Coordination Draft 9/9/2020

Trajectory Based Operations (TBO) Operator Benefits

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MITRE | Center for Advanced Aviation System Development

Outline

- TBO Overview
- Roles for TBO Success
- Envisioned End-to-End Operations
- TBO Benefits for Flight Operators

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TBO Overview

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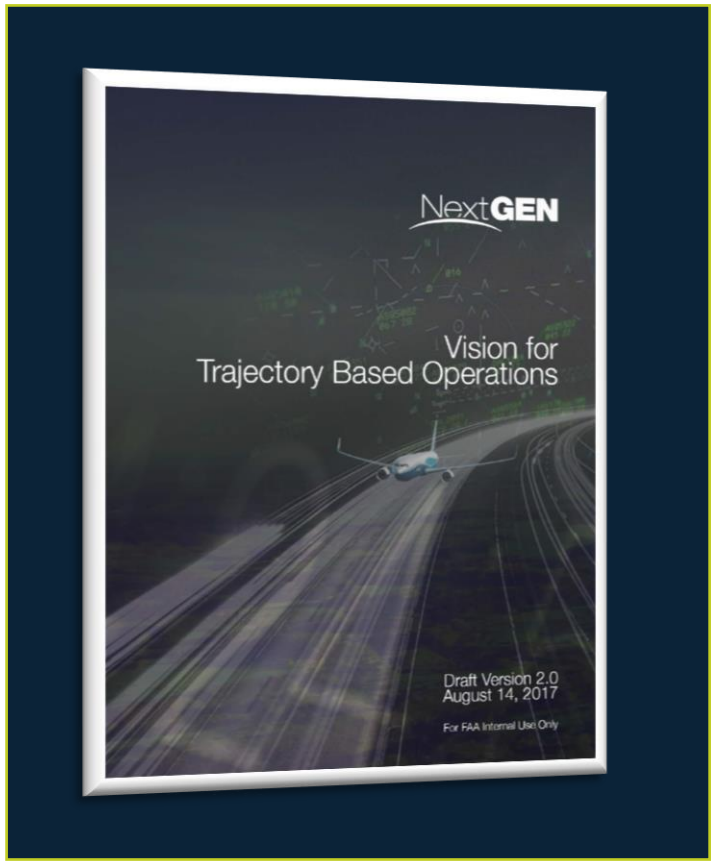
What is TBO?

Trajectory Based Operations (TBO) is an air traffic management method for strategically planning, managing, and optimizing flights throughout the operation



TBO…

- ✓ Has always been a long-term target of NextGen.
- ✓ Improves the ability to exchange trajectory information across systems in the NAS.
- ✓ Is based on the aircraft's ability to fly precise flight paths at precise times with seamless information exchange between air and ground systems.

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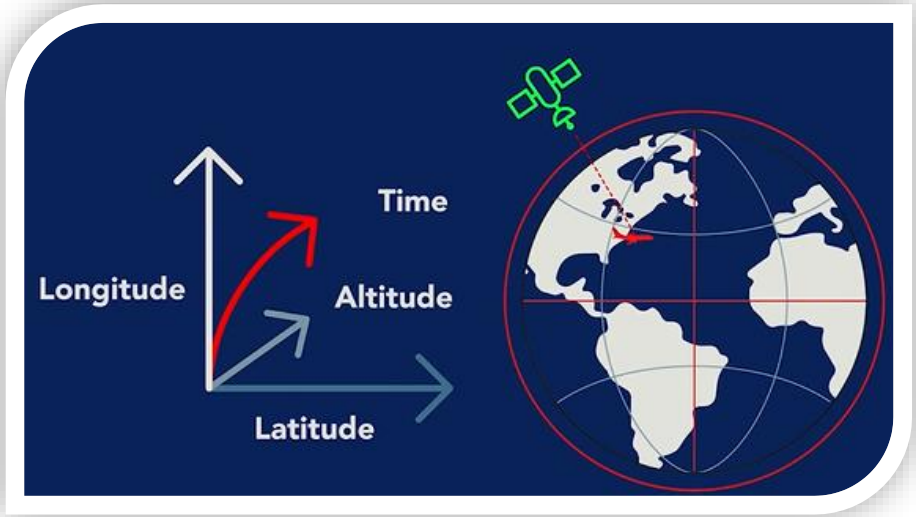
How Does TBO Work?

TBO is about predicting <u>where</u> a flight will be and at <u>what time</u>.

- This forms the basis for a ‘strategic plan’
- A trajectory is used as a reference for the flight and shared between systems and stakeholders
- A trajectory is defined in four dimensions: Latitude, Longitude, Altitude, and Time



- The trajectory is updated as operations evolve over time and new information becomes available

TBO is a collection of systems, capabilities, processes, and people working together to achieve operational objectives

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Roles for TBO Success

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TBO's Success Depends On….

FAA

- Methodical Implementation Approach
- On-going Research in TBO Capabilities
- Prepare FAA Workforce
- Maintain Planned Trajectories

Operators

- Understand TBO Vision and Implementation Strategy
- Provide Data to Support TBO Capabilities
- Develop Capabilities to Leverage TBO Data
- Prepare Operator Workforce
- Equip Aircraft as Described in the Minimum Capability List (MCL)

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How Does TBO Affect Pilots/Flight Crews?

Increased Use of

- ✓ Avionics and Flight Management System
- ✓ Performance Based Navigation
- ✓ Electronic Data Exchange via CPDLC

More predictable departure delays, when they occur

Less surface waiting in physical departure queue

Better understanding of expected arrival time due to adhering to planned trajectories

Fewer strategic reroutes with greater use of dynamic rerouting capabilities, as needed

Reduced vectoring in terminal and en route airspace

Reduced availability of pilot-requested runway assignments

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How Does TBO Affect FOCs?

Increased emphasis on strategic planning and a shift towards a continuous planning process	New processes provide key data elements for scheduling and flight routing alternatives
Greater emphasis on providing accurate and timely flight status information	New opportunities to receive, interpret, and leverage FAA-provided data
More seamless and targeted use of strategic initiatives with a reduction in “double” restrictions	Increased flexibility in the execution of strategic initiatives when they are needed
More predictable departure delays and flight path confidence	In some situations, equipped flights may be more efficiently served (e.g., CPDLC)

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Envisioned End-to-End iTBO

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Key TBO Benefits and Expectations

Throughput → Flight Efficiency → Predictability → Flexibility

- Increased Throughput
- More Efficient Delay Redistribution
- Increased Utilization of RNP RF Approaches
- Increased Route Flexibility
- Reduced Airborne Holding and Vectoring
- Greater Emphasis on Strategic Decisions
- Increased Daily Schedule Integrity
- Increased Efficiency in Constrained Environments
- Increased Flight Path Confidence
- Reduced End-to-End Variability

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ENVISIONED End-to-End iTBO

Notional Graphic

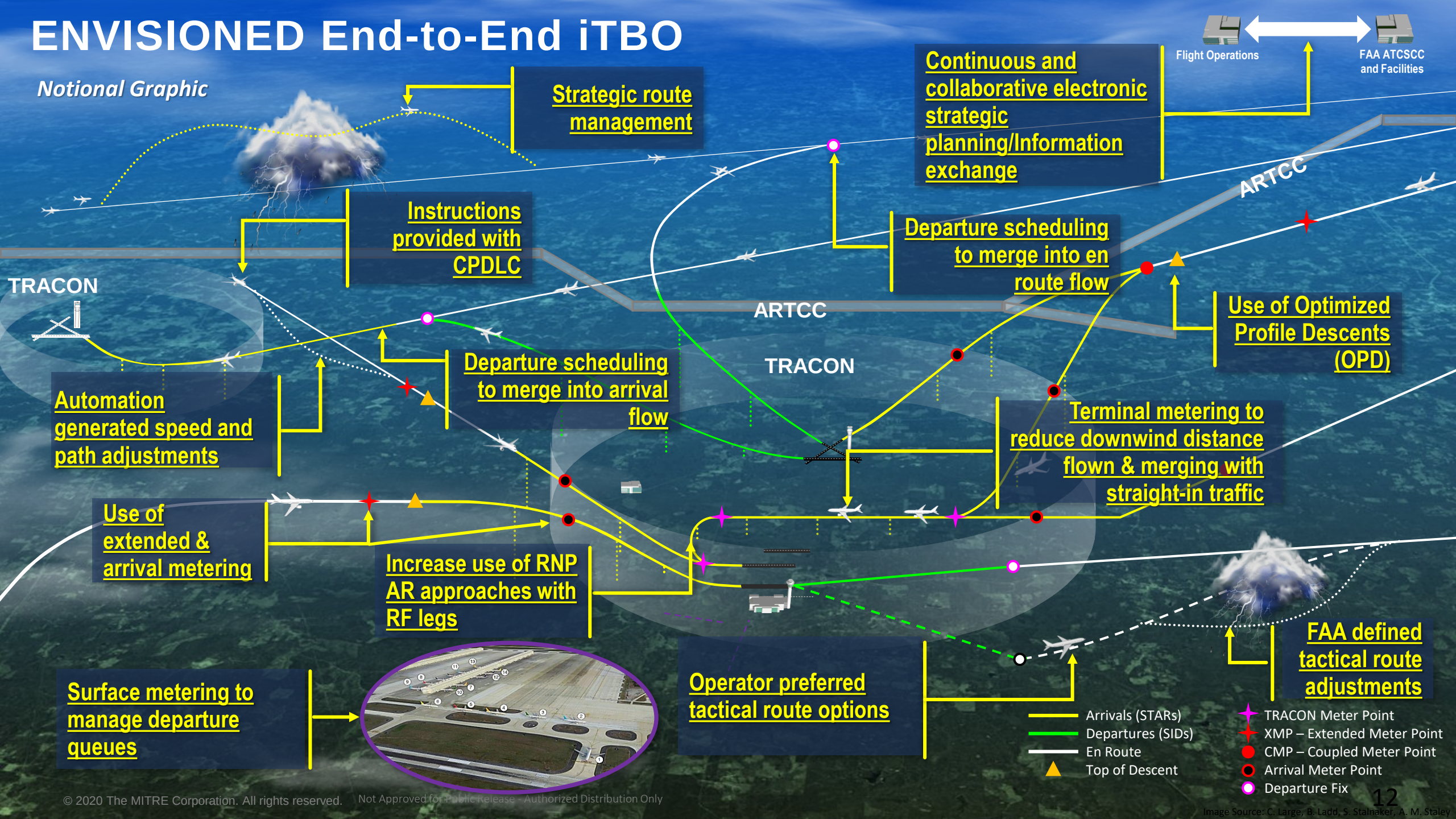

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Image Source: C. Large, B. Ladd, S. Stalnaker, A. M. Staley

Flight Operations

FAA ATCSCC and Facilities

Continuous and Collaborative Strategic Planning

Shift towards electronic real-time collaboration

FAA & Operators collaborate to develop and refine and update the Operations Plan

FAA evaluates en route and terminal forecasts, demand and other information to identify potential constraints

Operations Plan For:
- Active Metering
- Strategic TMIs
- Route Management
- Surface Management

Flight Operators submit accurate and timely flight planning information including EOBT, route preferences, and equipage

FAA Automation provides real-time flight specific trajectory information including ETAs and ETDs

Improved information sharing

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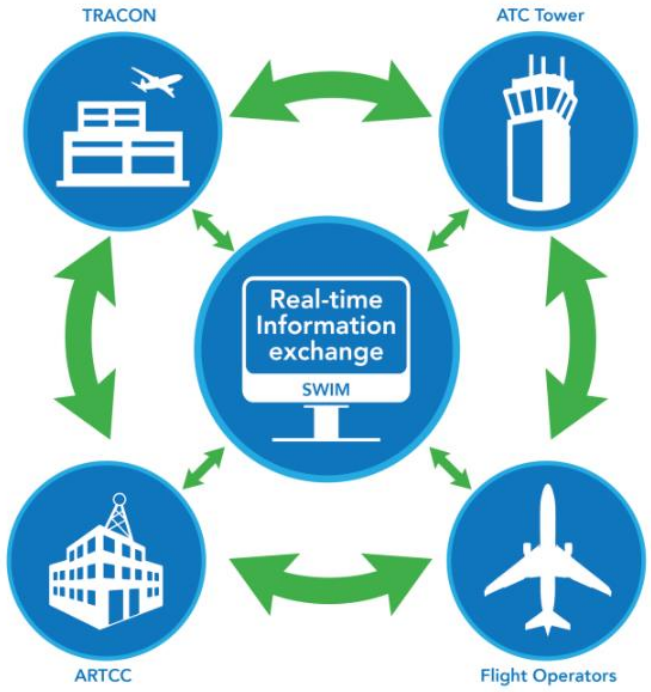
Increased Information Exchange

Greater information exchange via System Wide Information Management (SWIM) provides for better resource planning

Flight Operators Provide

- Planned & Actual surface movement times
- Preferred runway
- Gate accessibility
- Ramp open/closed status
- Intent to hold on non movement/movement area



Flight Operators Receive

- Expected OFF times
- Expected runway assignment
- Airport configuration/rates
- Surface metering times
- Flight specific TMI status
- Surface substitution options

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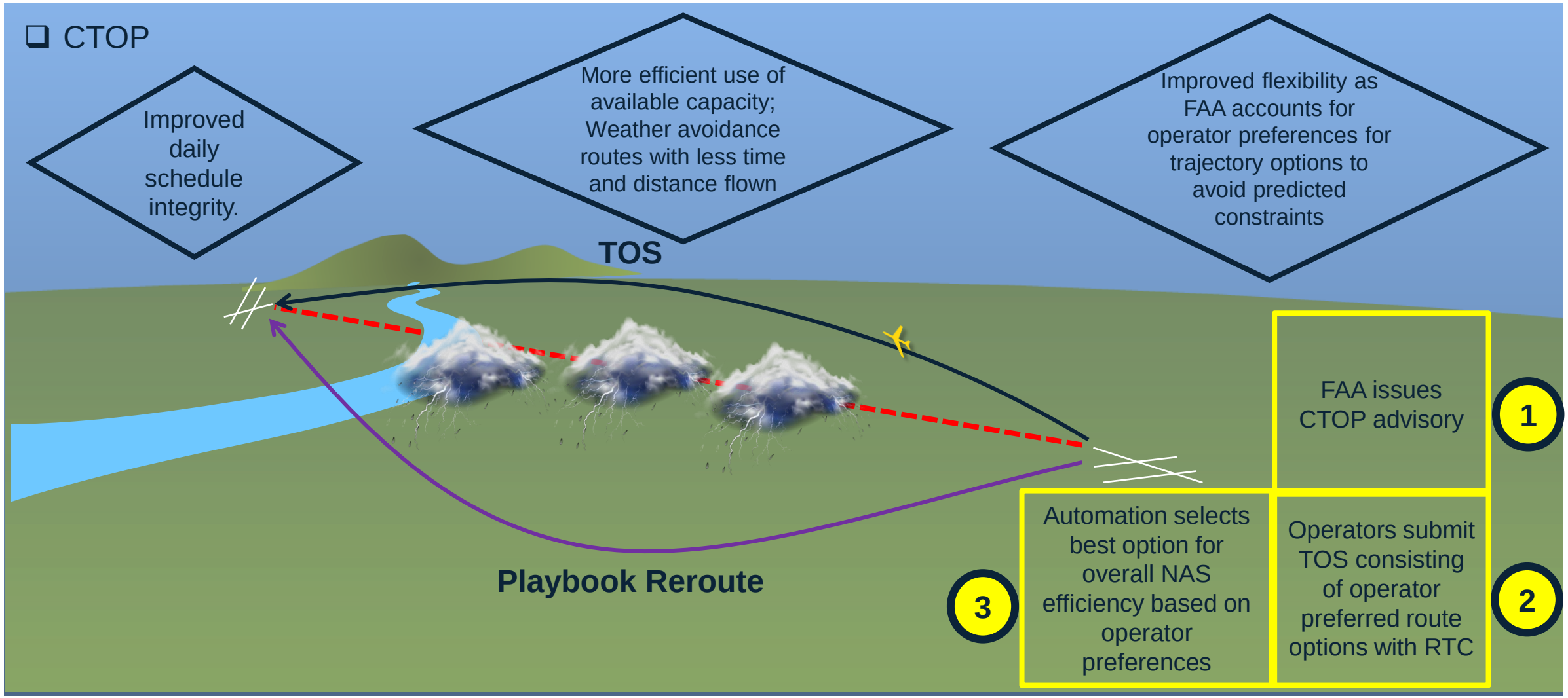
Strategic Route Management



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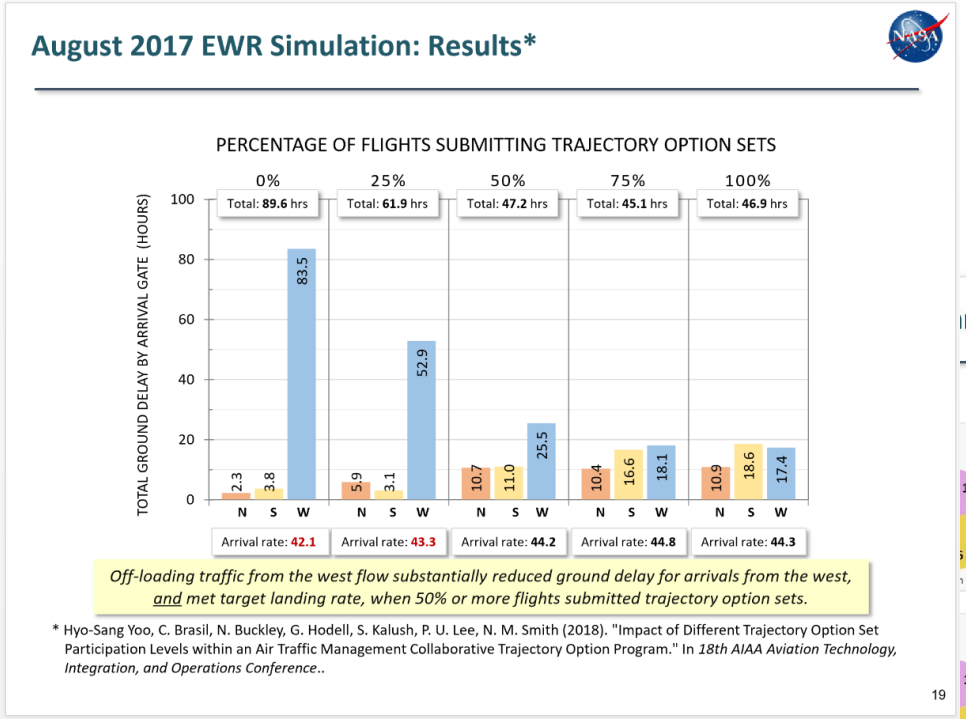
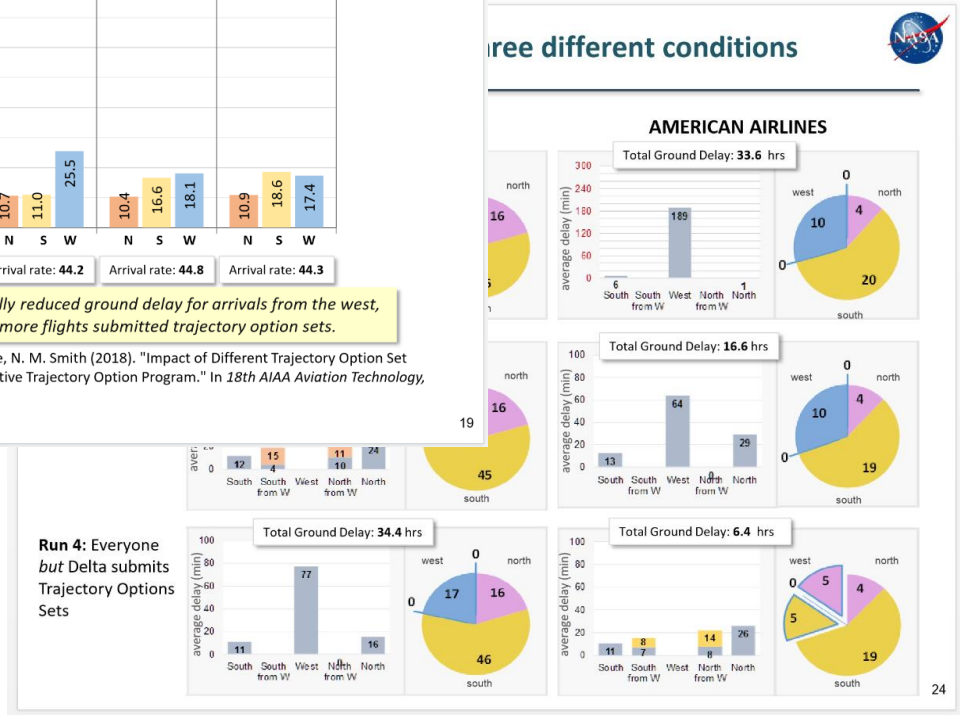
Strategic Route Management Benefits

- NASA analysis found that departure delay decreases substantially for **all flights** as percentage of flights submitting multi-option TOS during CTOP increases
- For non-participating flights, CTOP uses flight plan as a single option TOS
- Both the participating and non-participating operators benefited from use of TOS, but participating operators benefited more





Sources: *Integrated Demand Management (IDM) Project Overview*. Nancy Smith (NASA Ames), April 2, 2019.
Demonstrating Early-Adopter Benefits of Submitting Multiple Trajectory Options for Airlines. Gita Hodell, et al (NASA), AIAA Aviation Forum, June 2020.

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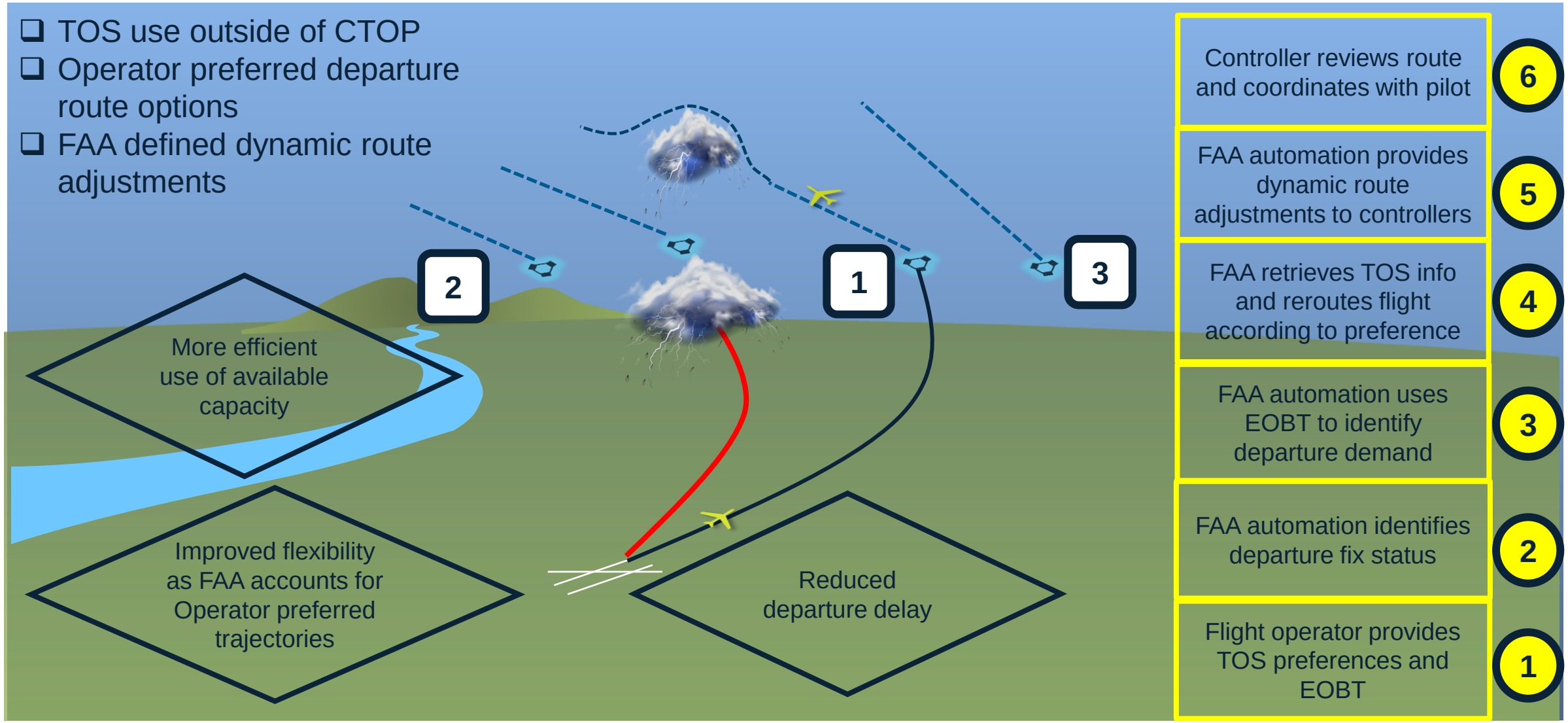
Tactical Route Management

- TOS use outside of CTOP
- Operator preferred departure route options
- FAA defined dynamic route adjustments



Controller reviews route and coordinates with pilot	6
FAA automation provides dynamic route adjustments to controllers	5
FAA retrieves TOS info and reroutes flight according to preference	4
FAA automation uses EOBT to identify departure demand	3
FAA automation identifies departure fix status	2
Flight operator provides TOS preferences and EOBT	1

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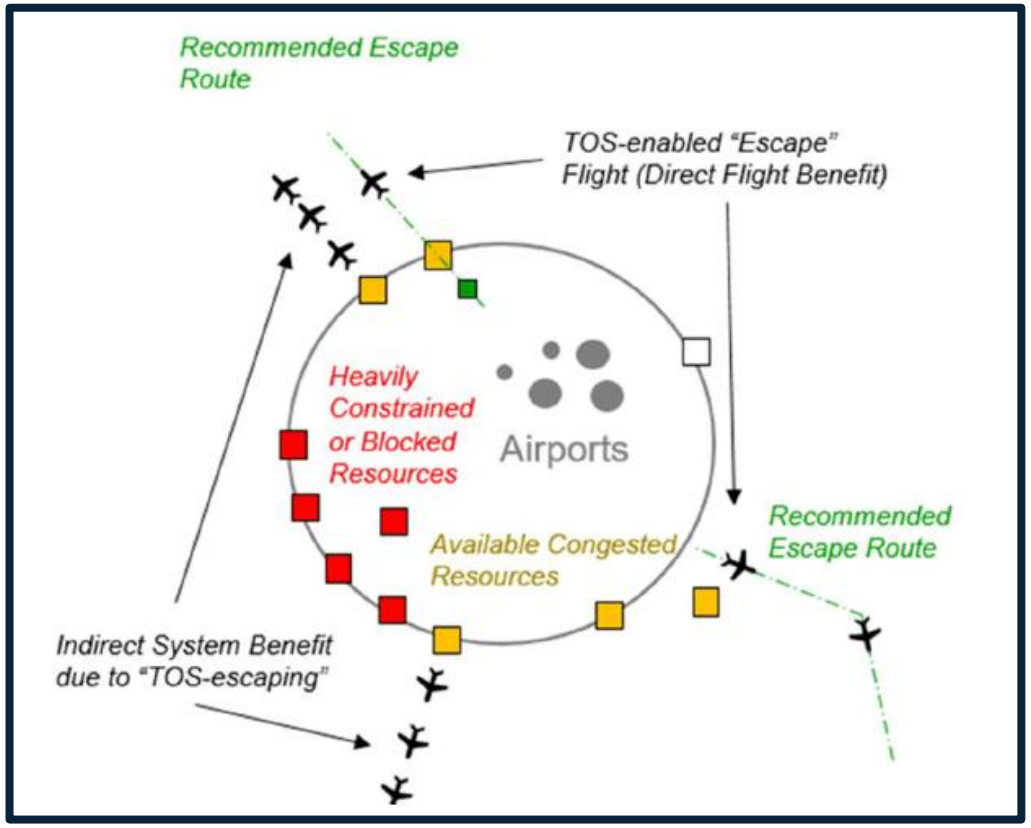
Tactical Route Management Benefits

Submission of trajectory options provides the FAA with operator preferred reroute options reducing departure delay

- In NY TRACON, increased use of TOS enabled offload routes would save airlines **730 hours of delay in a year.**
- In periods when offloads to alternative departure fixes are available, savings could be realized at these airports

Airport	Delay Savings (hrs)	Cost Saving (mil)
EWR	200-300	$0.9 – $1.3
PHL	350-550	$1.6 – $2.4
CLT	525-800	$2.3 – $3.5
ATL	550-825	$2.4 – $3.6



Robinson, M., et.al., Summary Letter to FAA of *User Preferences and Trajectory Option Sets (TOS) to Achieve Traffic Flow Management (TFM) Benefits*, MITRE, September 2017

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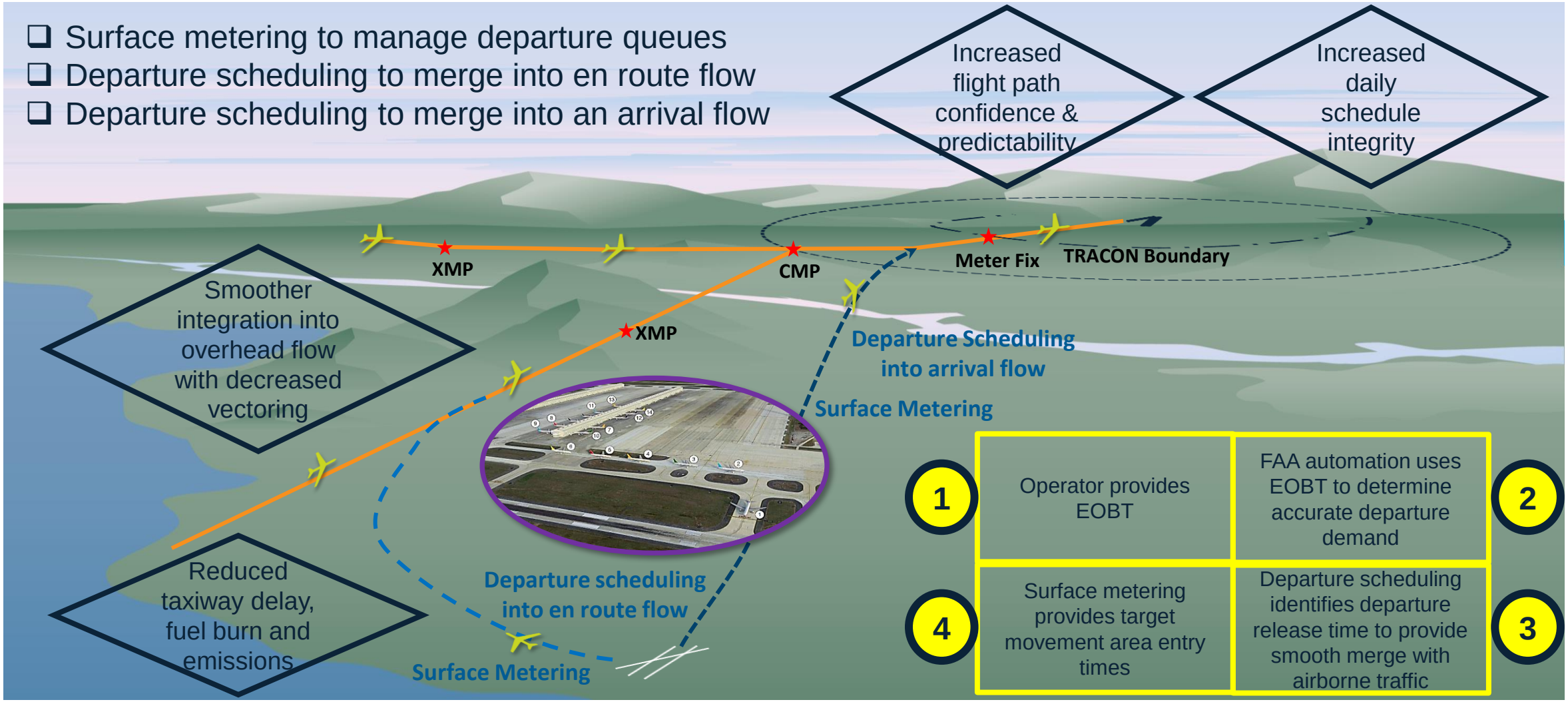
Time Based Management for Departures

- ❑ Surface metering to manage departure queues
- ❑ Departure scheduling to merge into en route flow
- ❑ Departure scheduling to merge into an arrival flow



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Time Based Management for Departures Benefits

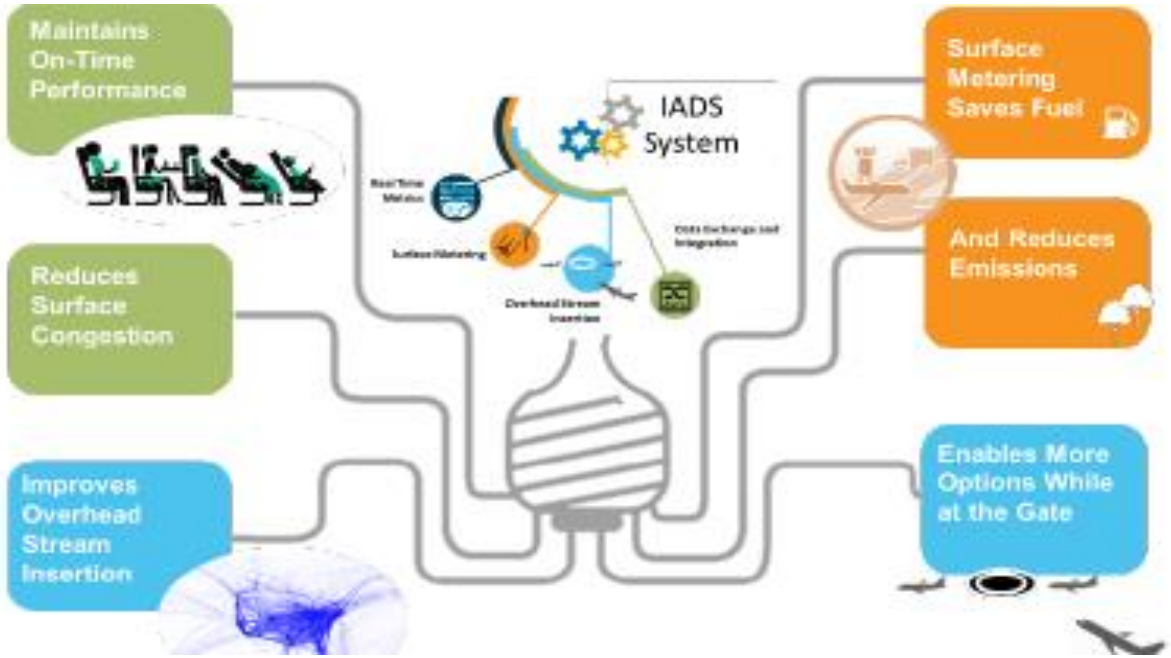
Less time on taxiway and efficient integration into overhead stream reduces delays, crew costs, fuel burn, and other engine run time costs

Observations at CLT

November 2017 through September 2019

- 2,755,166 lbs. of fuel saved
- CO_2 savings equivalent to 63,101 urban trees
- 357.4 hours of surface delay saved
  - $1,715,714 passenger value of time
  - $486,170 flight crew costs
- 2,122 hours of reduced runtime on engines

Multiple benefits mechanisms



Source: Benefits of Surface Departure Metering while 'doing no harm' to other operational metrics. Airspace Technology Demonstration 2 (ATD-2) Industry Workshop, Jeremy Coupe (NASA) September 4, 2019

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Time Based Management for Departures Benefits

Reduction in Taxi-Out Time

Observations for NY Departures to ATL

ZNY Implementation of EDC & IDAC

February – August 2017

Statistically significant decreases were observed for all origin airports except HPN.

| 34 |

Metric: Taxi-Out Time

Results for ATL; February - August Time Period

Difference in Means (min)

OD Pair	Demand Low	Demand Med	Demand High
EWR-ATL	-1.00	-0.96	-0.25
JFK-ATL	-0.97	0.08	-0.10
LGA-ATL	-0.77	-1.68	-3.68
HPN-ATL	1.03	-0.29	1.33
PHL-ATL	-0.15	-0.84	-1.44

Note: Table shows weighted results, all runways and entrances combined; TEB departures not included because of lack of OOOI data

Statistically significant increases (Post-period results > Pre-period results) are highlighted in red (disbenefit) and decreases (Post-period results < Pre-period results) in green (benefit); non-significant results are greyed out

Decreases in taxi-out time were observed for all airports except HPN

Results for statistically significant cases were monetized based on ADOC method[1]

1. See Appendix A for more information

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Source: ZNY En Route Departure Capability (EDC) and Integrated Departure/Arrival Capability (IDAC) Benefit Analysis. NextGen Operational Performance Assessment, Joint Analysis Team. Gabriela Marani, et al (MITRE). September 2019

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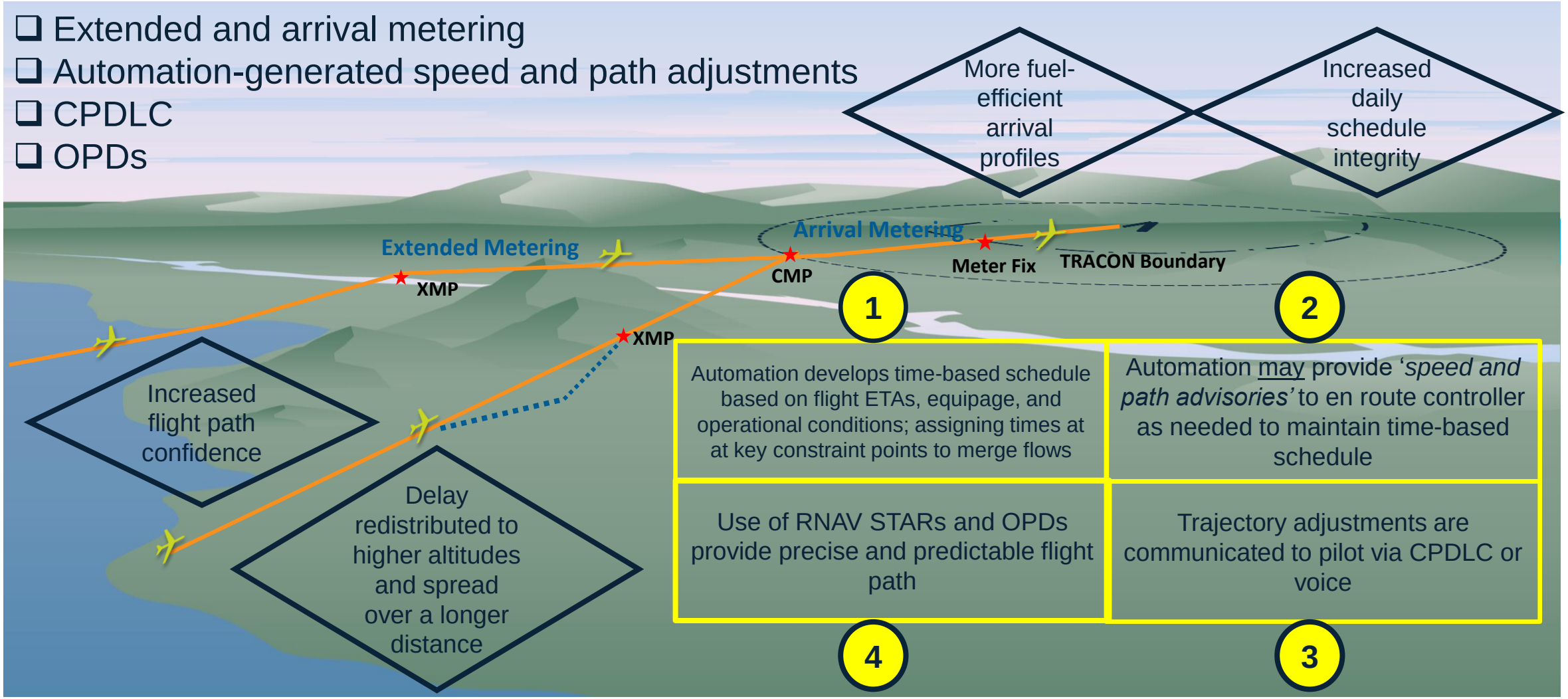
Efficient Airborne Operations

- ❑ Extended and arrival metering
- ❑ Automation-generated speed and path adjustments
- ❑ CPDLC
- ❑ OPDs



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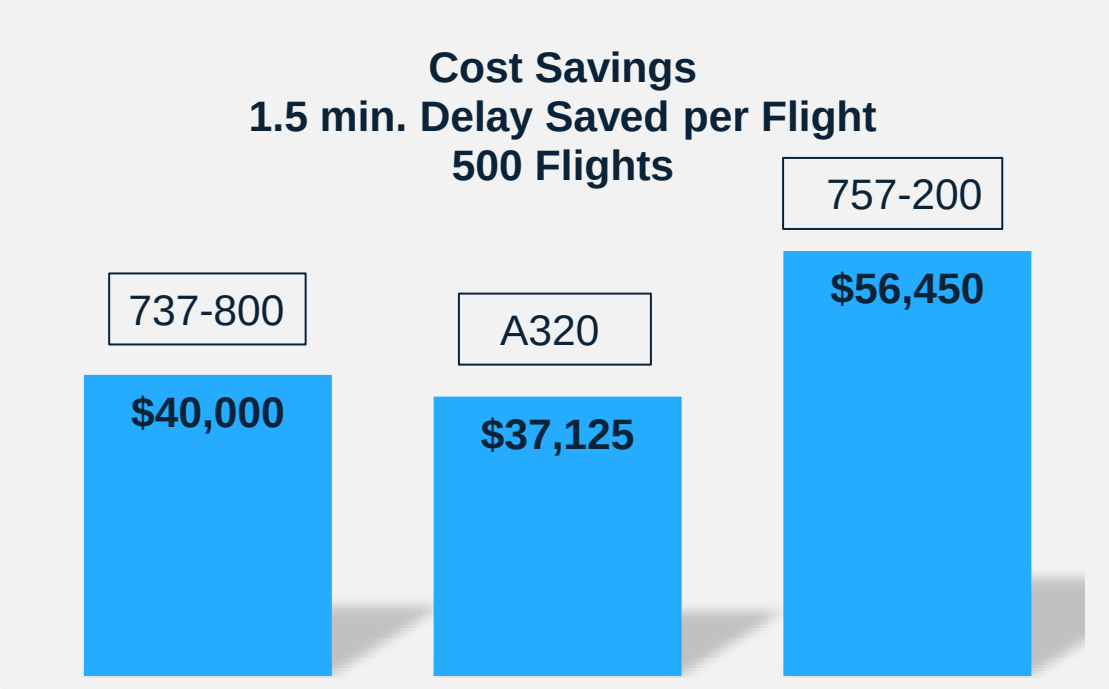
Efficient Airborne Operation Benefits(1/2)

The use of an advanced metering design and decision support tools for en route controllers enable aircraft to meet metering times more precisely, reduce vectoring in the terminal, and increase use of existing PBN procedures.

This results in more efficient airborne operations.

Evidence: In one study evaluating arrivals with an advanced metering design and controller decision support tools in place, procedure conformance increased by 10-15%. Additionally, flights that conformed to procedures reduced their terminal flight times by an average of **1.5 minutes**[1].

Possibility: For every 500 flights, this one-minute reduction would save thousands of dollars depending on aircraft type.



Source: Direct Operating Cost (ADOC) airborne per minute: 2018 (Form41)

1 Peak hours, jet only, Nov thru Mar 2013-2016

Source: Measuring Performance of Initial Ground-based Interval Management – Spacing (GIM-S) Operations, MITRE Brief, Lascara, B, et. al, June 27, 2017

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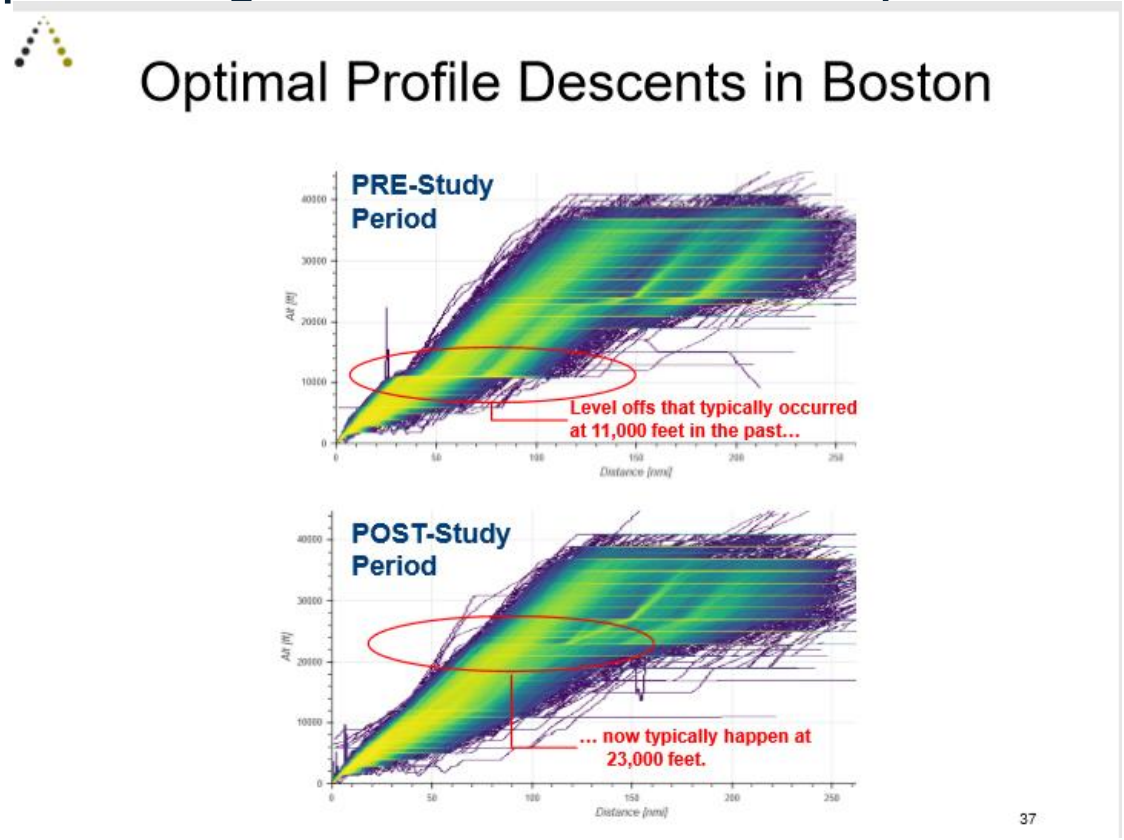
Efficient Airborne Operations: OPD Benefits (2/2)

OPDs reduce level offs during arrival providing fuel efficient descent profiles

In a study of 55 airports[1], RNAV OPDs r**educed distance in level flight by an <u>average of 2.80 NM</u> per arrival and the number of level off flight segments by an <u>average of 0.24</u>**

At the Houston metroplex more efficient descents will save over **<u>$6 mil. in fuel</u>** during a year



Source: RTCA Joint Analysis Team (JAT), October 2017

[1] January 2011 to March 2018
Source: NextGen Operational Performance Assessment (NOPA): *Benefits of Performance-Based Navigation (PBN) Area Navigation (RNAV) Standard Terminal Arrivals (STAR), MITRE, Gouldey, Sept. 2018..*

OIG Report # AV-2016-081, August 20, 2015 (Houston Airport)

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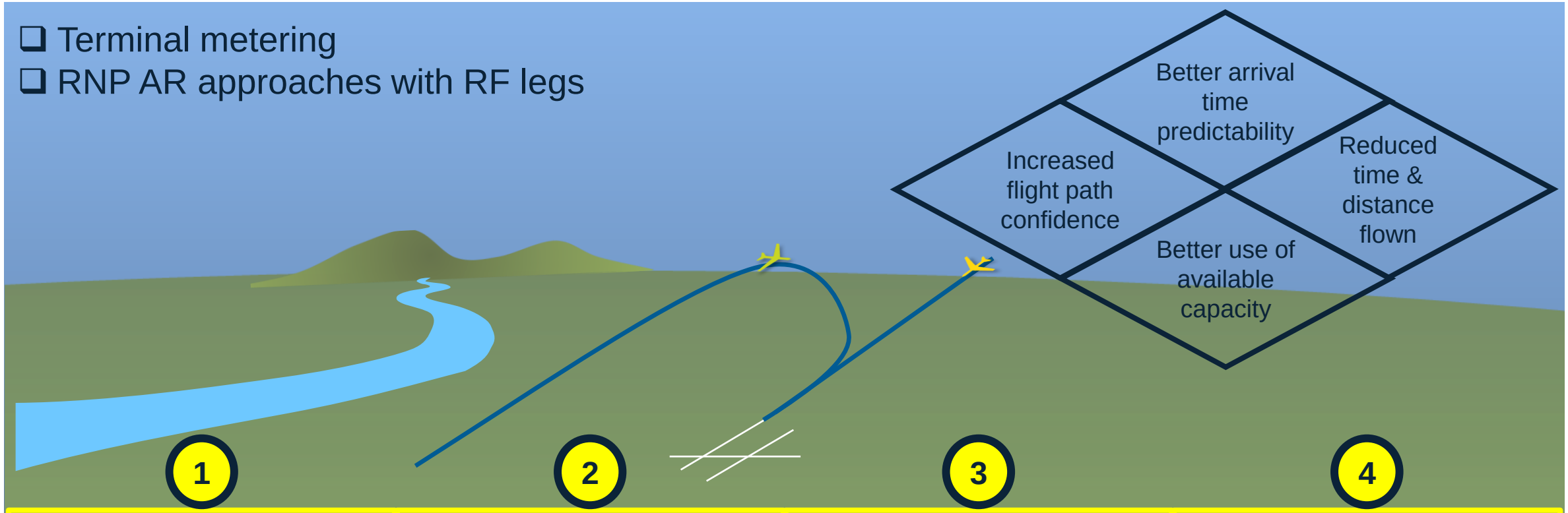
Efficient Terminal Operations

- ❑ Terminal metering
- ❑ RNP AR approaches with RF legs



1	2	3	4
Flight operators ensure required equipment and related training are reflected in the flight plan	Terminal metering efficiently builds a schedule providing for merge straight-in and curved approaches, and keeping flights on appropriate procedures based on equipage	Terminal Controllers manage flights using Decision support tools to maintain the time-based schedule to the runway	Use of RNP Approaches for equipped flights provide precise and predictable routes

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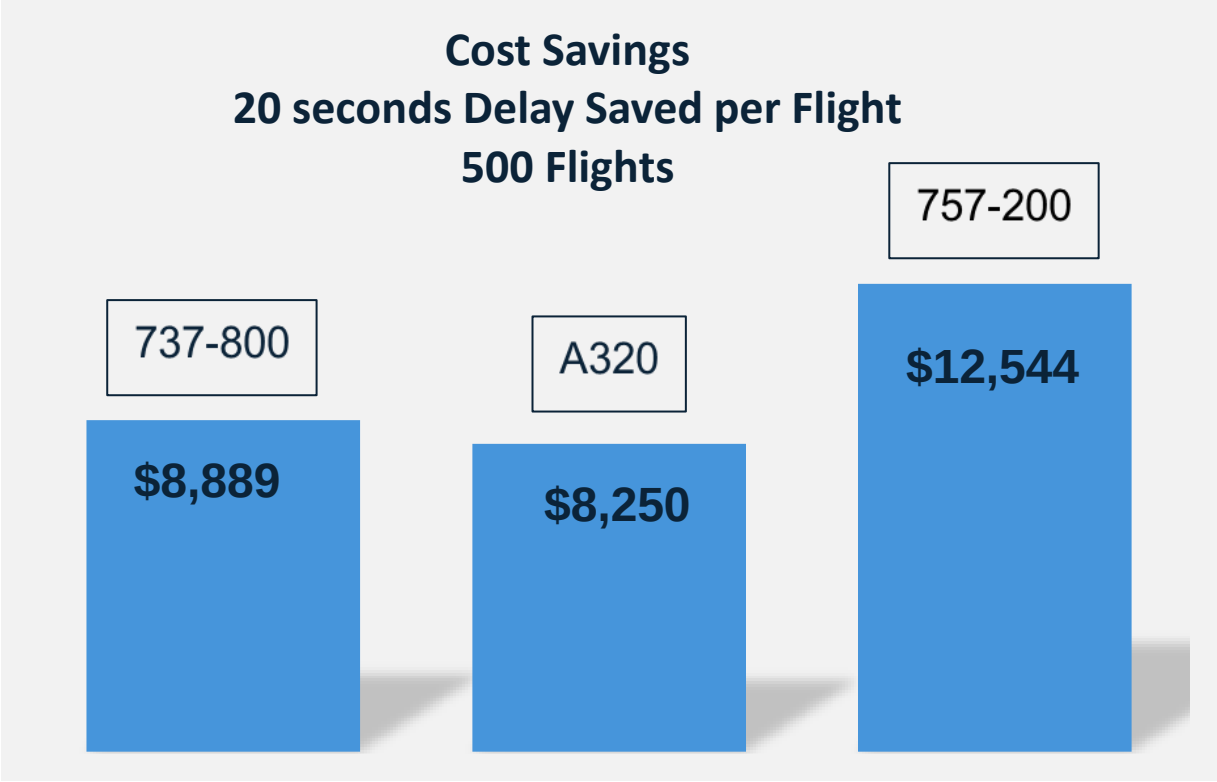
Terminal Metering Benefits

Terminal metering reduces low altitude flight times and distances

Evidence: Terminal metering is expected to provide efficient trajectories and less vectoring. Lab simulation found

- Reduced time in TRACON between **14 and 25 seconds per flight**
- Saved **7 and 15 gallons** of fuel per flight

Extension: If 20 seconds of delay were saved per flight for 500 flights, it would save thousands of dollars depending on aircraft type



Source: Direct Operating Cost (ADOC) airborne per minute: 2018 (Form41)

Source: TSAS Benefits and Equipage, MITRE Internal Huddle (HITL April 2013), Lowry, McGarry, Wynnyk, Oct. 27, 2017.

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ENVISIONED End-to-End ITBO

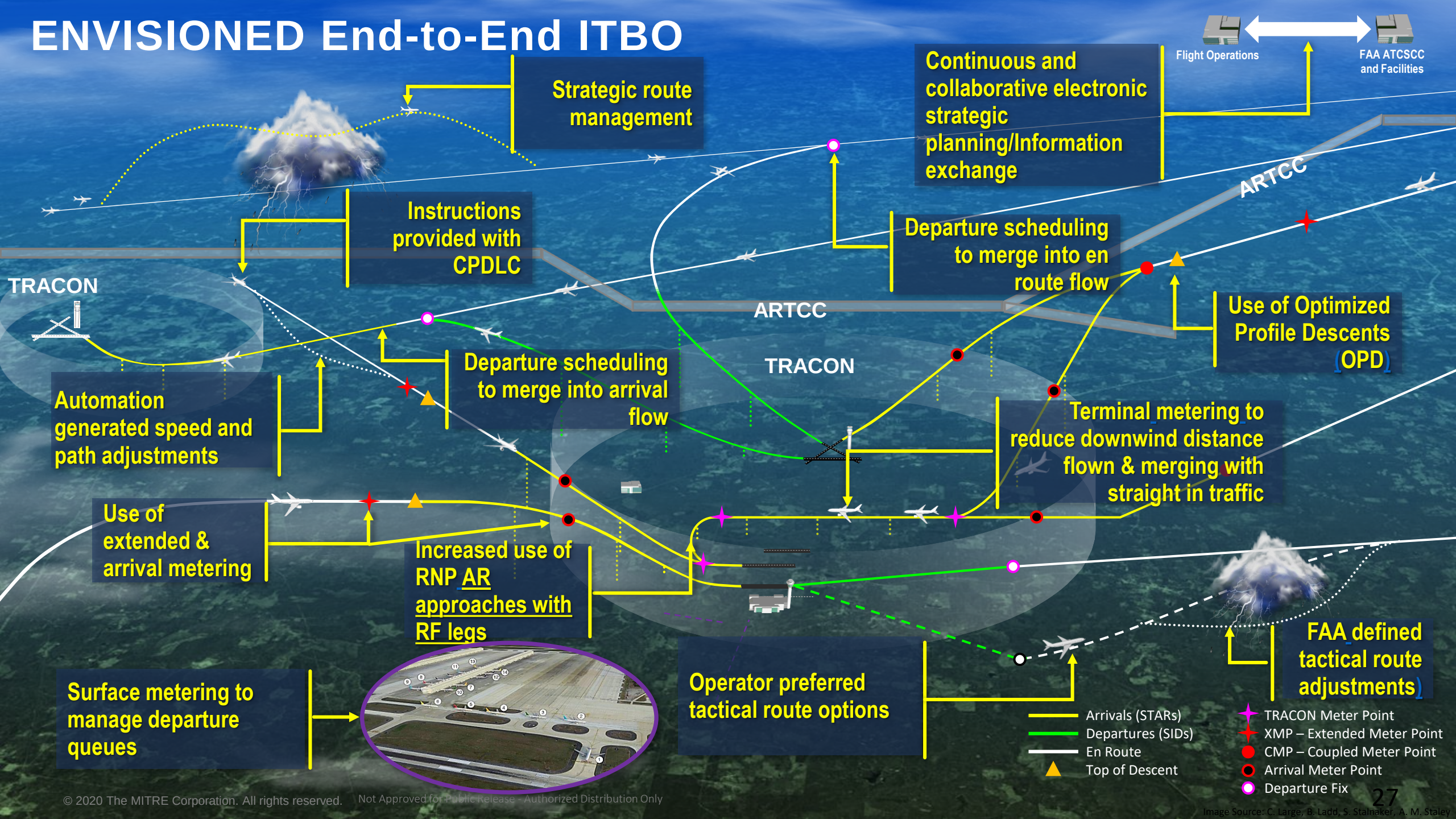

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Image Source: C. Large, B. Ladd, S. Stalnaker, A. M. Staley

Additional TBO Benefits for Flight Operators

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Key TBO Benefits and Expectations

Throughput → Flight Efficiency → Predictability → Flexibility

- Increased Throughput
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- Increased Route Flexibility
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- Greater Emphasis on Strategic Decisions
- Increased Daily Schedule Integrity
- Increased Efficiency in Constrained Environments
- Increased Flight Path Confidence
- Reduced End-to-End Variability

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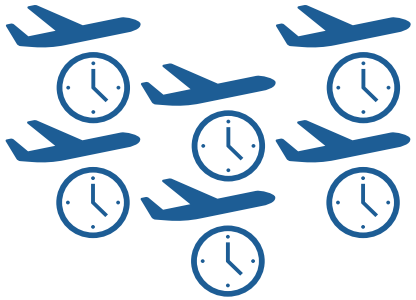
Improved Strategic Decisions

Increased information sharing and continuous strategic planning leads to better aircraft, gate, personnel, and equipment use and FAA resource allocation improving predictability, system efficiency, and customer experience

System efficiency



Improved customer experience

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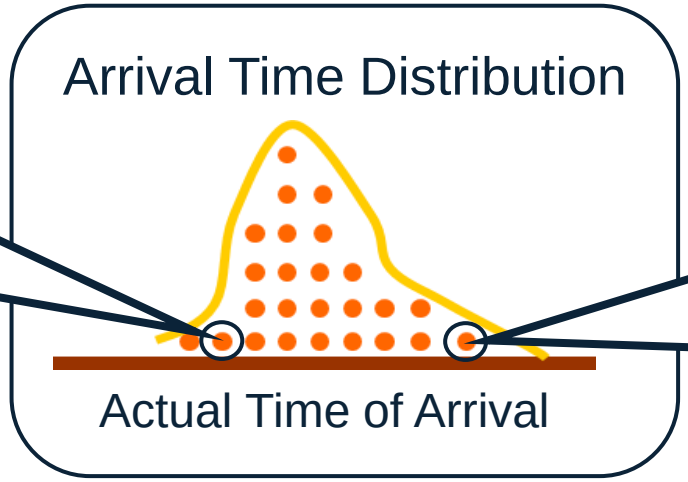
Improved Daily Schedule Integrity

Shared operator provided trajectory and FAA provided constraint information improves operating time integrity (ETD and ETA) and downstream decision-making.

"We knew the flight was going to arrive early, so we swapped gates and ground crews and were ready for it when it landed."



"There were a lot of weather and traffic constraints today. However, we knew exactly when the inbound flight was going to arrive. We swapped aircraft and crews to minimize the impact and advised all affected inbound and outbound passengers."

High confidence in knowledge that flights will depart and arrive as expected based on today's conditions

- Improved customer experience
- Minimize downstream crew and aircraft delay
- No waiting for ground crews or arrival gate

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Efficiency in Constrained Environments

TBO provides greater efficiencies in constrained environments through use of Time-Based Management (TBM), efficient descent procedures, and RNP-AR[2] approaches with RF[3] legs

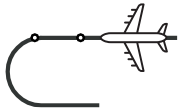
Time-Based Management

Redistributed delay to higher altitudes and on the ground

Efficient STARs

More efficient vertical profiles

RNP-AR Approaches with RF leg



More efficient arrival tracks

Increased Throughput

Decreased Flight Direct Operating Costs

[1] IAW with NSIP and FAA PBN NAS Strategy
[2] Required Navigation Performance Authorization Required
[3] Radial to Fix

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Flight Path Confidence

TBO enables aircraft dispatchers to consistently plan realistic (i.e., “predictable”) trajectories and reduce contingency fuel

Aircraft dispatchers add contingency fuel to flights to account for flight path uncertainty

- Wind and other weather conditions
- Anticipated traffic delays
- Any other conditions that may delay landing

It costs 3% additional burn per hour to carry contingency fuel

TBO will help reduce excess contingency fuel through flight path confidence by

- Enhancing information sharing
- Improving strategic planning
- Widespread use of time-based metering
- Use of Precise RNAV/RNP Routes
- Better mitigate constraining weather conditions
- Decrease traffic delays
- Reduce other conditions that delay landing

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Reduced Total End-to-End Time Variability

Airlines consider total end-to-end time mean and dispersion when setting schedules

Long-Term Predictability → More Efficient end-to-end strategic planning and scheduling

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Summary

- TBO will improve throughput, predictability, flight efficiency, and flexibility
- To increase opportunities to realize TBO benefits, Operators should consider…
  - Developing data exchange interfaces to provide estimated and actual surface movement times, runway preferences, gate/ramp status, flight substitution, and multiple route options.
  - Developing mechanisms to ingest and process SWIM data to support dispatcher and ATC coordinator decision-making.
  - Providing a filtering mechanism so dispatchers receive pertinent messages that exclude routine controller to pilot communications (e.g., frequency changes).
  - Training workforce on internally developed capabilities, as needed.
  - Informing their personnel about TBO capabilities and location specific implementations (e.g., arrival/surface metering and Terminal Sequencing and Spacing) as timelines are determined.
  - Equipping aircraft as described in the Minimum Capability List to achieve optimum NextGen Benefits.

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