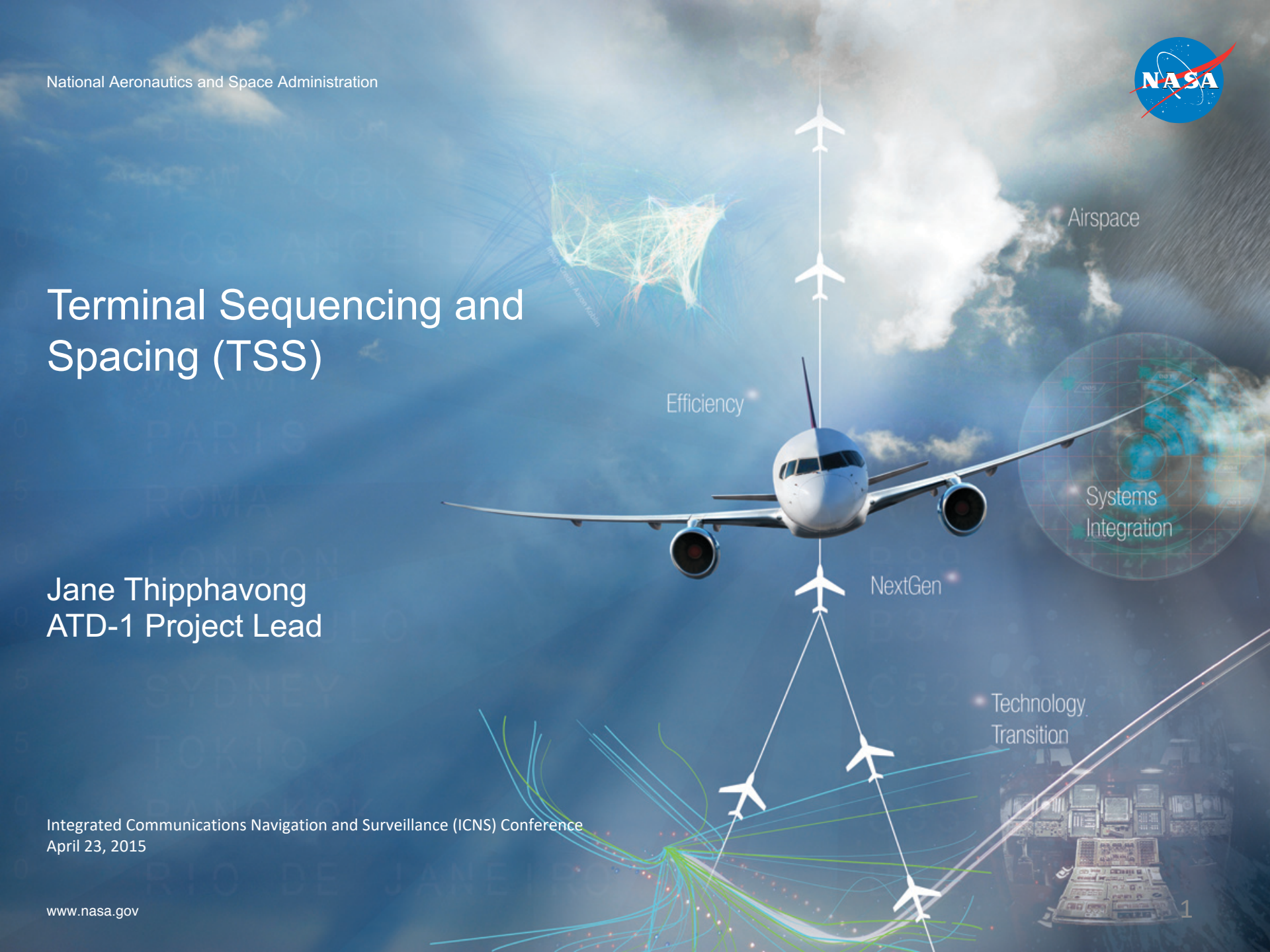
National Aeronautics and Space Administration



Terminal Sequencing and Spacing (TSS)

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Integrated Communications Navigation and Surveillance (ICNS) Conference
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- ATM Technology Demonstration #1 (ATD-1)
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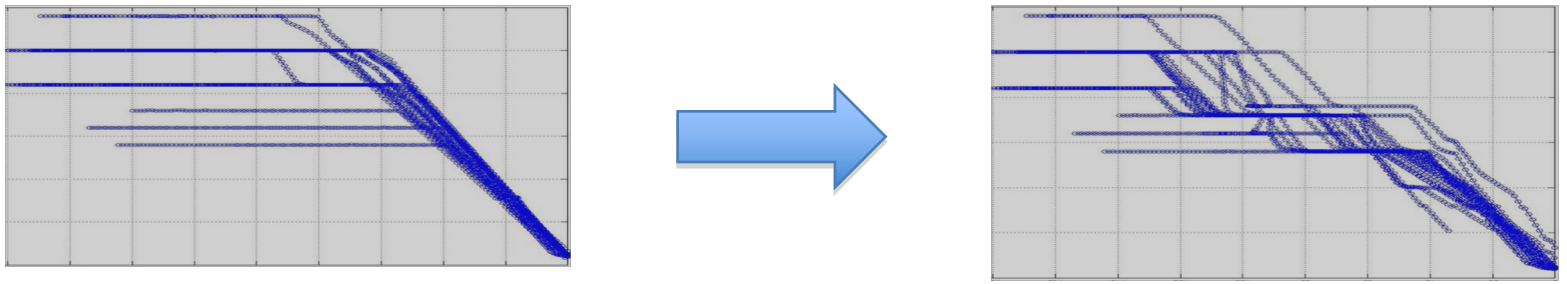
Today's National Airspace System

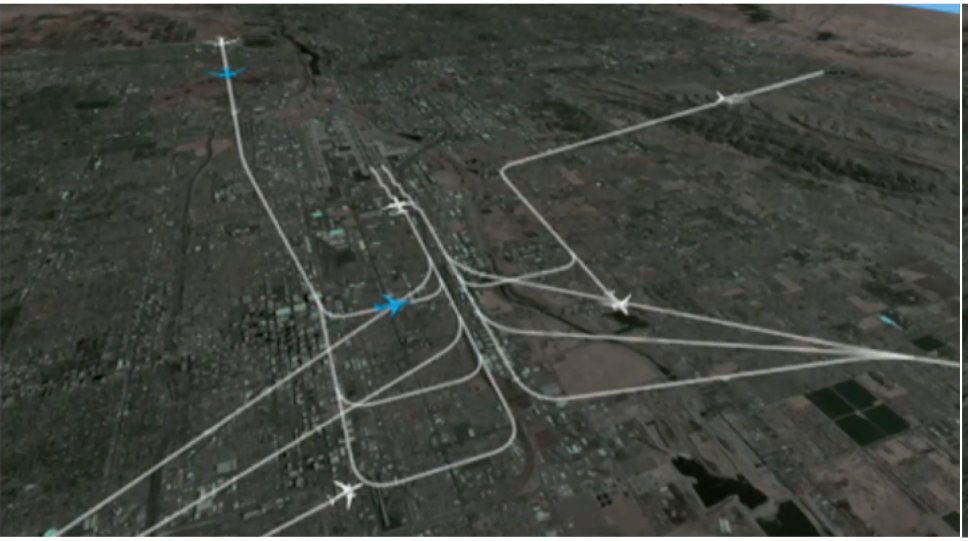
- Aircraft can execute efficient flight paths
  - Efficient profiles can be provided as long as they are not interrupted by other traffic (e.g., conflicts)

- Air traffic controller's role is to keep aircraft separated, maintain throughput, and provide efficient flight paths
  - All three objectives are difficult to meet when traffic demand is high



Objectives

- Demonstrate routine use of Performance-Based Navigation (PBN) during busy traffic periods



- Accelerate transfer of NASA scheduling and spacing technologies for inclusion in late mid-term NAS

https://www.youtube.com/watch?v=ngKazVQN4BI

ATM Technology Demonstration #1 (ATD-1): Integrated Arrival Solution

FIM Flight Deck Interval Management for Arrival Operations

CMS Controller-Managed Spacing in Terminal Airspace

TBFM Time-Based Flow Management (TBFM) **with Terminal Metering**

Terminal Sequencing and Spacing (TSS): Planned FAA Capabilities

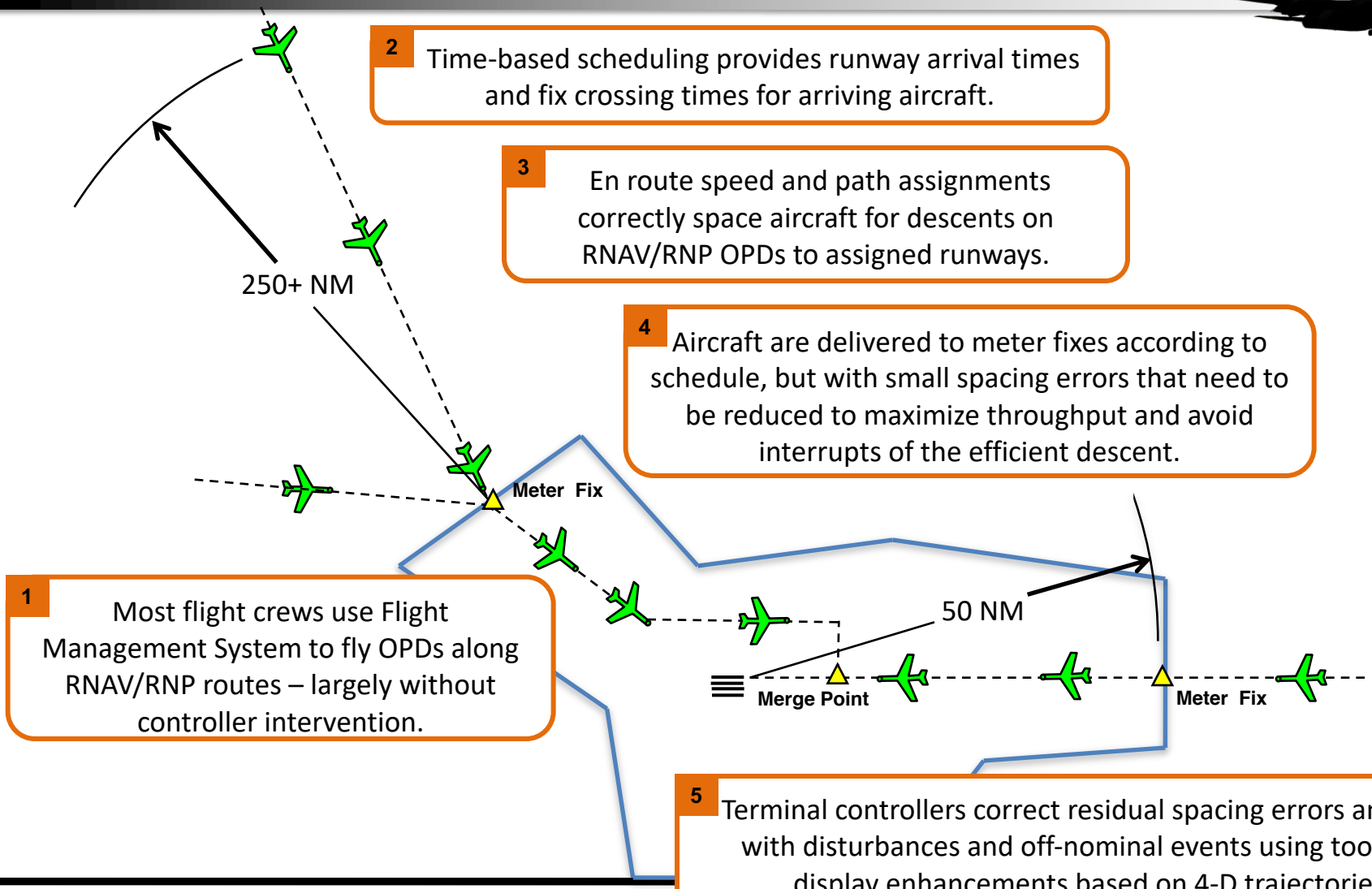
TSS

FIM Flight Deck Interval Management for Arrival Operations

CMS Controller-Managed Spacing in Terminal Airspace

TBFM Time-Based Flow Management (TBFM) **with Terminal Metering**

Operational Scenario



2 Time-based scheduling provides runway arrival times and fix crossing times for arriving aircraft.

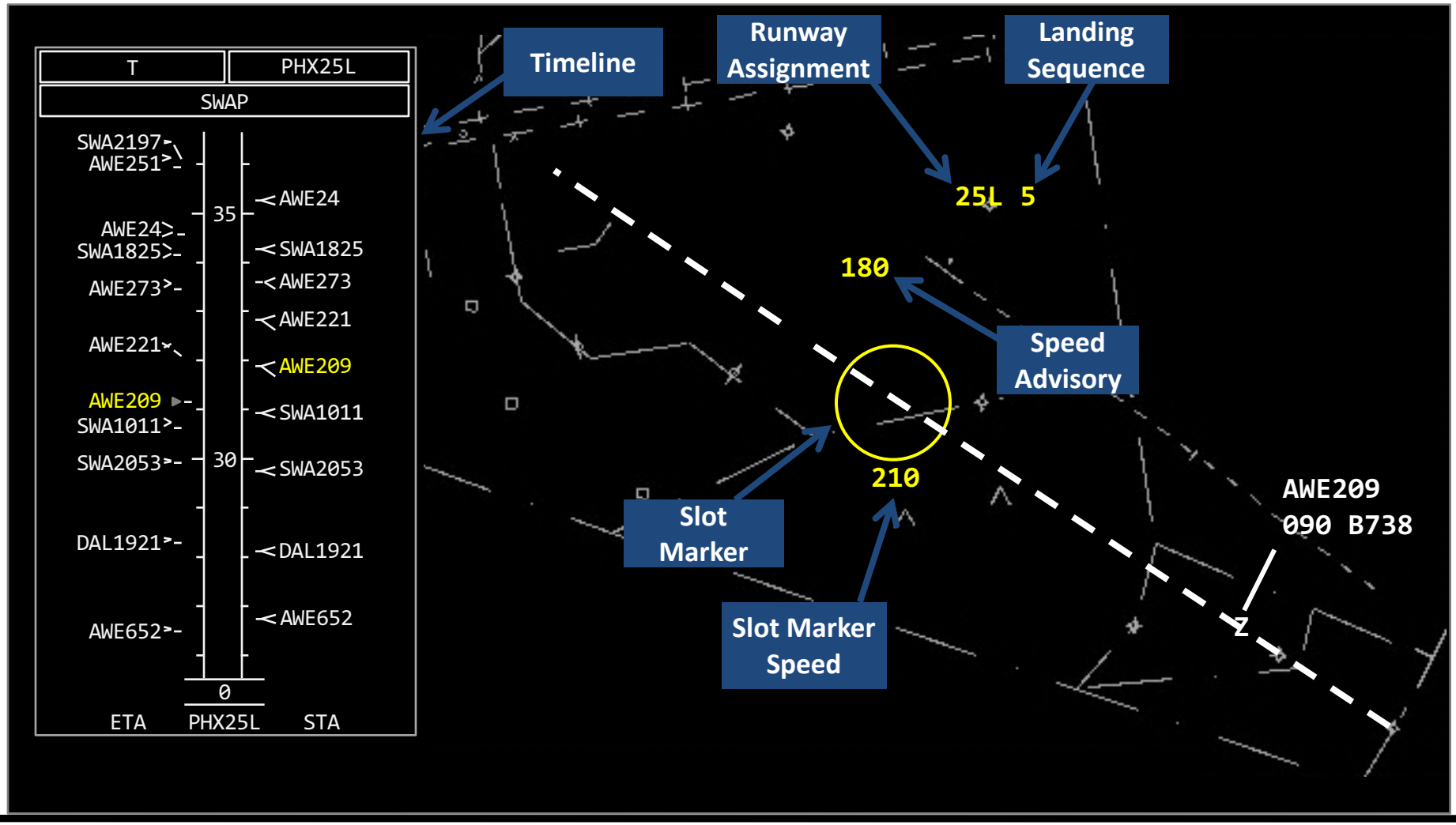
3 En route speed and path assignments correctly space aircraft for descents on RNAV/RNP OPDs to assigned runways.

4 Aircraft are delivered to meter fixes according to schedule, but with small spacing errors that need to be reduced to maximize throughput and avoid interrupts of the efficient descent.

1 Most flight crews use Flight Management System to fly OPDs along RNAV/RNP routes – largely without controller intervention.

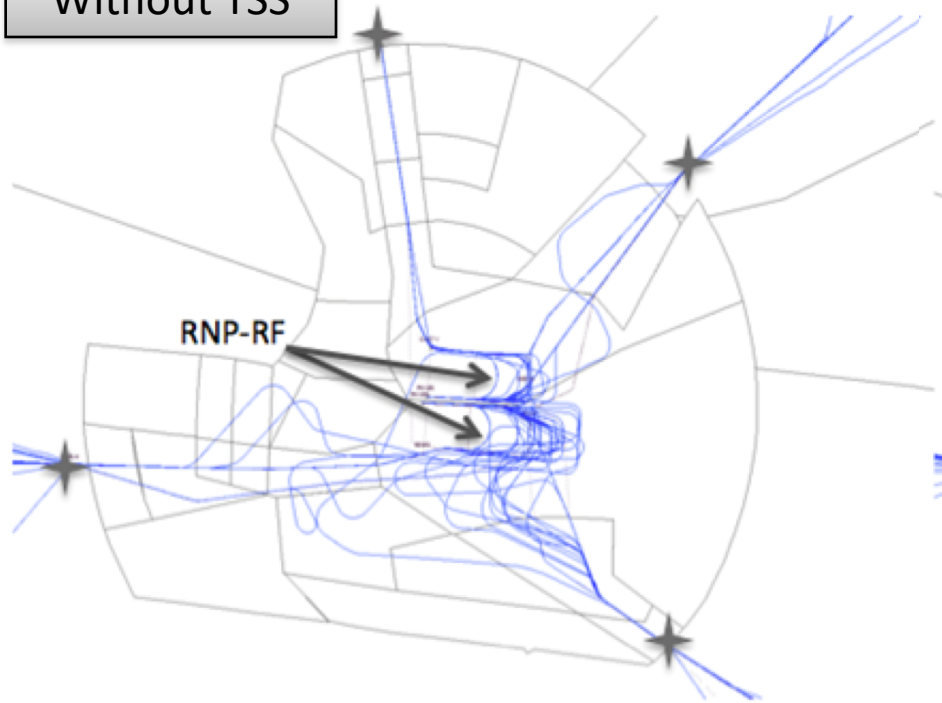
5 Terminal controllers correct residual spacing errors and cope with disturbances and off-nominal events using tools and display enhancements based on 4-D trajectories.

NASA TSS Prototype Capabilities

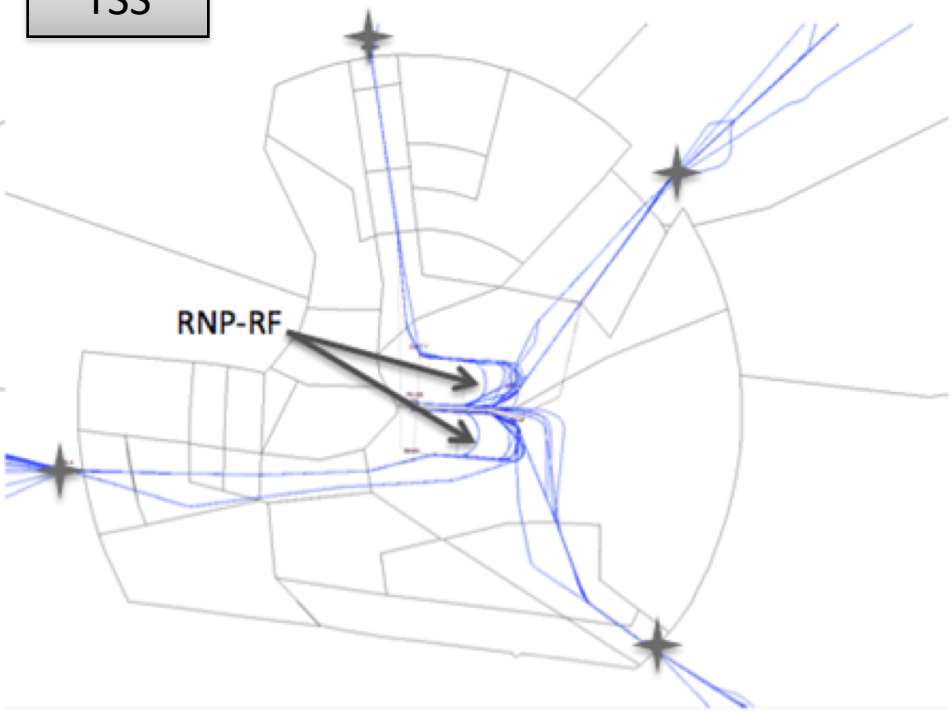


Results

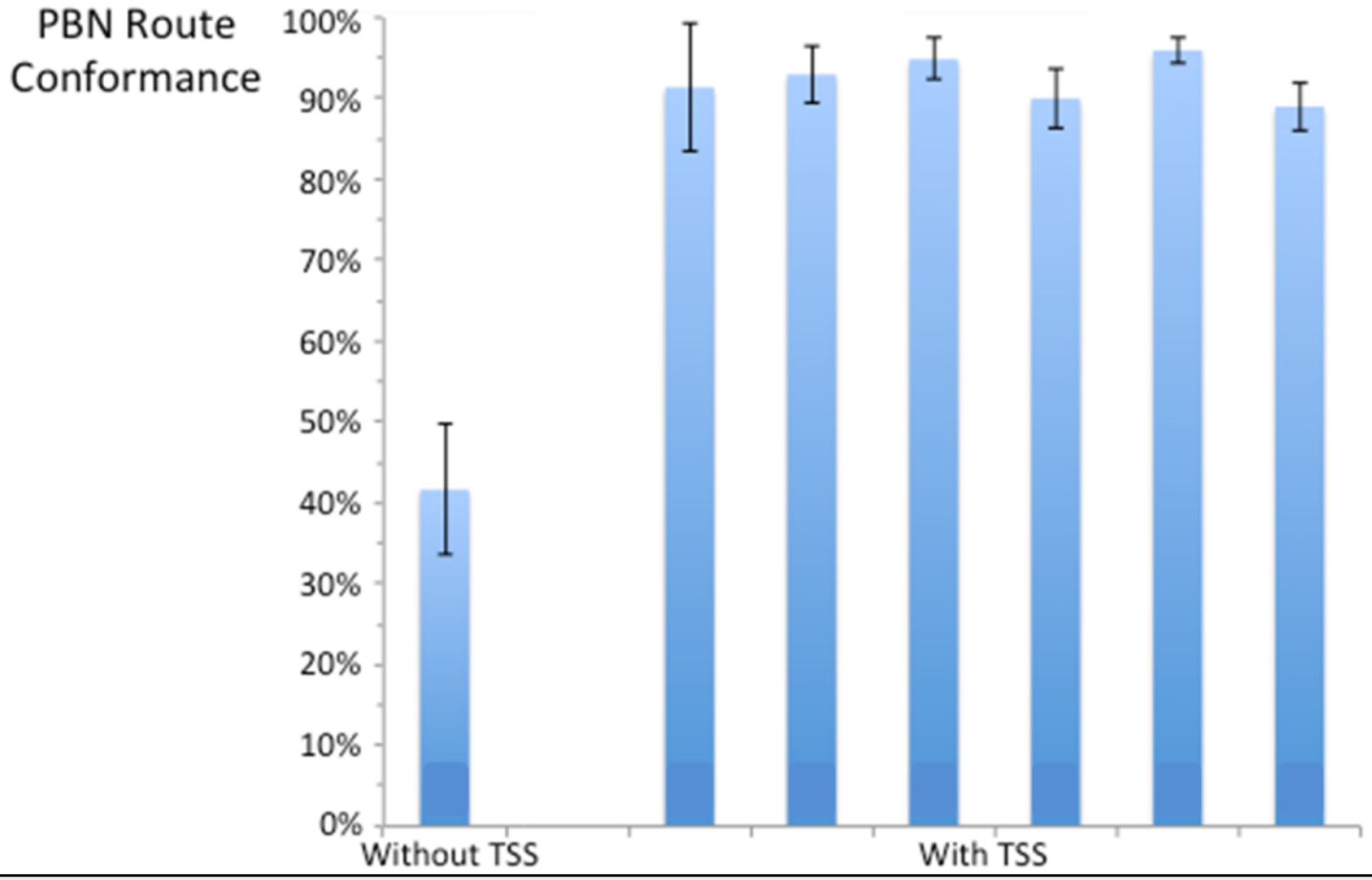
Without TSS



TSS



Results



Robinson, J., Thipphavong, J., Johnson, W., "Enabling Performance-Based Navigation Arrivals: Development and Simulation Testing of the Terminal Sequencing and Spacing System," 11th USA/Europe ATM R&D Seminar, Portugal, 23–26 June 2015.

TSS Technology Transfer Status

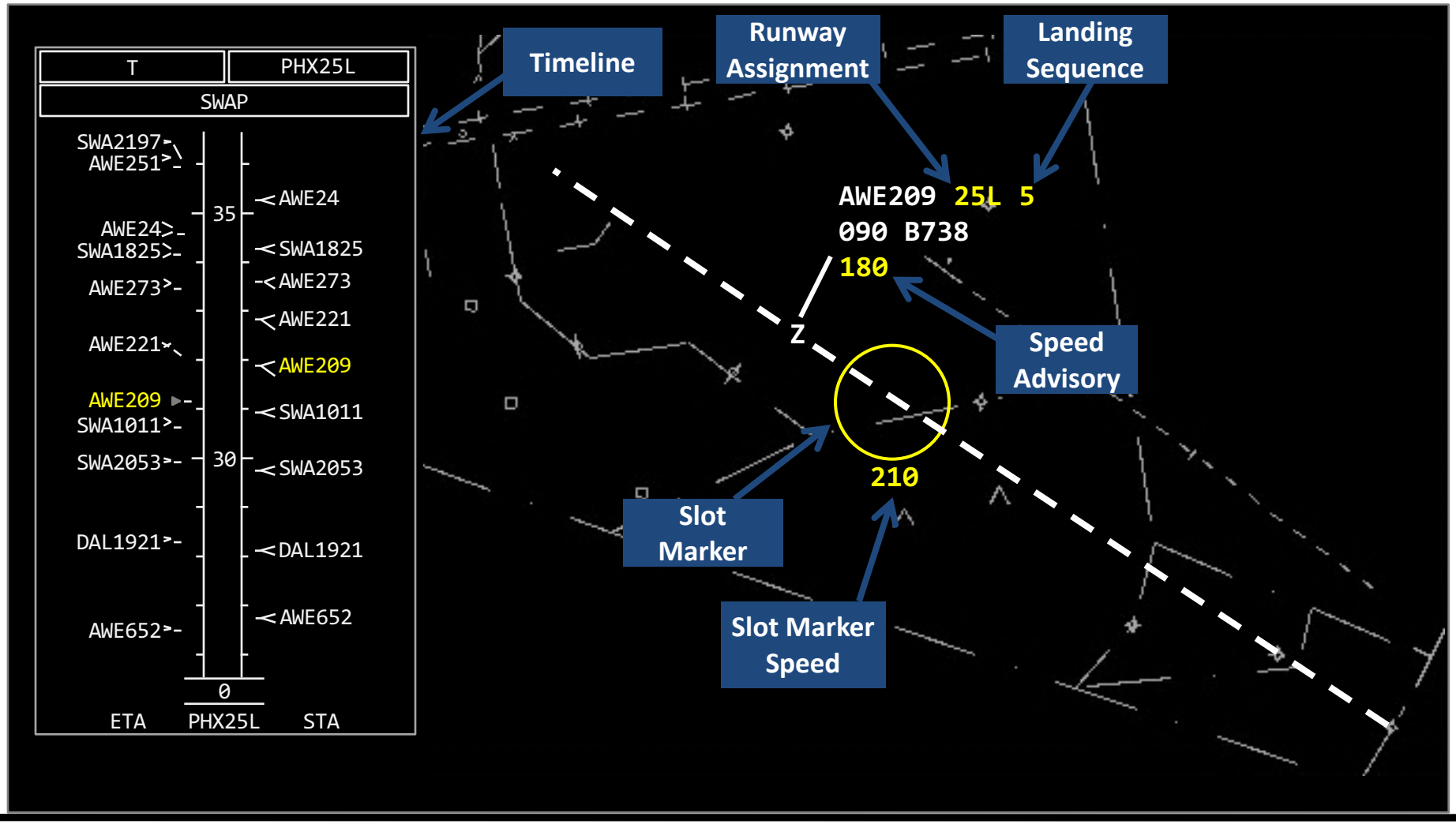
- ATD-1 transferred Terminal Sequencing and Spacing (TSS) technologies to the FAA, Fall 2013
- TSS enables routine use of underutilized advanced avionics and PBN procedures
  - Efficiency-related benefits to airlines operating at the five initial TSS sites estimated to be $20M/year
  - Additional benefit of improved throughput would be significantly larger
- FAA is planning for an initial capability in the NAS in 2018

Potential Data Communications Enhancements to TSS

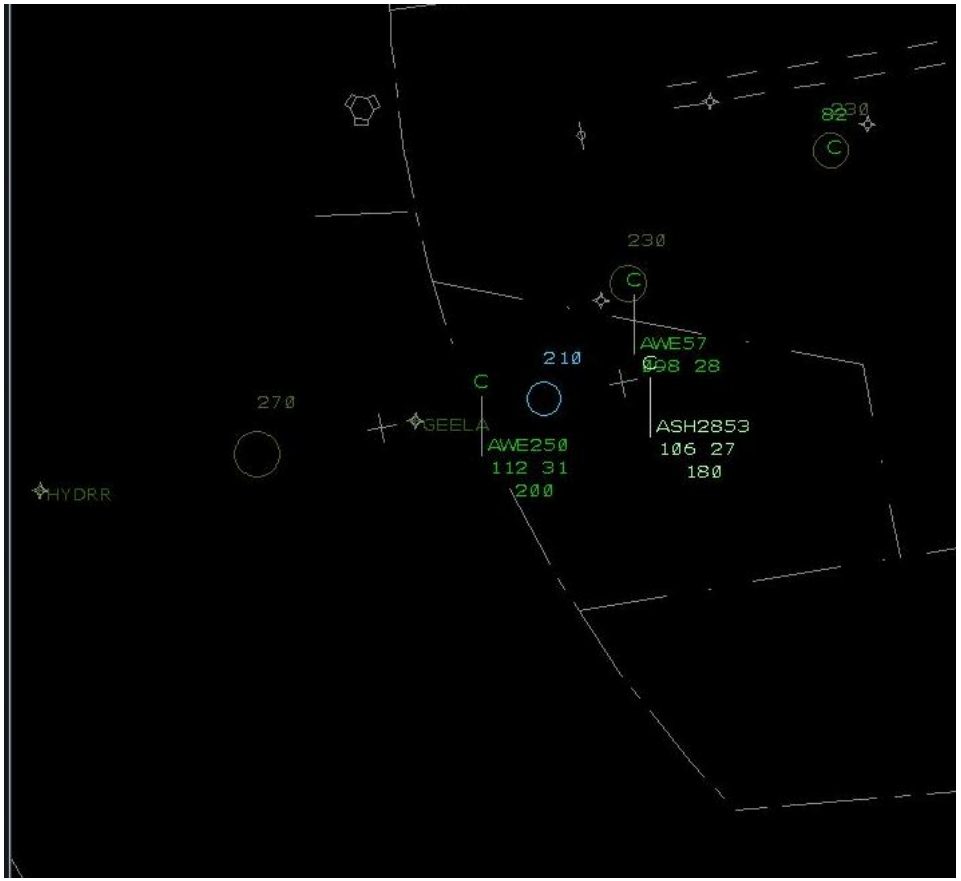
- Receive more accurate trajectory information
  - FMS-computed ETAs to waypoints on RNAV route
  - Updated route information
  - Aircraft state (e.g., current airspeed, winds, weight)

- Share TSS arrival plan information to flight deck
  - Assigned runway and associated approach transition
  - Communicate schedule information to facilitate conformance for equipped aircraft

NASA TSS Prototype Capabilities

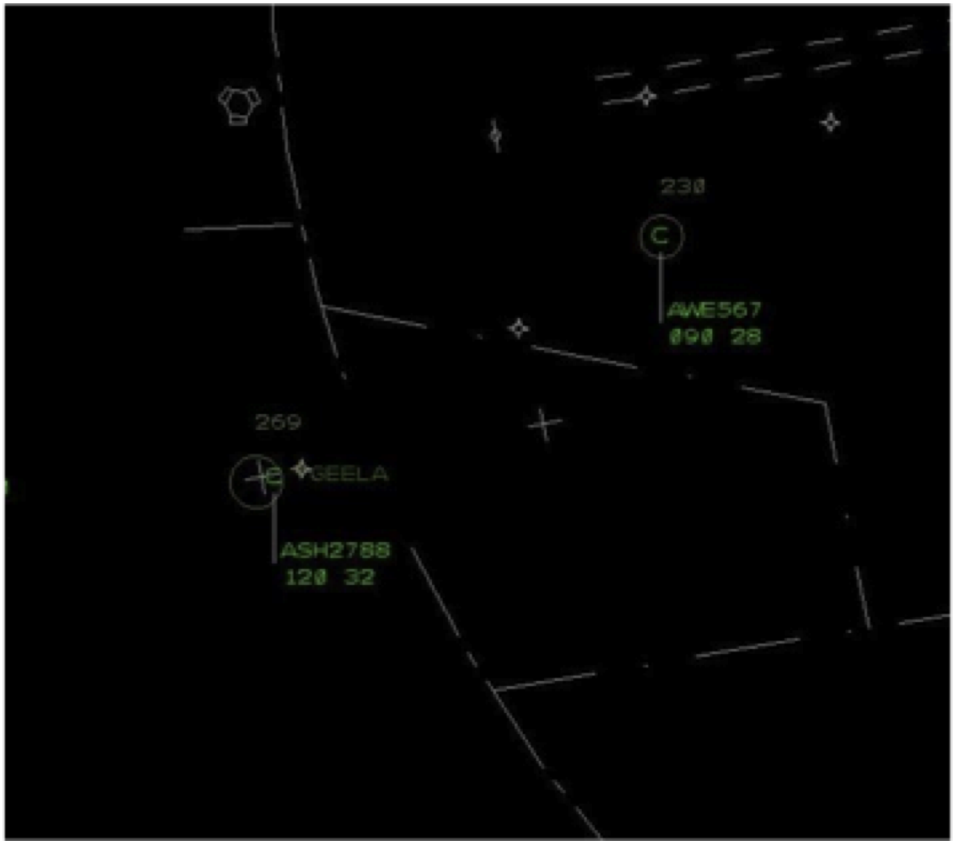


Shared View Between Controller and Pilot: Early Case



Aircraft is ahead of slot, and a speed advisory from the ground system to reduce to 180 KIAS is displayed to flight crew and controller. The nominal slot speed is 210 KIAS.

Shared View Between Controller and Pilot: On-Schedule Case



Aircraft is in desired position inside slot. The nominal slot speed is 269 KIAS.

Concluding Remarks

- TSS enables routine use of underutilized advanced avionics and PBN procedures
- NASA developed TSS as an operational prototype system
- ATD-1 transferred TSS technologies to the FAA, Fall 2013
- FAA is planning for an initial capability in the NAS in 2018
- Potential data communications enhancements to TSS
  - Receive more accurate trajectory information
  - Share TSS arrival plan information to the flight deck

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