



Overview of Trajectory Based Operations (TBO)

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Presentation to NEC NIWG

11/01/17



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Presentation Outline

- **TBO Definition and Benefits**
- **History and Background**
- **Relationship to Industry Recommendations**
- **TBO Elements in Detail**
- **Getting to TBO**

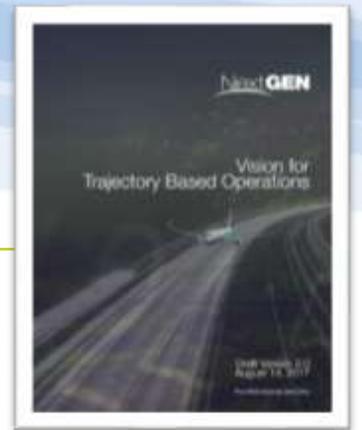


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What is the Definition for TBO?



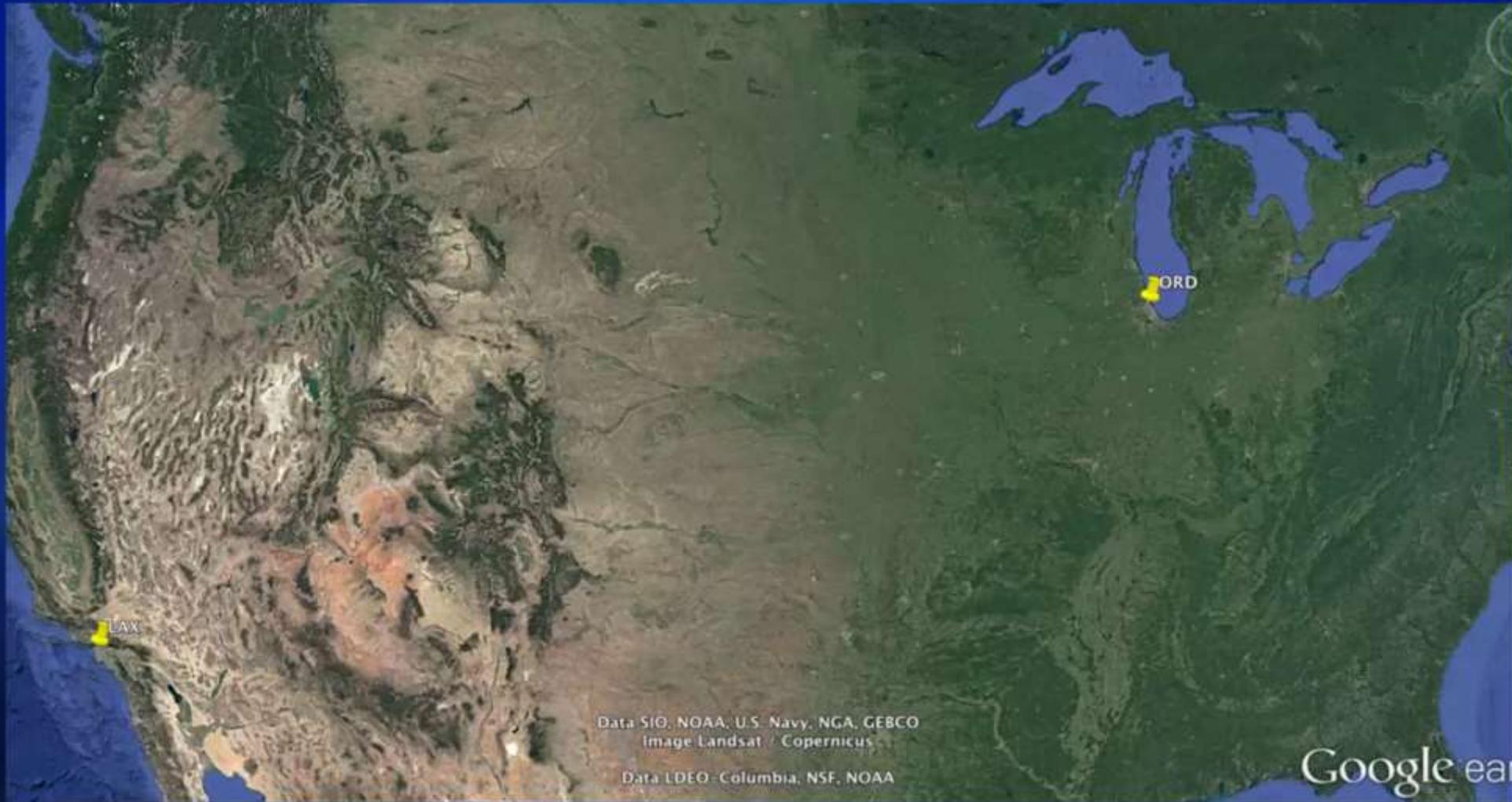
...an ATM method for **strategically planning, managing, and optimizing flights** throughout the operation by using **time-based management, information exchange** between air and ground systems, and the **aircraft's ability to fly precise paths in time and space.**



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Trajectory Based Operations



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TBO Objectives

- More efficient use of system capacity by maximizing airspace and airport **throughput** using time-based management techniques and precise, repeatable PBN procedures
- Improved operational **predictability** through more accurate and efficient end-to-end strategic planning and scheduling
- Enhanced **flight efficiency** by delivering more efficient flows into and out of major metropolitan areas through integrated operations, including the continuous use of more PBN procedures
- Increased operational **flexibility** through increased user collaboration regarding preferred trajectories and priorities to support business objectives



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What TBO Is Not (despite what some may think it is)

- **The “Evaluator”**
- **Totally automated**
- **“Free-flight” everywhere**
- **Self-separation**
- **Conflict-free all the time**
- **4D “Contracts”**

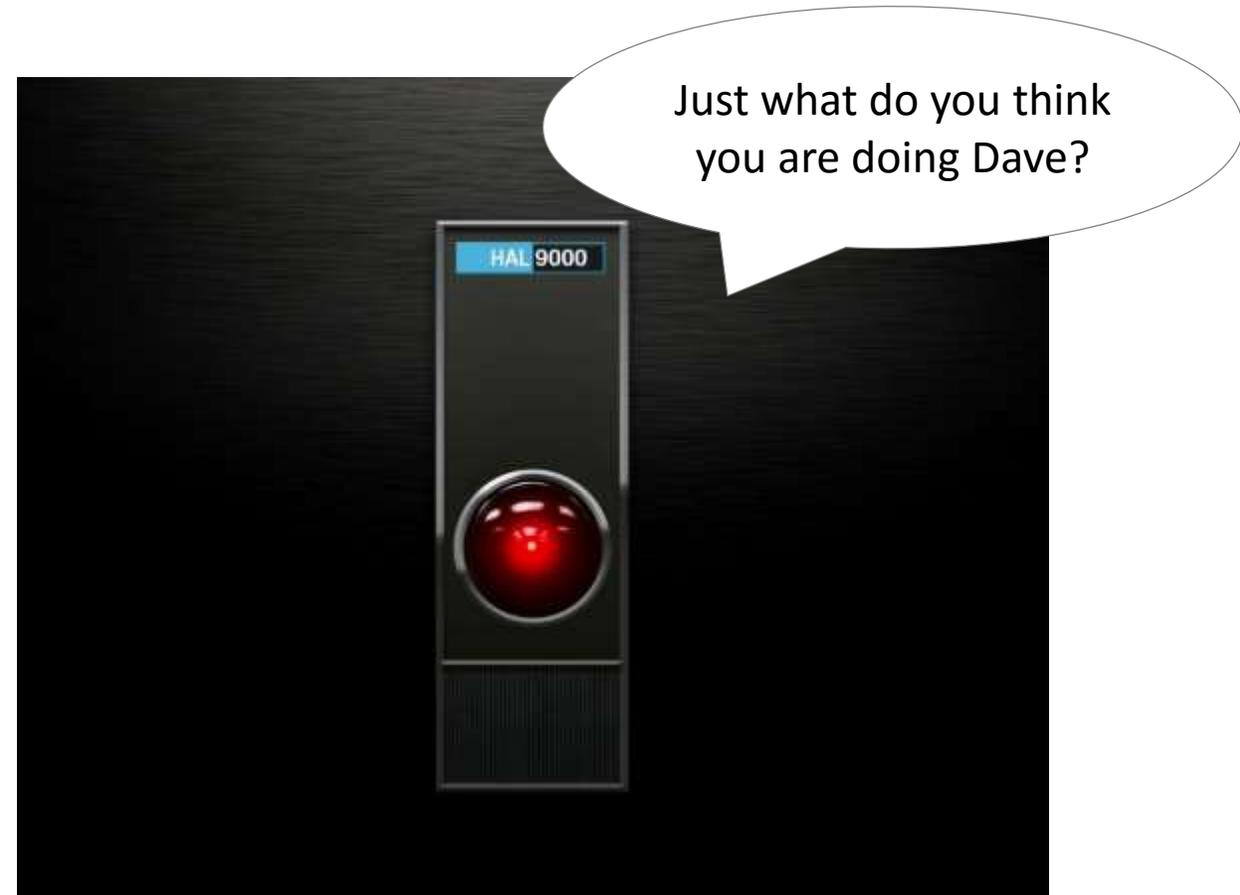


Image: 2001: A Space Odyssey



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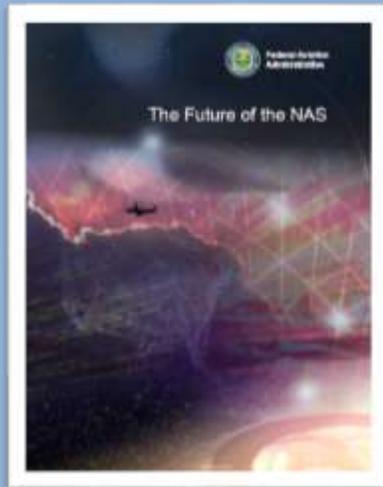
History: How Did We Get Here?

Trajectory Based Operations (TBO) Has Always Been The Target of NextGen



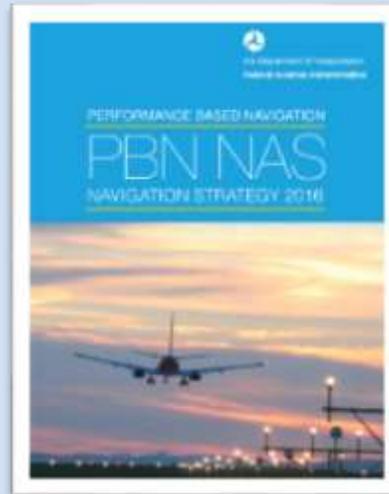
Background: Recent TBO Foundational Initiatives

Future of the NAS



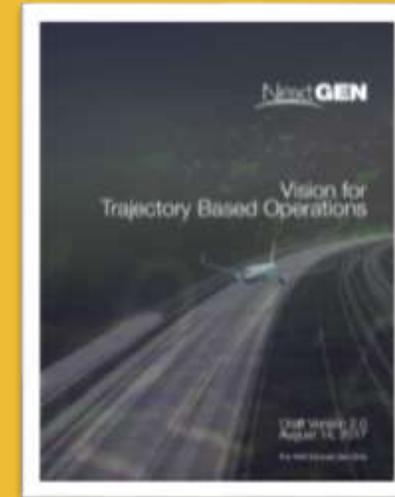
- Concept document
- Future look ahead at NAS evolution
- Goals for modernization
- Update to Midterm Con Ops

PBN NAS Nav Strategy



- Strategy document
- Roadmap for Performance Based Navigation
- Outlines transition to a truly PBN-centric NAS

Vision for TBO



- Describes interim 2025 operational change
- Concept description to improve stakeholder understanding
- Framework to prioritize implementation plans



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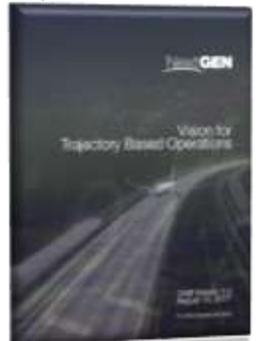
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Background: PBN Time, Speed, Spacing Work Group



- **PBN NAS Navigation Strategy**
 - ✦ Collaborative FAA and Industry Effort
 - ✦ Key Strategic Commitments include “Shifting To Time- and Speed-Based Air Traffic Management”
- **FAA asked RTCA to recommend T/S/S Capabilities needed for PBN NAS Nav Strategy**
- **RTCA T/S/S Task Group provided recommendations**
 - ✦ Shift to Time-Based Management (TBM)
 - ✦ Continue deployment of enabling NextGen capabilities, Address Operations Culture, Training, and Integrate Aircraft Data with Ground Systems
 - ✦ Clarify Vision
- **FAA developed Vision for TBO**

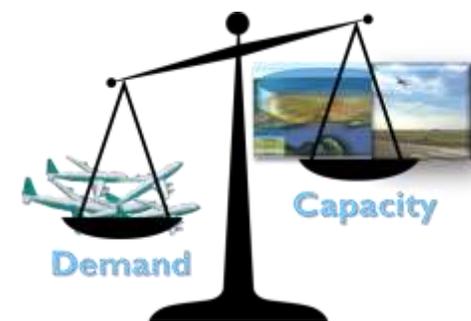
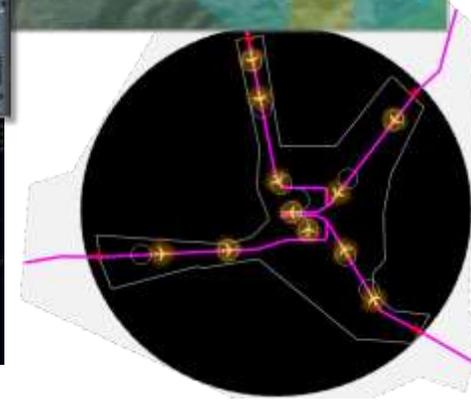
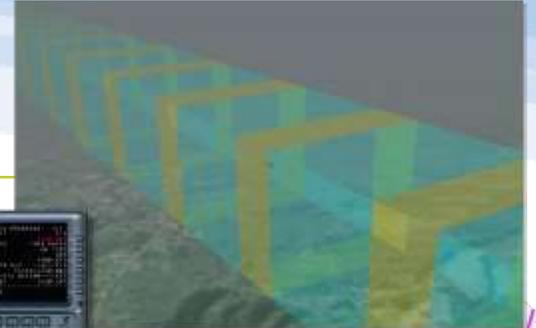


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TBO...It's What You Have Been Asking For!

- Performance-Based Navigation
- Predominant Use of Time-Based Management
 - En Route Controller and Traffic Manager Decision Support Tools (DSTs)
 - Terminal Controller and Traffic Manager DSTs
 - Tower Controller and Traffic Manager DSTs
- Improved Strategic Traffic Management Planning
- Data Sharing and User Collaboration



Source: FAA



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Source: FAA

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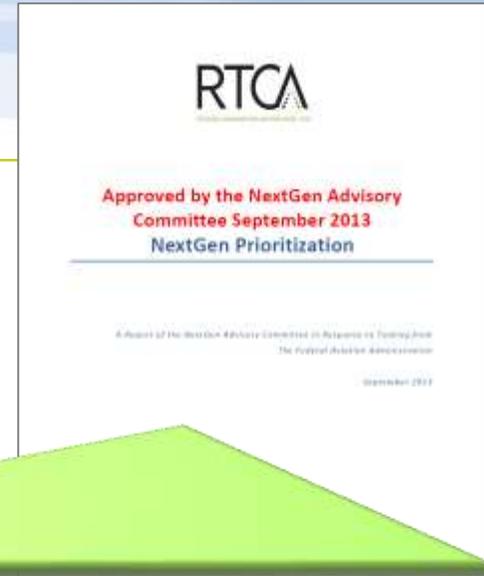


Tier 1A: Capabilities that are deemed to be high benefit and high readiness. These should be considered highest priority, and be given full resources to achieve or IOC dates or accelerate those dates. Budget cuts should not affect these capabilities. It is important to note that several of these are interdependent and lead to service improvements. For example, PBN will not achieve the projected benefit in congested terminal airspace without the merging and spacing tools or CSPO work being completed.



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Tier 1A Recommendations

- PBN - PBN +
- Multiple Runway Ops – Sep standards reduced (CSPO) +
- Surface Ops - Data Sharing +
- TBFM - Metering/Merging/Spacing (Enroute and Terminal) (Ground-based) +
- Separation Management - Wake Re-Categorization & Wake Separation +
- PBN – OAPM⁶ +

Legend:

- ✓ Delivered
- + Expanding
- Next



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Tier 1B: Capabilities that are deemed to be high benefit and low or medium readiness. These capabilities should also be given full resources to achieve or IOC dates or accelerate those date. In the case of Tier 1B, attention should be given to address and resolve all technical and non-technical issues, and the capabilities should be accelerated if possible. Budget cuts should not affect these capabilities.



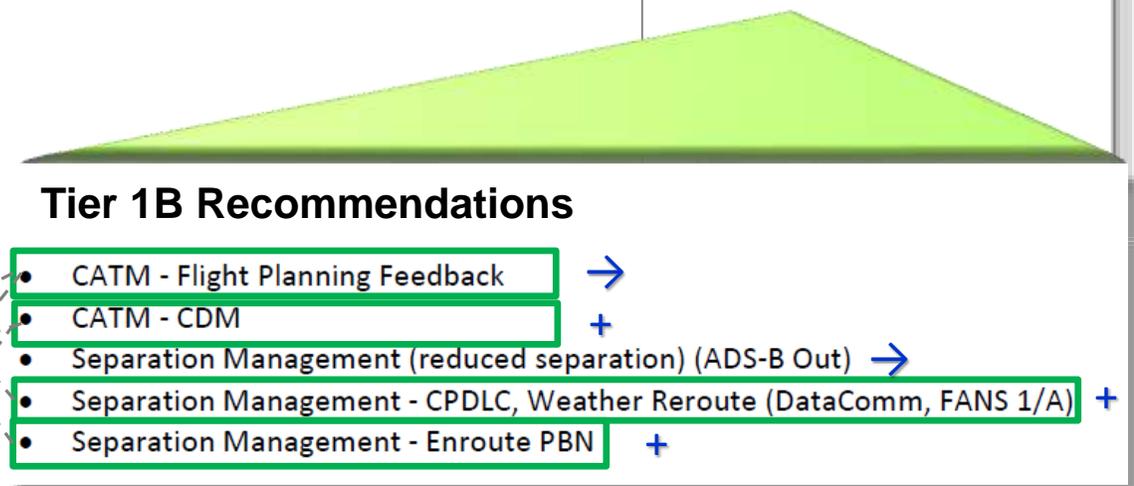
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Recommendations related to specific capabilities:

1. Continue TBFM system improvements to ensure a strong foundation to build upon for future capabilities that will address the sequencing and spacing necessary for routine use PBN in all domains. Particular attention and emphasis should be placed on site adaptation and issue resolution. Although improvements in TBFM trajectory modeling have occurred, excellence in site adaptation is crucial to producing desired results. →
2. Expand and standardize the use of TBFM in the NAS to meet the goals contained in operational use policy that covers EnRoute, TRACON and Tower airspace. Providing quality change management processes, including early training of the workforce is a key aspect of continued implementation of TBFM. The FAA must have a commitment to have resources necessary for staffing, training and support to sustain this significant change. →
3. Evaluate alternate use of CRDA given the extended period of time before the more complete solutions that are currently in development are available. It must be emphasized that the use of existing tools is only seen as a means to provide partial capability during the transition period. →
4. The NAC endorses implementing GIMS-S at the nine Terminal Sequencing and Spacing sites prior to 2020. +
5. Implement the TSAS rollout plan in the near-term time frame at 9 sites, and complete TSAS at NSG 1 Airports and NSG 2 hub airports in the mid-term timeframe. →

Legend:

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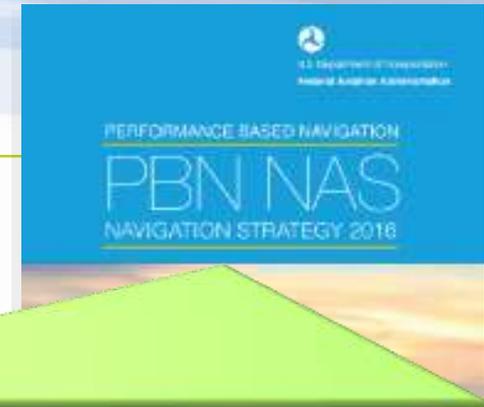
- 7. The FAA plans for Path Stretch include initial operating capability (IOC) at TSAS sites beginning in 2022. The NAC endorses this GIM-S with path stretch timeline. Deployment of GIM-S with path stretch at all TBFM airports, where appropriate, should occur near the end¹ of mid-term time horizon. →
- 8. Begin the process of integrating aircraft trajectory data with ground systems in the midterm →
- 9. Consider CRDA as a mid-term solution for flow merging and spacing based on site-specific analyses. →
- 10. Integrate Data Comm capability into the initial requirements for GIM-S with Path Stretch. →
- 11. Make the use of RTA available as a supplement to other timing tools during this time frame recognizing that there is a need for a communication mechanism that reconciles between flight crews, dispatchers and controllers. →

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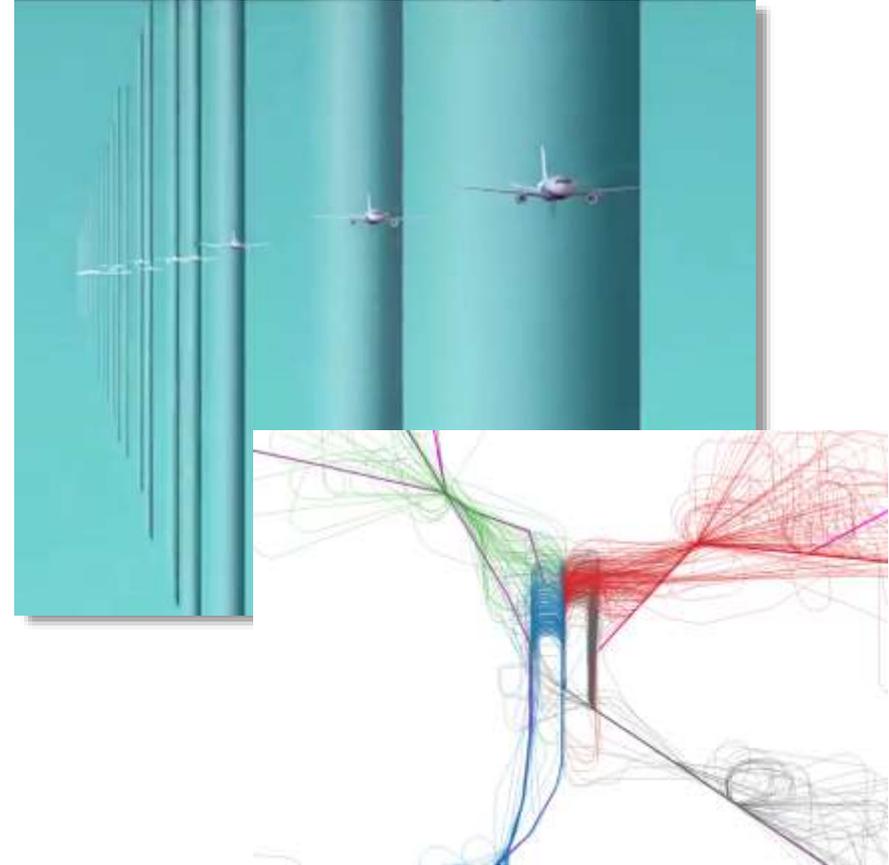
- Operating with PBN throughout the NAS, using the right procedure to meet the need; +
- Using navigation structure where beneficial and flexibility where possible; +
- Shifting to time- and speed-based air traffic management; ✓
- Delivering and using resilient navigation services; +
- Modernizing the FAA navigation service delivery to + reduce implementation time; +
- Enabling lower visibility access; and +
- Innovating and continuously improving. +

Legend:
 ✓ Delivered
 + Expanding
 → Next



Some Reasons for PBN Use Status Today

- **Due in Part To:**
 - ✦ **Use of Static, Distanced-Based Restrictions** to balance demand with capacity which introduces uncertainty
 - Same distance value between flights can result in too much or too little traffic
 - Lack of converging flow coordination can result in ‘ties’ that require vectoring
 - ✦ **Incomplete Information about Future Trajectory and Use of Open-Loop Clearances**
 - Introduces uncertainty to strategic planning and traffic management

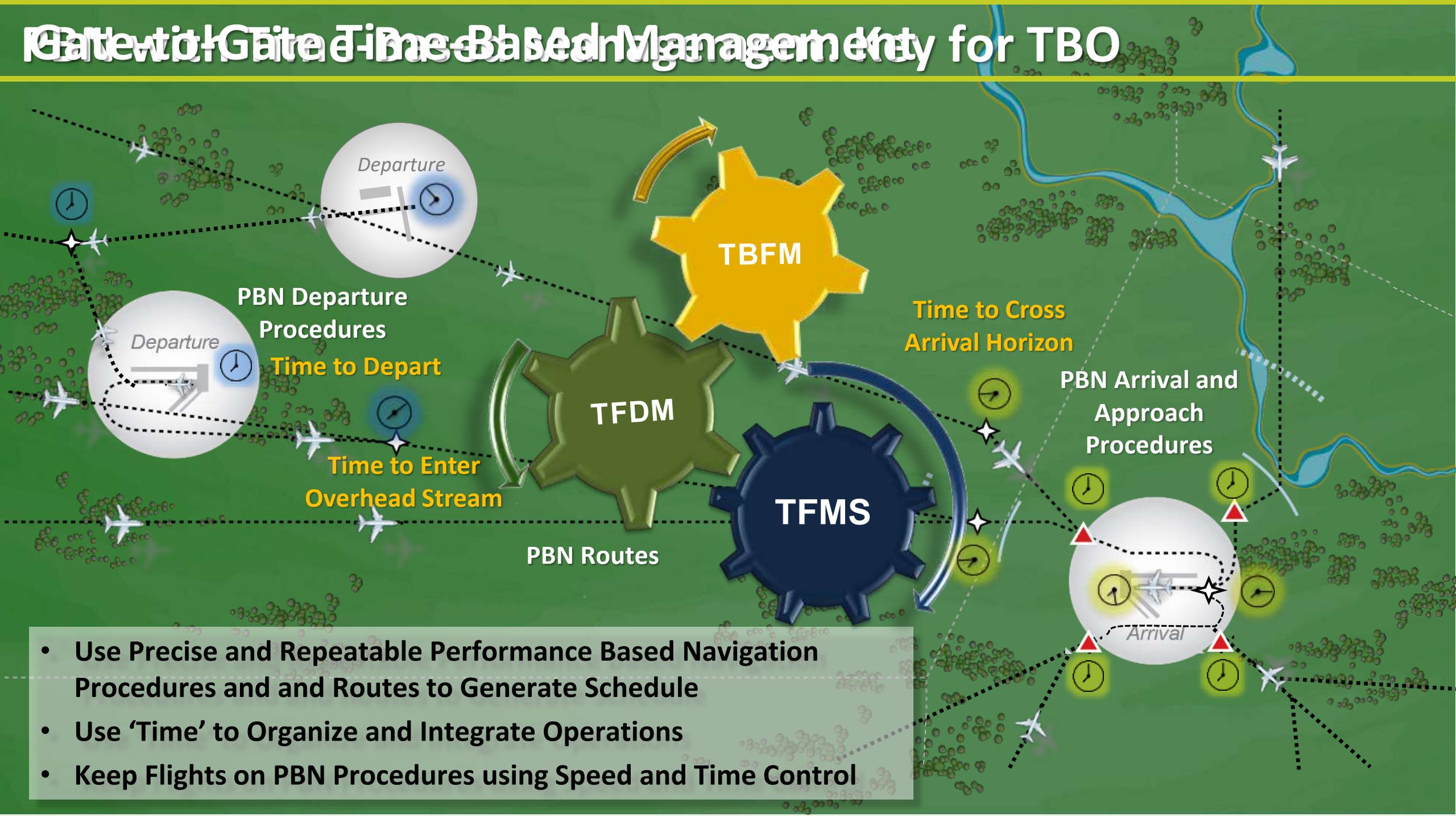


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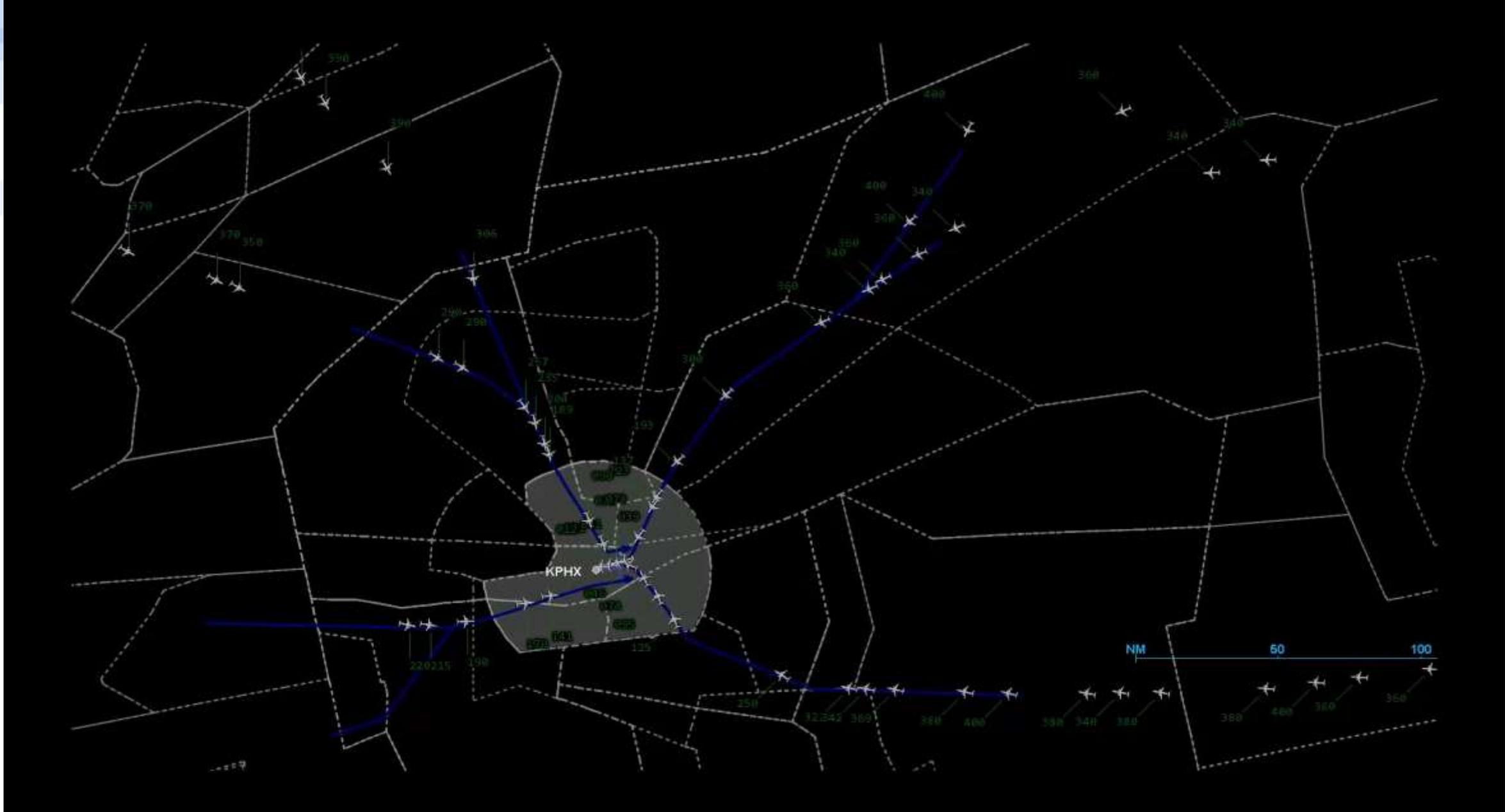
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Gate-to-Gate Time-Based Management for TBO



- Use Precise and Repeatable Performance Based Navigation Procedures and Routes to Generate Schedule
- Use 'Time' to Organize and Integrate Operations
- Keep Flights on PBN Procedures using Speed and Time Control



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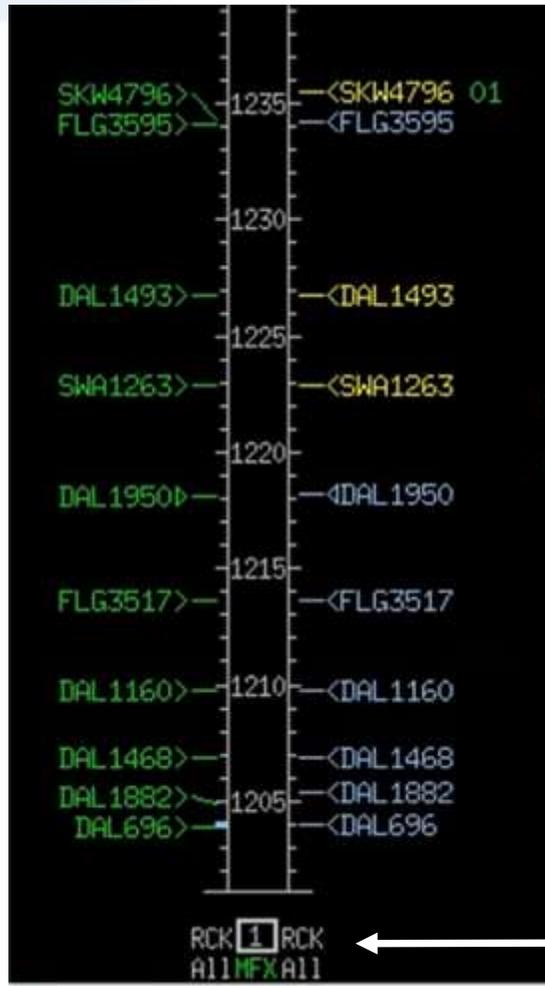


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Time-Based Management and Key Scheduling Variables

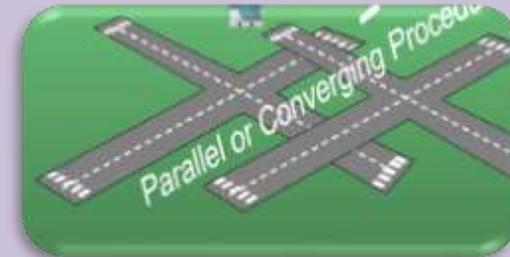
Estimated
Time of
Arrival



Scheduled
Time of
Arrival

Crossing Point

Capacity Constraints



Separation Minima



Departure Release



Flight Path



Flight Profile



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Arrival* and Departure Metering Across the NAS Today

**TBM Already Used In Many Places
Need To Build Upon That To Evolve Operations**

-  Arrival Procedures
-  Nominal Arrival Scheduling Horizons
-  Departure Scheduling Airports

*Filtered to Facilities that Actively Meter at least 15 days per month. April 2017 Data.

Airports Receiving Metering Arrivals: ATL, CLT, DEN, EWR, HOU, LAX, MEM, MSP, PHL, PHX, SAN, SEA, SFO, and SLC

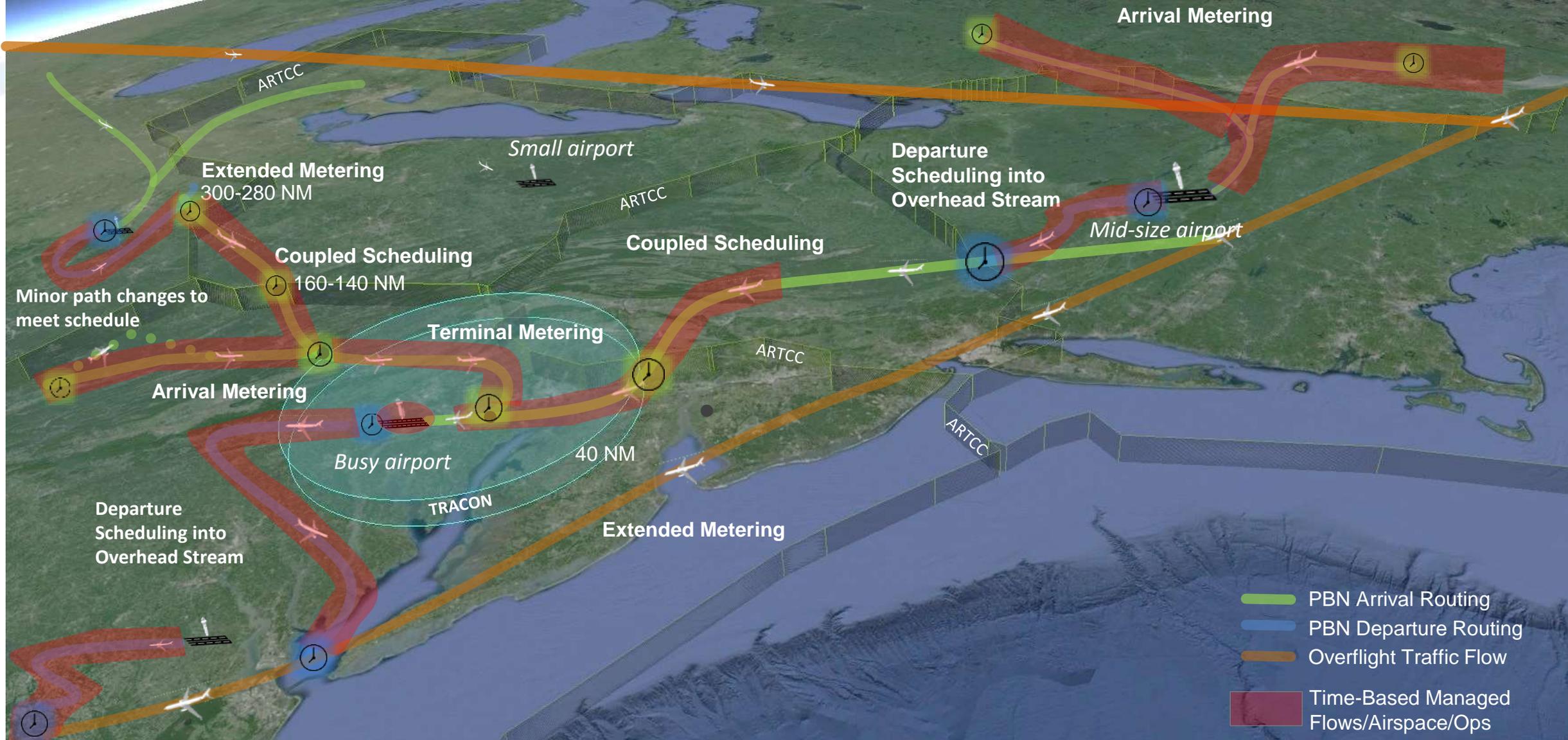


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Future Operations, Where Appropriate



Graphic Not to Scale

Getting to Trajectory Based Operations Requires Partnership Among FAA and Operators



Source: FAA



Source: BigStock Photo



Source: Aviation Week



Source: MITRE CAASD



Source: MITRE CAASD



Source: MITRE CAASD



Execution

PBN and Automation

Planning

Scheduling

| Flight ID | Scheduled Time of Arrival (STA) | Actual Time of Arrival (ETA) | Adjustment Value |
|-----------|---------------------------------|------------------------------|------------------|
| 1434324 | 22:10 | 22:15 | +5 |
| 1434325 | 22:15 | 22:20 | +5 |
| 1434326 | 22:20 | 22:25 | +5 |
| 1434327 | 22:25 | 22:30 | +5 |
| 1434328 | 22:30 | 22:35 | +5 |
| 1434329 | 22:35 | 22:40 | +5 |
| 1434330 | 22:40 | 22:45 | +5 |
| 1434331 | 22:45 | 22:50 | +5 |
| 1434332 | 22:50 | 22:55 | +5 |
| 1434333 | 22:55 | 23:00 | +5 |
| 1434334 | 23:00 | 23:05 | +5 |
| 1434335 | 23:05 | 23:10 | +5 |
| 1434336 | 23:10 | 23:15 | +5 |
| 1434337 | 23:15 | 23:20 | +5 |
| 1434338 | 23:20 | 23:25 | +5 |
| 1434339 | 23:25 | 23:30 | +5 |
| 1434340 | 23:30 | 23:35 | +5 |



Source: FAA



FAA



Source: MITRE CAASD

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Getting to Trajectory Based Operations

The Human is Key in Operational Transition



- Human-Centric and Holistic Approach to Implementation and Training
- Communicating Team Perspective
- Applying Regional TBM Solutions

- Evolution of Workforce Skillsets while Maintaining Proficiency in Conventional Techniques



Source: BigStock Photo



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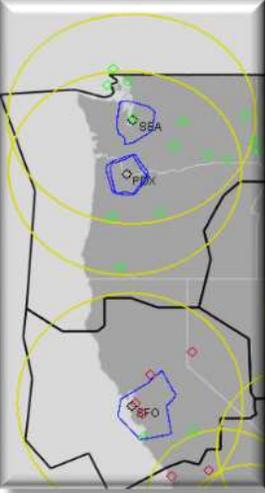
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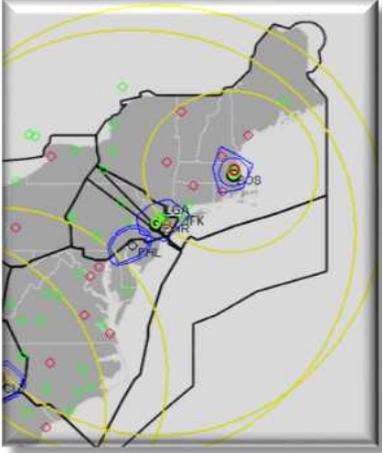
Getting to Trajectory Based Operations

Regional TBM Solutions via Operating Area Approach

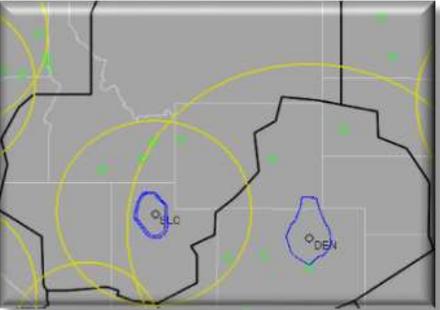
Upper North West Area



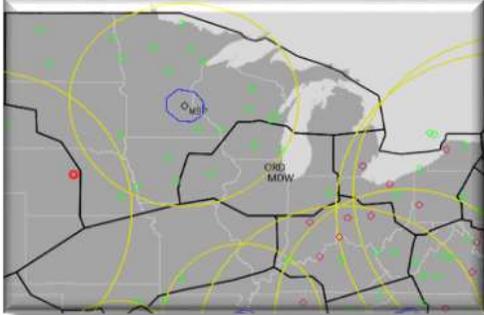
North East Corridor Area



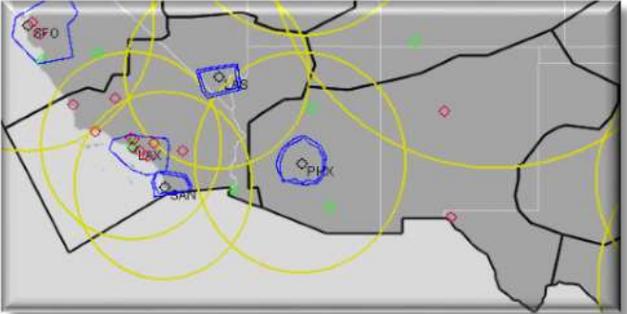
North West Mountain Area



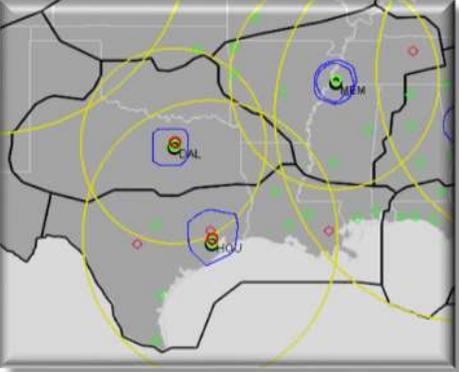
North Central Area



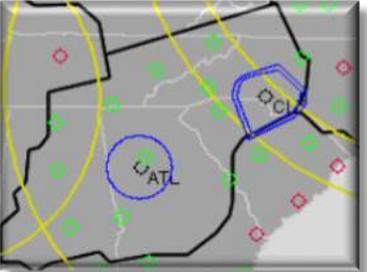
South West Area



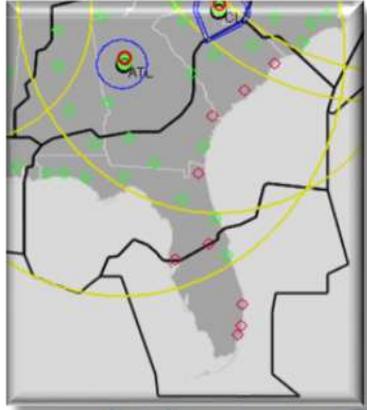
South Central Area



Mid East Area



South East Area



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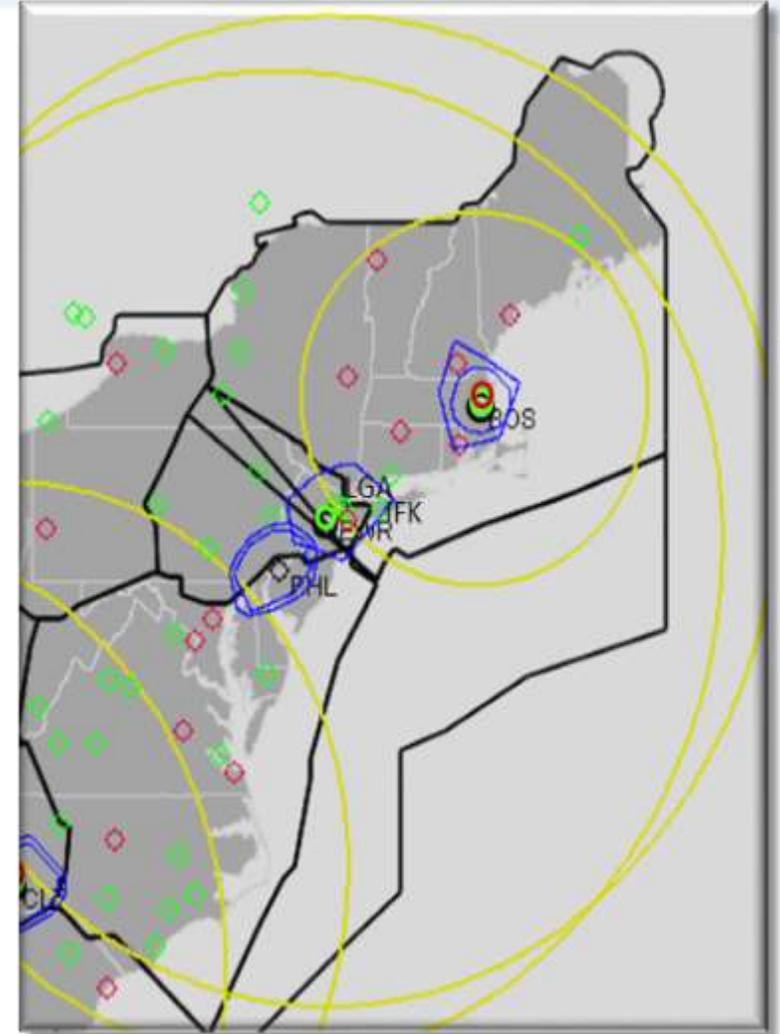


Getting to Trajectory Based Operations

North East Corridor (NEC) Summary

| ARTCC | TRACON | NAV Service Group 1 | NAV Service Group 2 |
|-------|--------|---------------------|---------------------|
| ZBW | A90 | | BOS |
| | | | BDL |
| ZNY | N90 | EWR, LGA, JFK | TEB, HPN |
| | PHL | PHL | |
| ZDC | PCT | DCA, BWI, IAD | |
| | | | RDU, RIC |

Operating Area

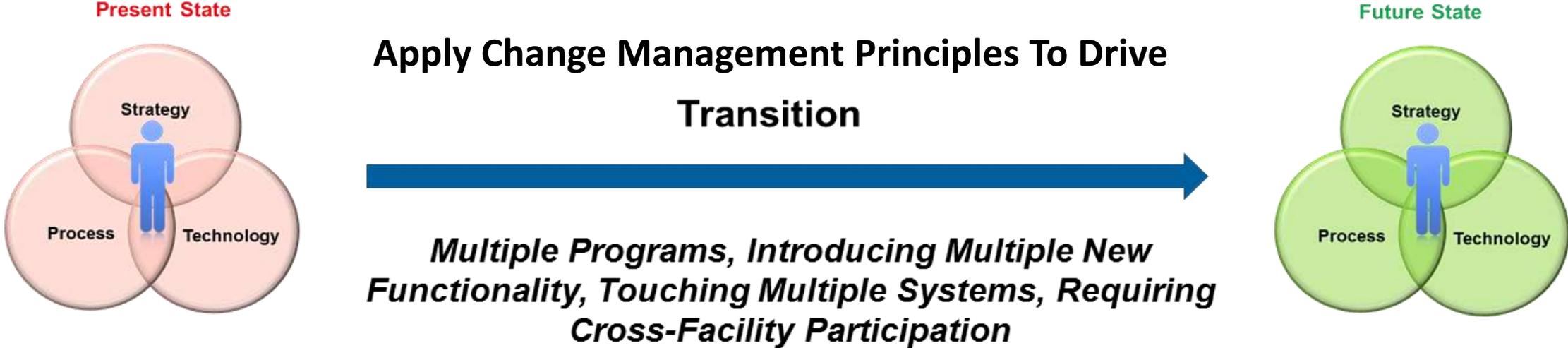


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Getting to Trajectory Based Operations Relies On A 'System of Systems' For Change



Impacts FAA Workforce AND Operator Workforce



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Getting to Trajectory Based Operations

Key Operator Equipage Needed

- **PBN***
 - ✦ **By 2025, aircraft without the following performance requirements may not be able to efficiently access Nav Service Group (NSG)1 airports**
 - RNAV (GPS) approach capability with vertical guidance
 - RNP 1 capability
 - DME navigation
 - RF capability
- **Data Provision and Collaboration Ability**
 - ✦ 11 Data Elements
 - ✦ Submission of User Preferences
- **Data Communication**
- **Time of Arrival Control**
- **ADS-B**



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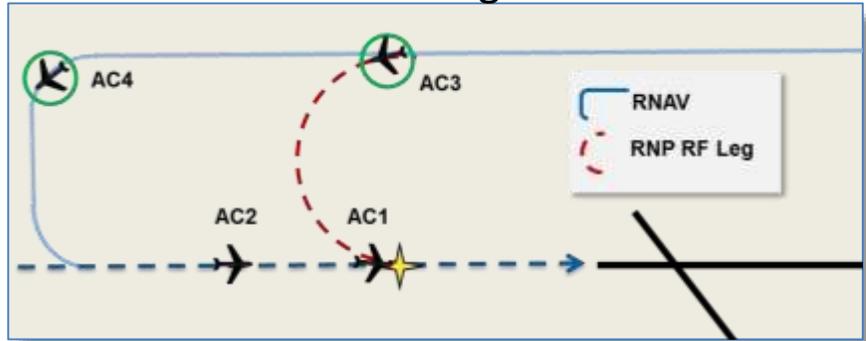
**2016 PBN NAS Navigation Strategy, p. 23*



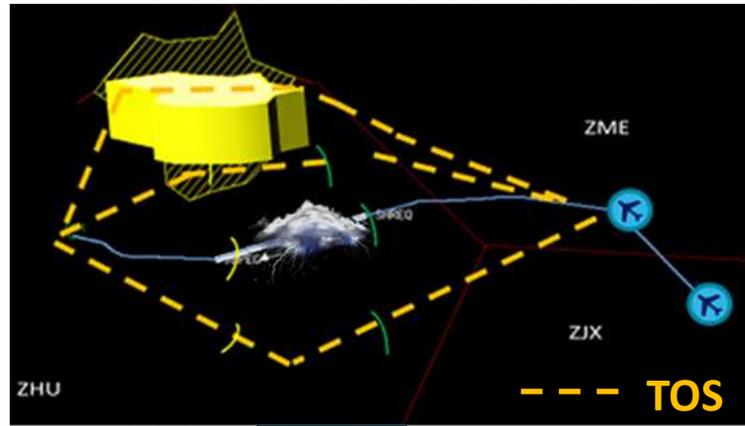
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Examples of Key Operator Equipage Relationship to Benefits

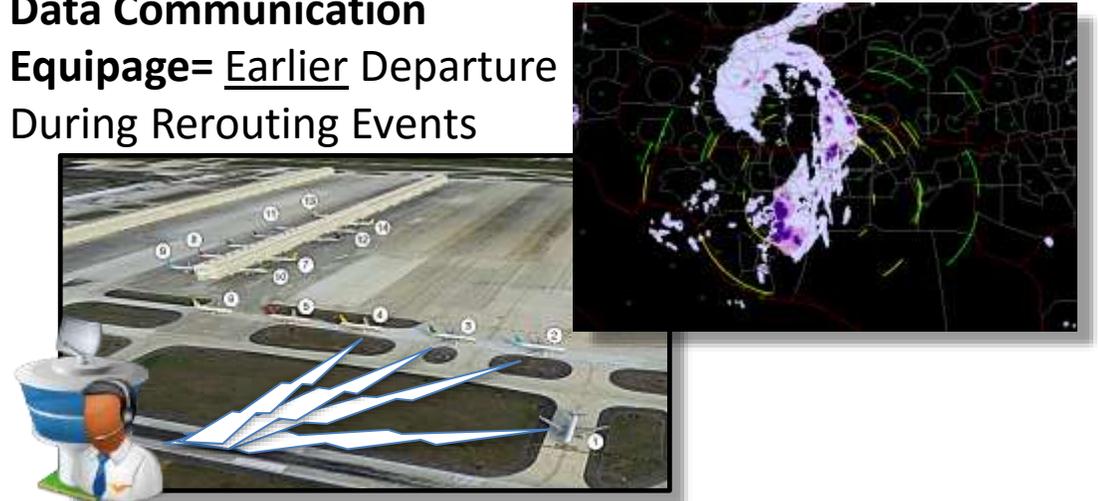
PBN Equipage (RNP)= Shorter Flight Distance and Flight Time



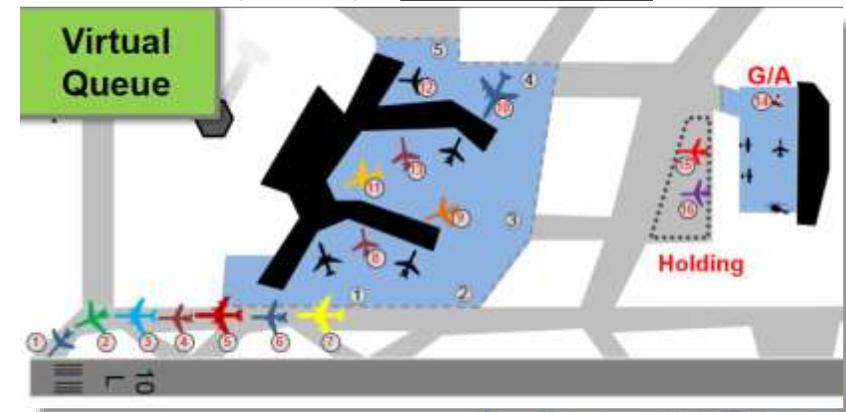
Data Provision (User Preferences)= Optimized Reroute Around Constraints



Data Communication Equipage= Earlier Departure During Rerouting Events



Data Provision (EOBT)= Less Waiting After Pushback



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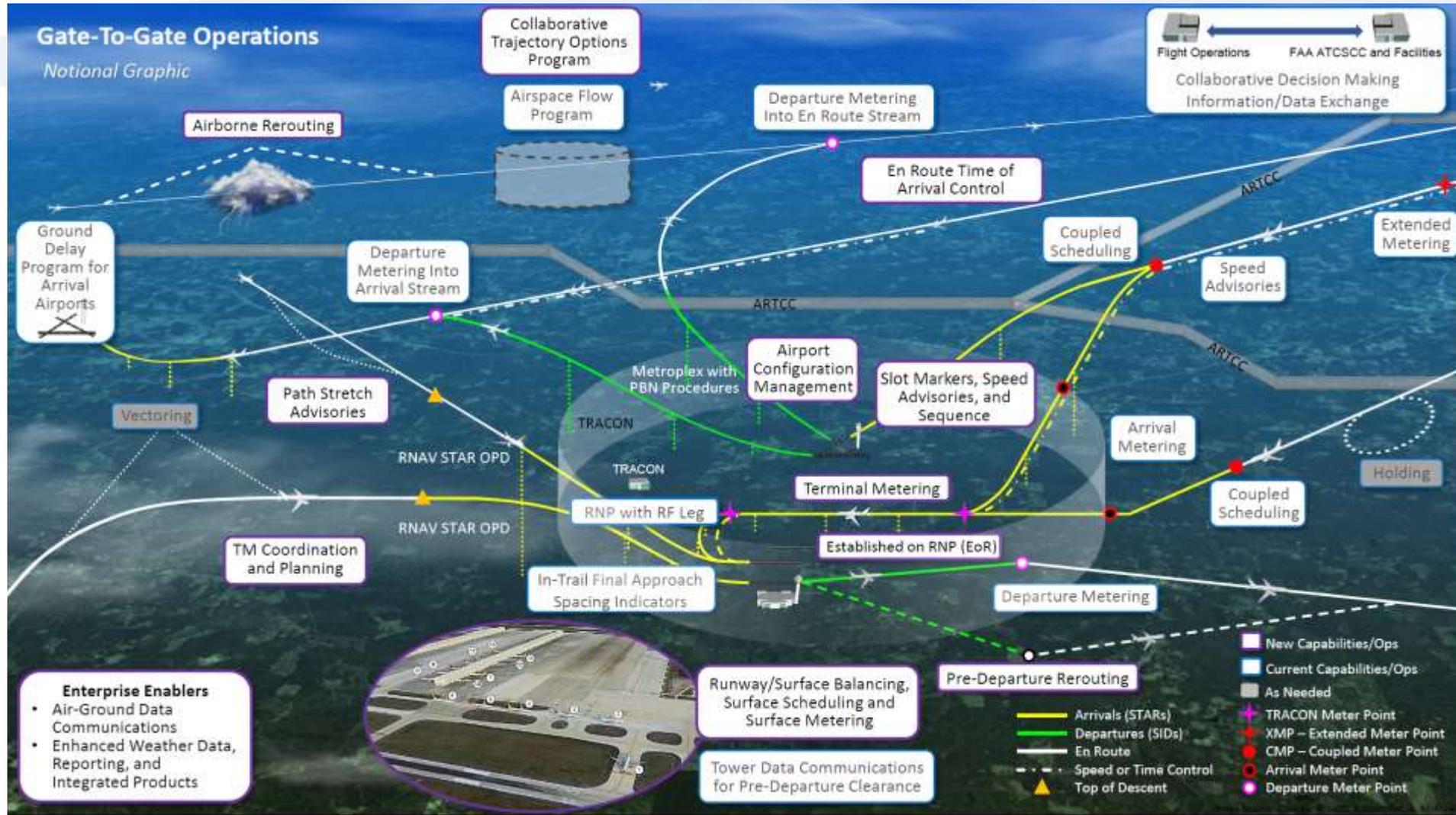
Show TBO Video



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Initial Scope for Implementing TBO



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Thank You for Your Time!



Source: BigStock ID 48526436



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- **Electronic Flight Data**
- **Runway/Surface Balancing**
- **Surface Scheduling and Metering**

- **Better Utilization of Current Capabilities:** En Route Departure Capability (EDC), Departure Scheduling, Airborne Metering, Integrated Departure Arrival Capability (IDAC), and GIM-S (Extended Metering, Coupled Scheduling, and Automated Speed Advisories)
 - **Terminal Sequencing and Spacing (TSAS)**
 - **En Route Path Change Advisories**
 - **Traffic Manager DST**
- **Better Utilization of Current Capabilities:** Flight Schedule Monitor (FSM), Departure Viewer, Traffic Situation Display (TSD), NAS Monitor, NTML, Airspace Flow Program (AFP), Ground Delay Program (GDP), Collaborative Trajectory Options Program (CTOP), and Collaborative Decision-Making (CDM)
 - **Pre-Departure Reroutes (PDRR)/Airborne Rerouting (ABRR)**
 - **Improved Demand Modeling (IDM)**
 - **Integrated Departure Route Planning (IDRP)**