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# **EVALUATION OF THE TERMINAL SEQUENCING AND SPACING SYSTEM FOR PERFORMANCE-BASED NAVIGATION ARRIVALS**

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# Air Traffic Management Technology Demonstration-1 (ATD-1) System

## *Integrated Arrival Management*

Flight Deck Interval Management (FIM)



Controller Managed Spacing (CMS) in Terminal Airspace



Traffic Management Advisor with Terminal Metering (TMA-TM)



# Update from Previous Work

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- NASA *Terminal Area Precision Scheduling and Spacing (TAPSS)* system referred by FAA as *Terminal Sequencing and Spacing (TSS)* system
- Best-equipped, Best-served concept
- Phoenix Sky Harbor International Airport, potential ATD-1 field test site
- Extensive data collection with currently active controllers



- Terminal Sequencing and Spacing (TSS) system
- Objectives
- Human-In-The-Loop (HITL) Simulations
- Results



# TSS System

## *Integrated Arrival Management*

Flight Deck Interval Management (FIM)



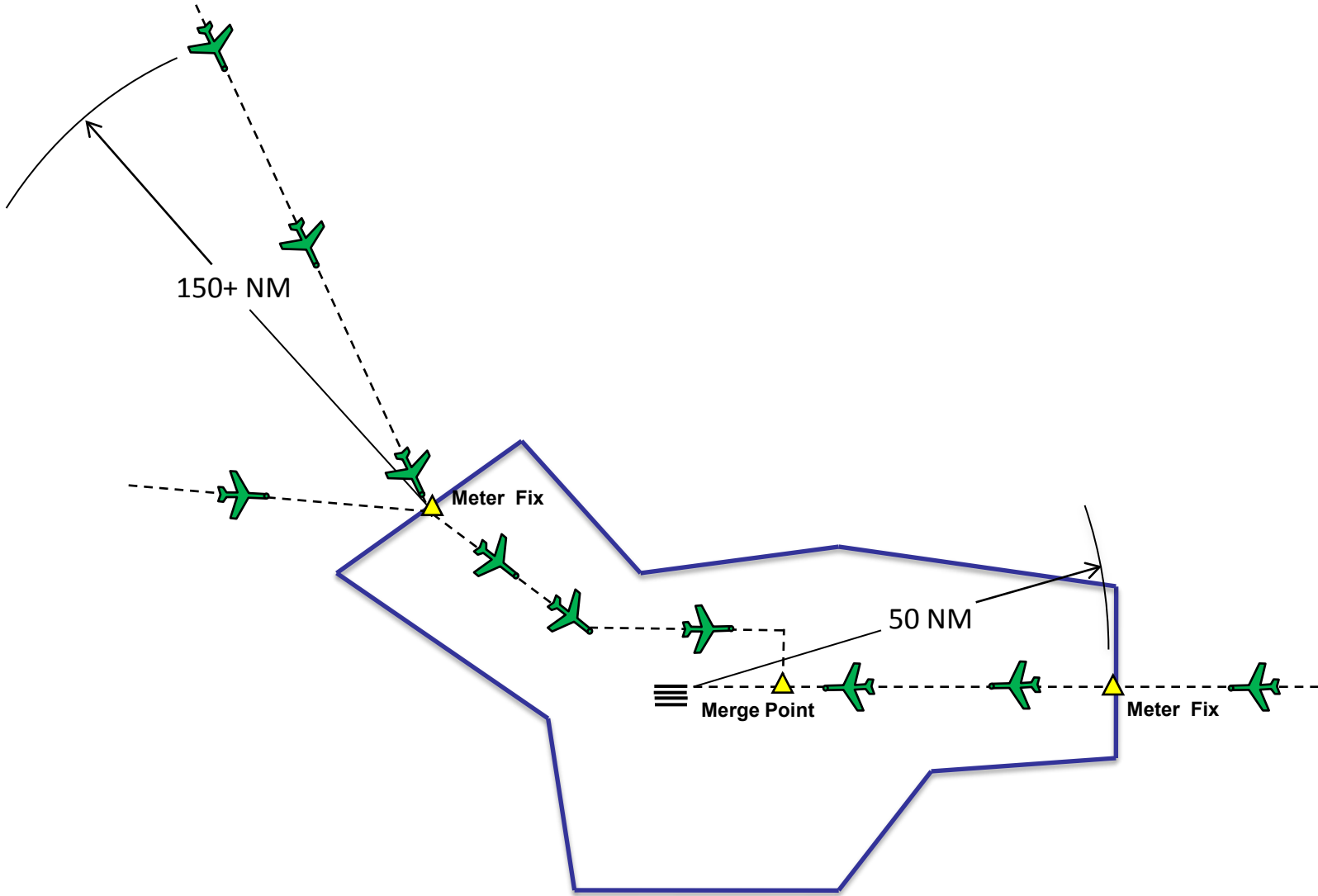
Controller Managed Spacing (CMS) in Terminal Airspace



Traffic Management Advisor with Terminal Metering (TMA-TM)



# TSS Operational Concept





# Performance-Based Navigation (PBN) and TSS <sup>7</sup>

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- PBN: a key enabling capability to increase capacity in the Next Generation Air Transportation System
- PBN defines aircraft performance requirements in terms of navigation specifications
  - Area Navigation (RNAV)
  - Required Navigation Performance (RNP)
- Over 90% of commercial jets are RNAV-equipped and less than half have RNP equipage
- TSS designed to support increased use of PBN operation
  - Increased throughput
  - Fuel efficient arrivals



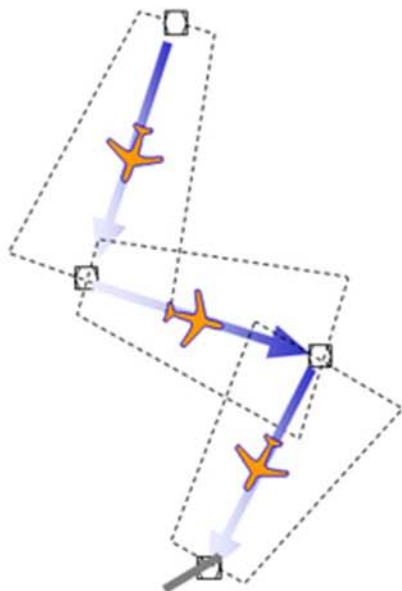
# Research Objectives

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Demonstrate that using TSS

- Enables PBN arrival procedures and Best-Equipped-Best-Served concept (BEBS) in a mixed equipage environment

*Classic*

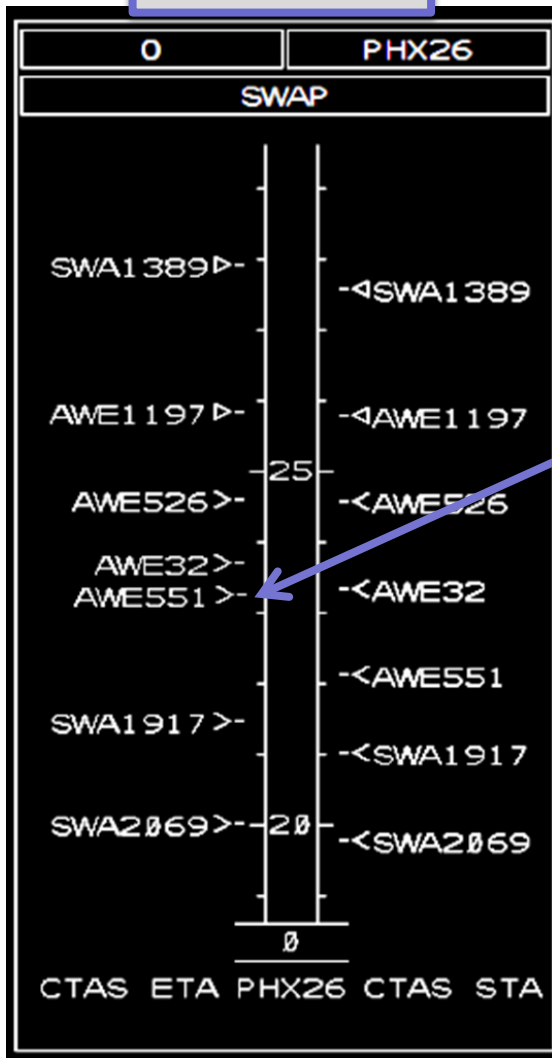






# Terminal Controller Advisory Tools

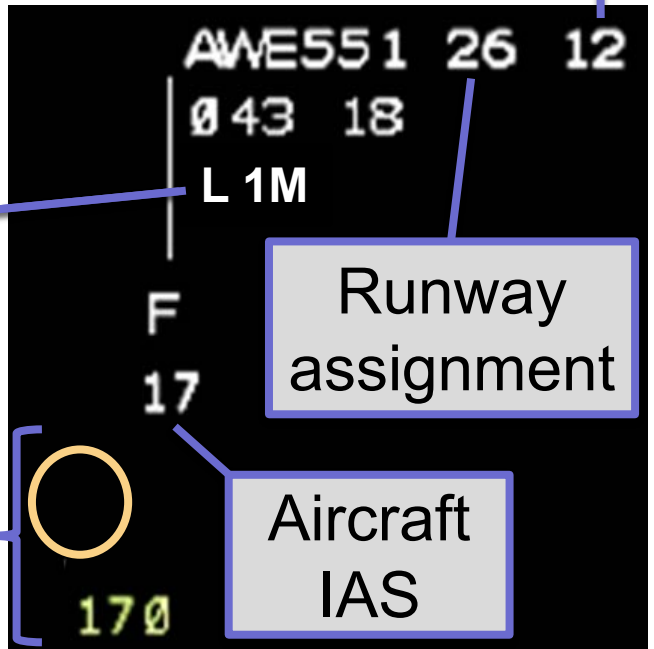
Timeline



Sequence number

E/L indicator

Slot marker and its IAS

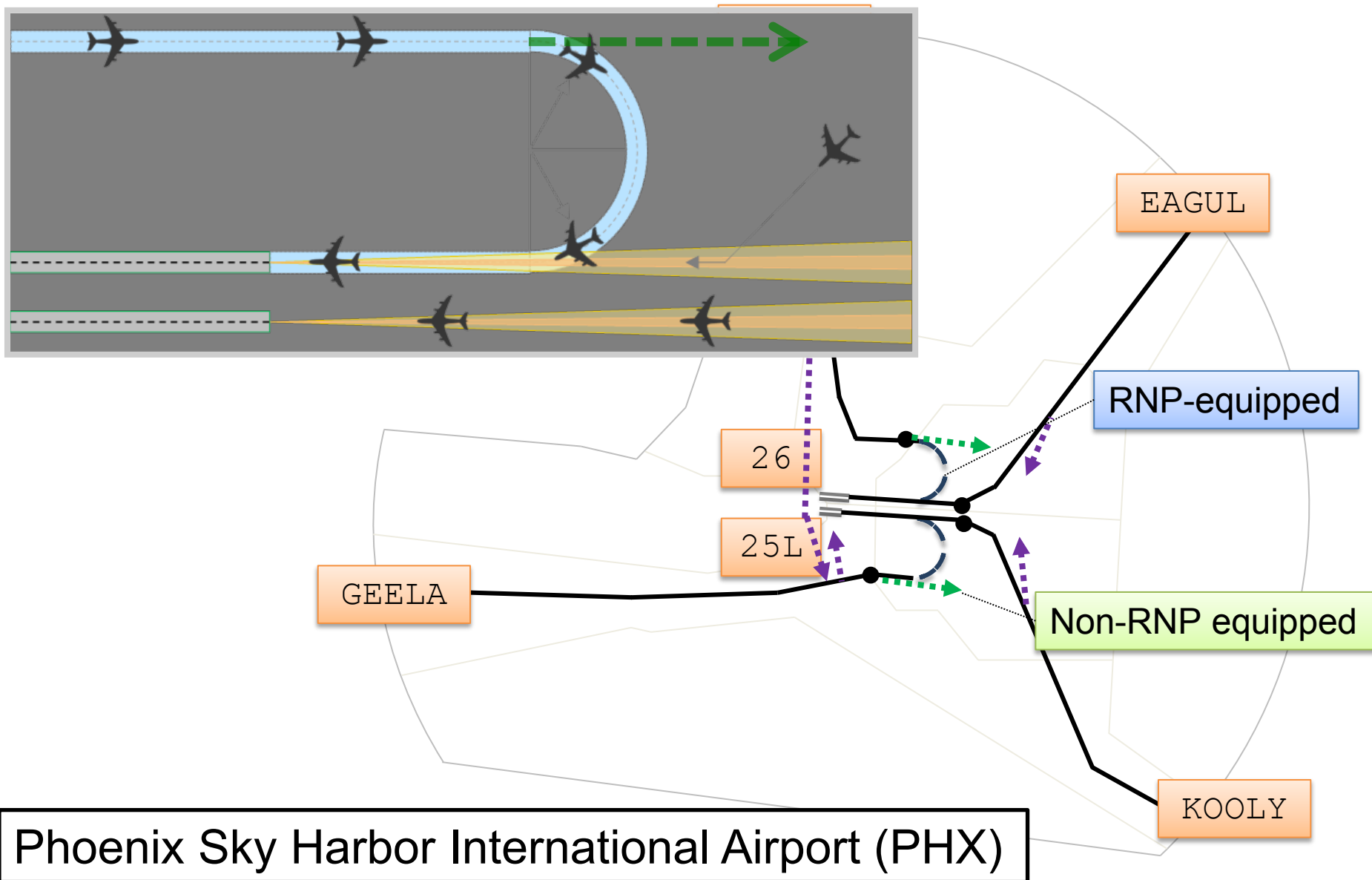


Runway assignment

Aircraft IAS



# Simulation Airspace





# HITL Simulation Method

- NASA Ames ATC simulation facility
- Two scenarios
  - B-1, B-2
  - 29-34% RNP-equipped
  - 5% Classic
- TMA-TM scheduler settings
  - Terminal delay 18 – 45 sec
  - Buffer 0.3 NM
- Controllers
  - 4 En route confederates, recently retired
  - 4 Terminal participants
    - 3 currently active, 1 recently retired
    - 4 recently retired

Scenario	Tool Condition	Winds	Runs
B-1	Baseline	Matched	3
		Mismatched	
	TSS	Matched	3
		Mismatched	
B-2	Baseline	Matched	3
		Mismatched	
	TSS	Matched	3
		Mismatched	



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# RESULTS



# Results: Throughput

**Baseline**

Peak throughput **93 ac/hr**

**13.7 NM**

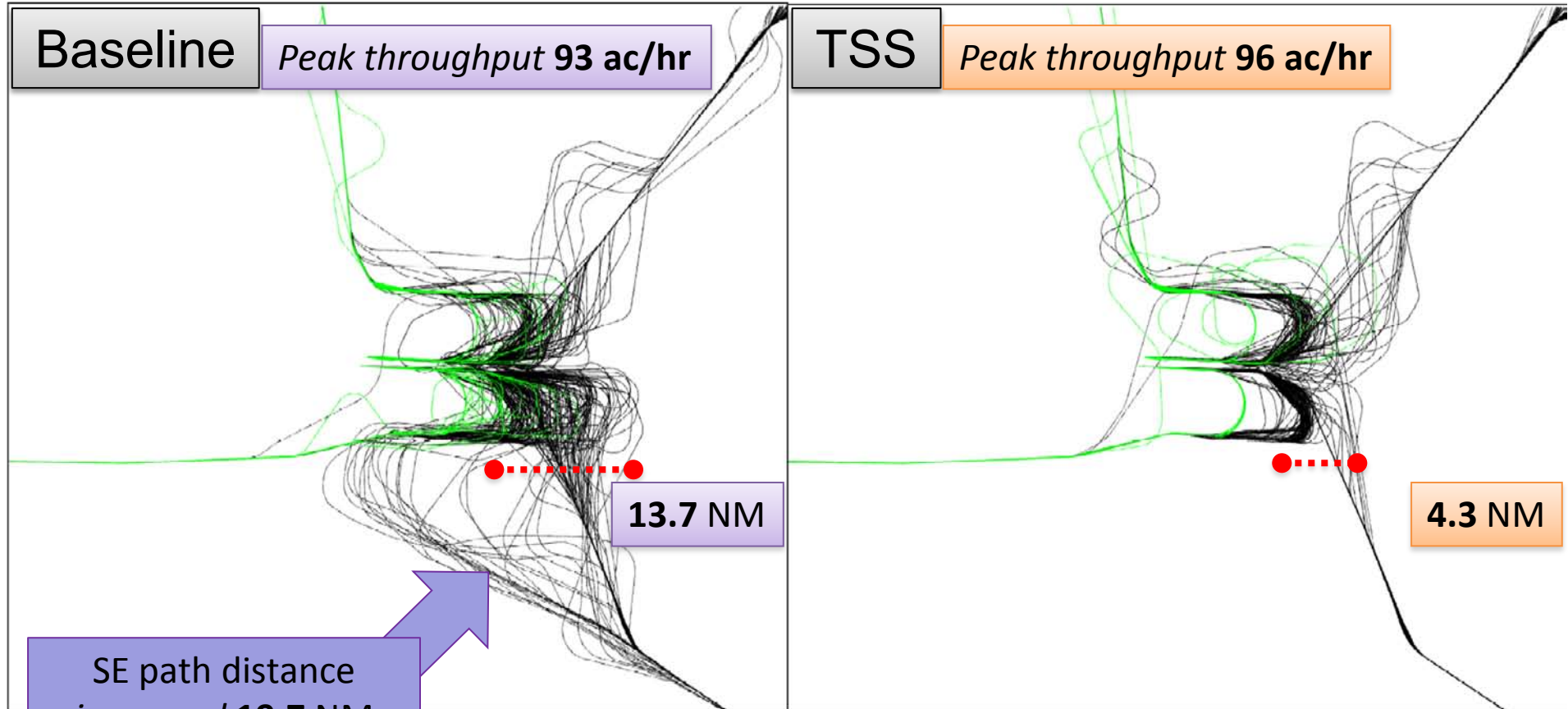
SE path distance  
increased **19.7 NM**  
For upwind traffic

**TSS**

Peak throughput **96 ac/hr**

**4.3 NM**

Throughput increased **3 ac/hr**  
Level segment time reduced **21%**



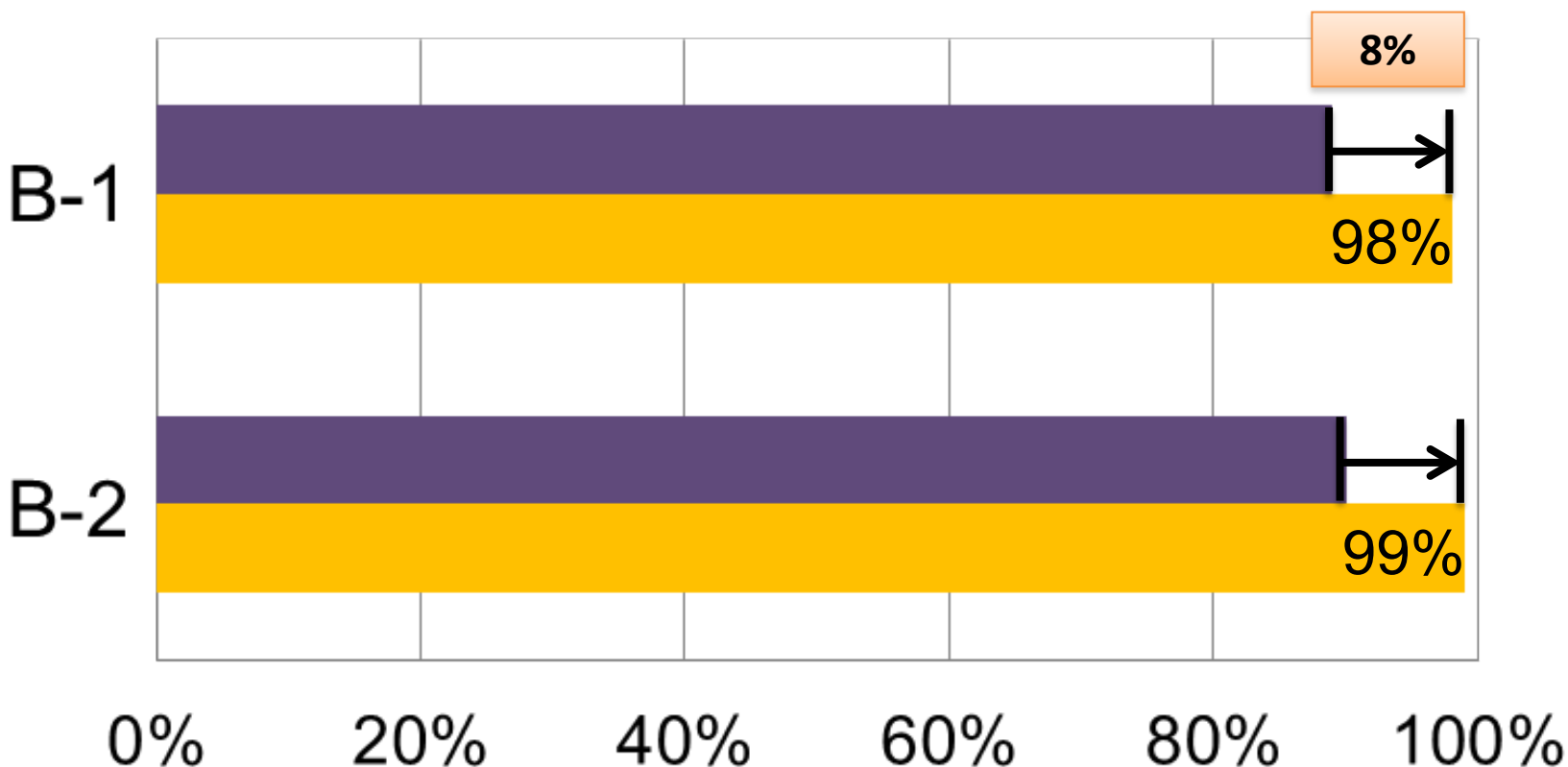


# Results: Percentage On-path RNP Approaches

Difference statistically significant at the  $p < 0.01$  level

Scenario

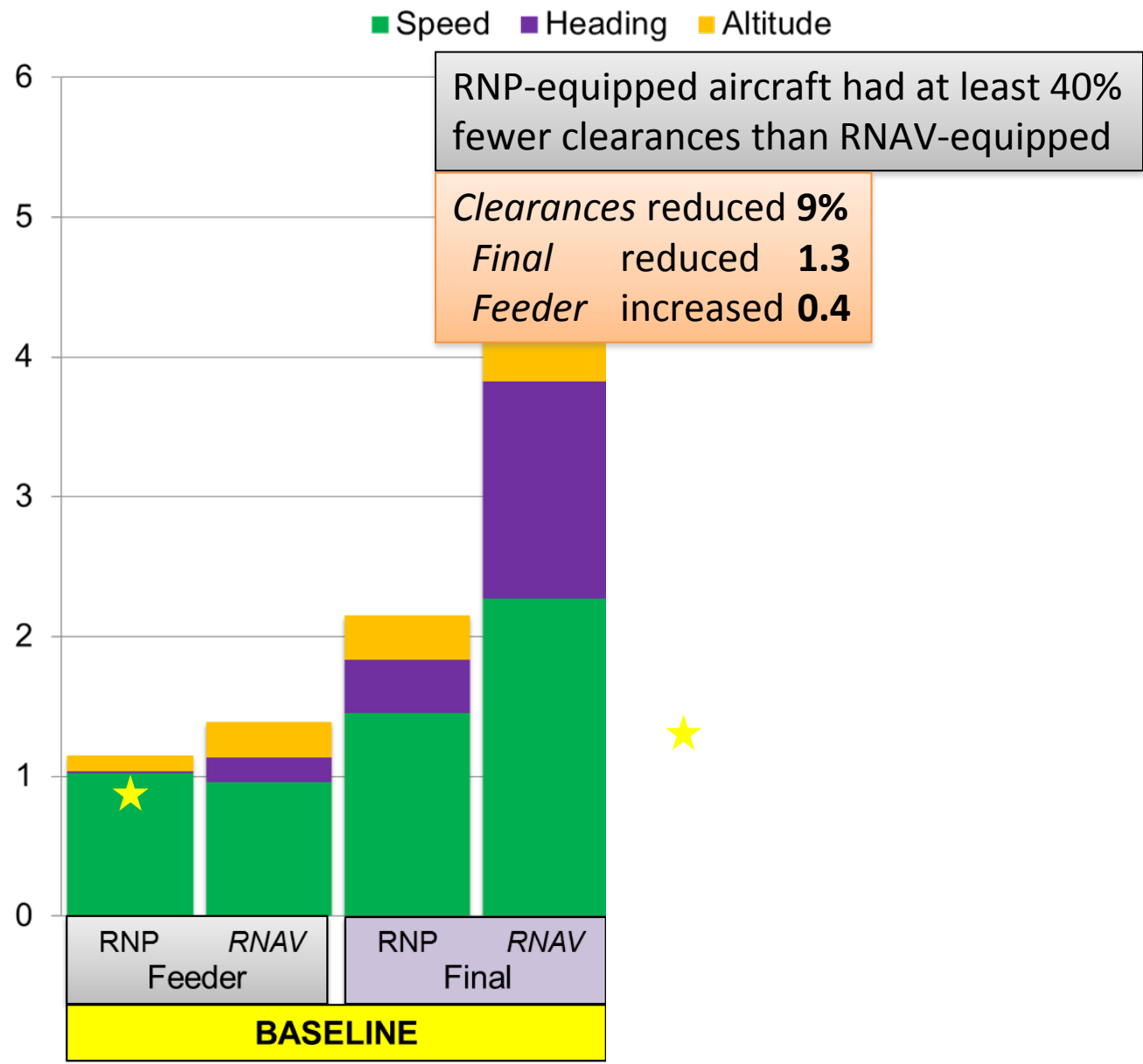
■ Baseline ■ TSS





# Results: Avg. Number of Controller Clearances

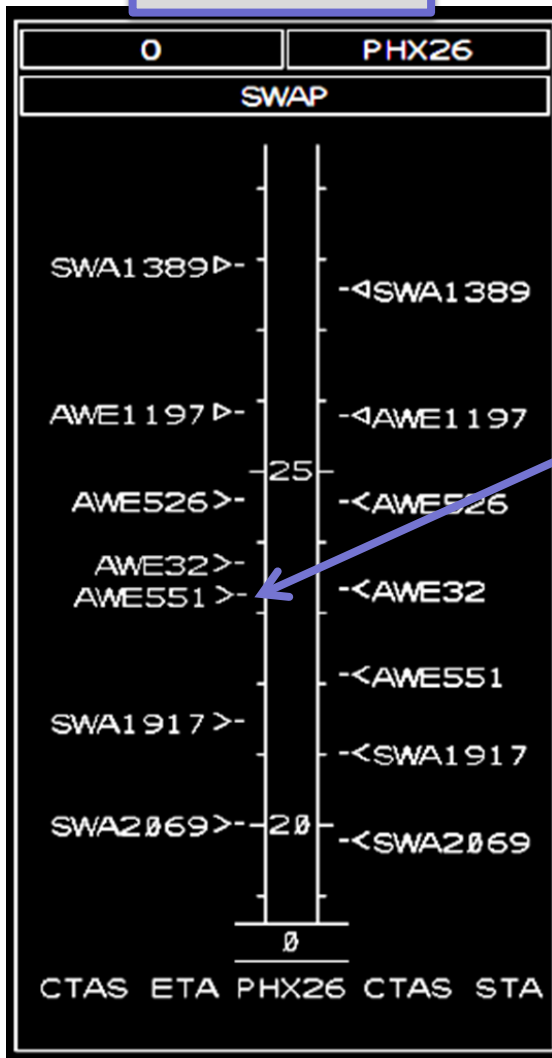
Average number of clearances per aircraft





# Terminal Controller Advisory Tools

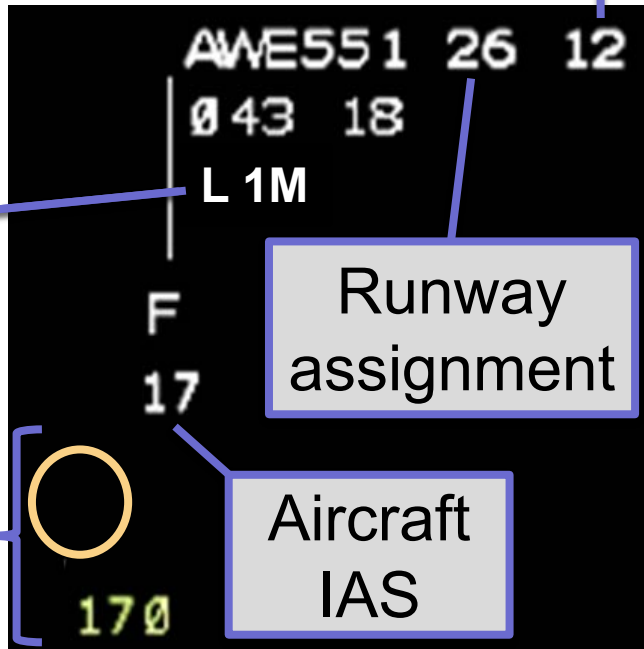
Timeline



Sequence number

E/L indicator

Slot marker and its IAS



Runway assignment

Aircraft IAS

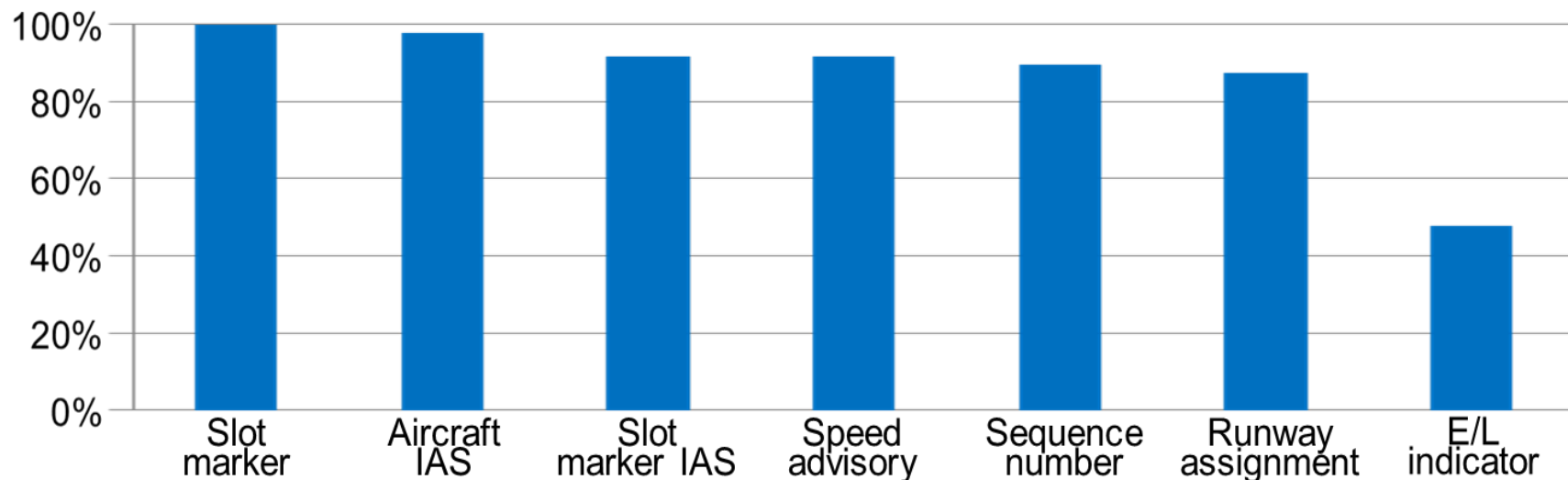




# Results: Tool Usage, Self-reported

N = 4 controller participants x 12 simulation runs

Percentage of controller responses

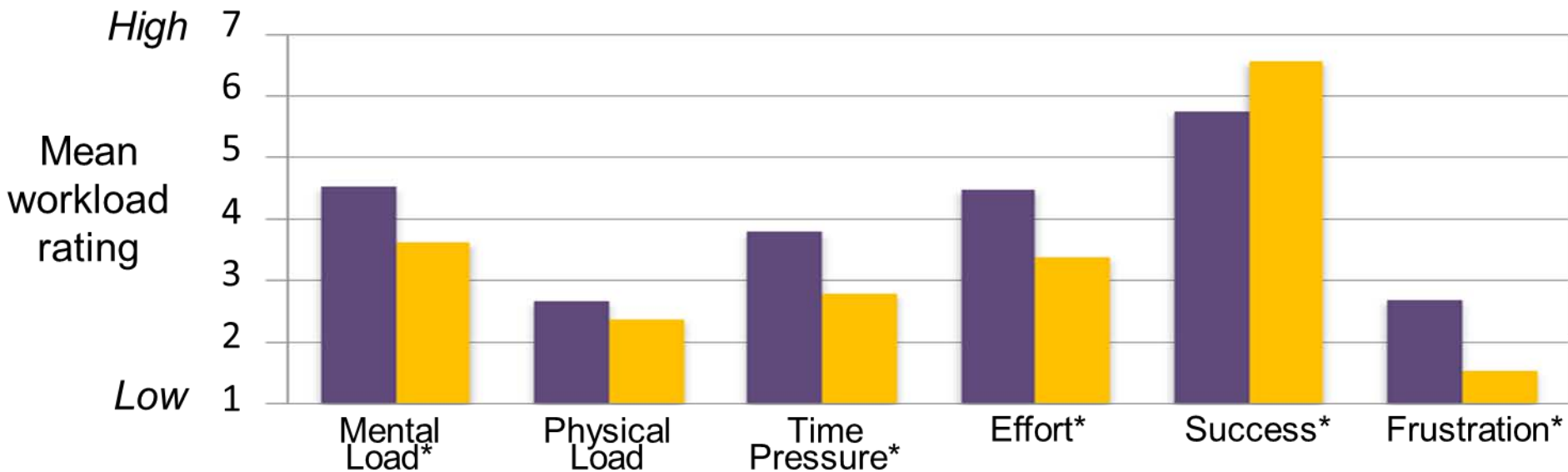




# Results: Controller Workload

\* Difference statistically significant at the  $p < 0.01$  level

■ Baseline ■ TSS





- TSS evaluated in HITL simulations using currently active controllers
- TSS enables PBN in a mixed equipage environment, and under saturated traffic demand levels
- TSS enables *Best-Equipped, Best-Served*:  
RNP vs RNAV equipage
- TSS tech transfer to FAA Fall 2013



# Thanks



Are you sure that they'll reach a common language soon?

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