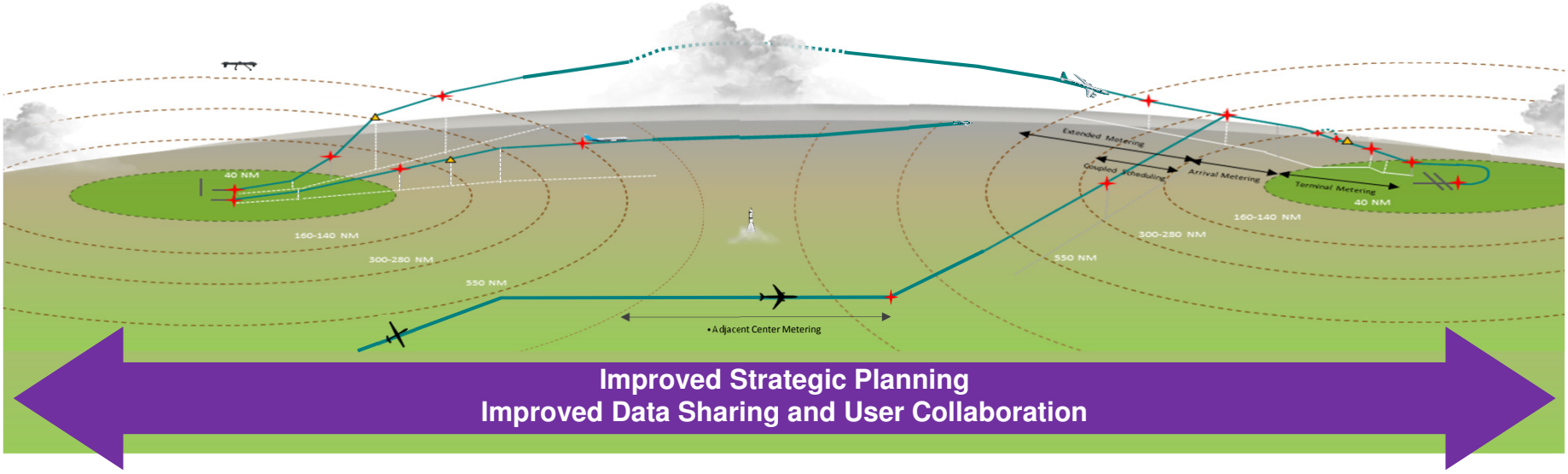
Navigation Services across Airport Groups

Summary of Availability in the Far-Term (2026-2030)



Trajectory Based Operations (TBO)

'TBO is an ATM method for strategically planning, managing, and optimizing flights throughout the operation by using time-based management, information exchange between air and ground systems, and the aircraft's ability to fly precise paths in time and space.'

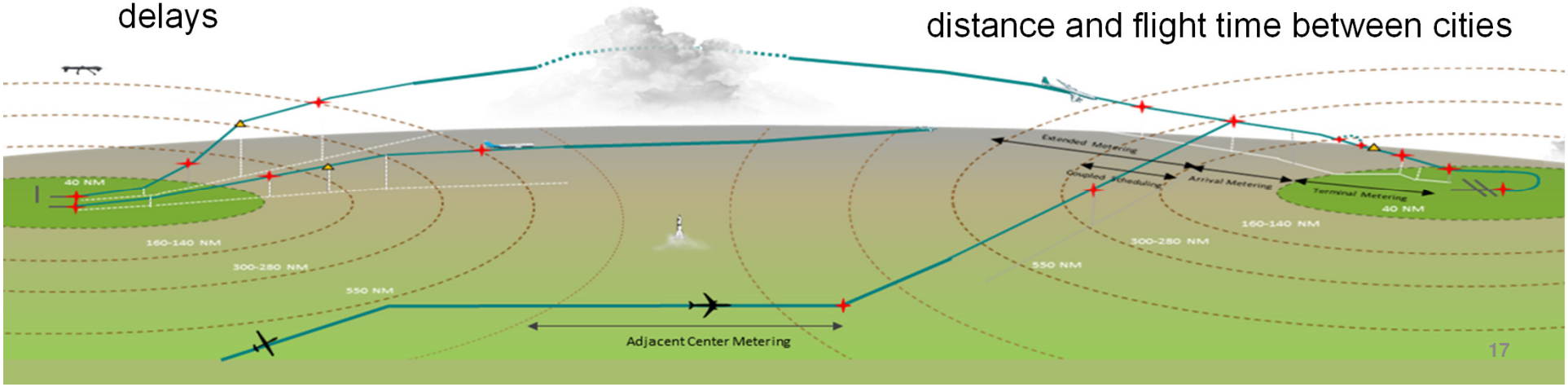


TBO = TBM + PBN

TBO manages aircraft based on **where they will be** at "critical points in time" during the flight. Two key elements of TBO are (1) Performance Based Navigation and (2) Time-Based Management.

Trajectory Based Operations Objectives

- Efficient use of available airspace and airports
- Improved schedule predictability - fewer delays
- Increased operational flexibility
- Improved flight efficiency – shorter flight distance and flight time between cities



cfm

THE POWER OF FLIGHT

IF YOU STOP EVOLVING
YOU STOP FLYING.