National Aeronautics and Space Administration (NASA)

HIGHLY AUTOMATED ARRIVAL MANAGEMENT AND CONTROL SYSTEM SUITABLE FOR EARLY NEXTGEN

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Outline

- Background and Motivation
- Terminal Area Precision Scheduling and Spacing System
  - Missed-Approach Concept of Operations
  - Mixed capability Operations RNP and RNAV
- Simulation Evaluation Description
- Simulation Results
- Concluding Remarks

NASA's Airspace Systems Program Technical Challenges

Goal: Enable NextGen from gate to gate and reduce the total cost of air transportation operations

Thrust: Aircraft and ground-based technologies to simultaneously increase national airspace system throughput/capacity while increasing aircraft level efficiency

TC 1 – Develop tactical automation technologies for complex operational choke points including surface, arrival/departure, and dense terminal operations.

TC 2 – Establish the basis for air/ground functional allocation for separation assurance including safe, graceful degradation of performance in response to off-nominal conditions.

TC 3 – Develop strategic automation technologies that integrate probabilistic weather information and flow management capabilities.

TC 4 – Conduct seamless integration of automation applications in a resilient, end-to-end Trajectory-Based Operations system.

TC 5 – For the highest levels of NextGen performance and beyond, develop concepts, technologies, and system-wide evaluation and validation approaches.

Cross-Cutting Challenge: All densities and all weather conditions

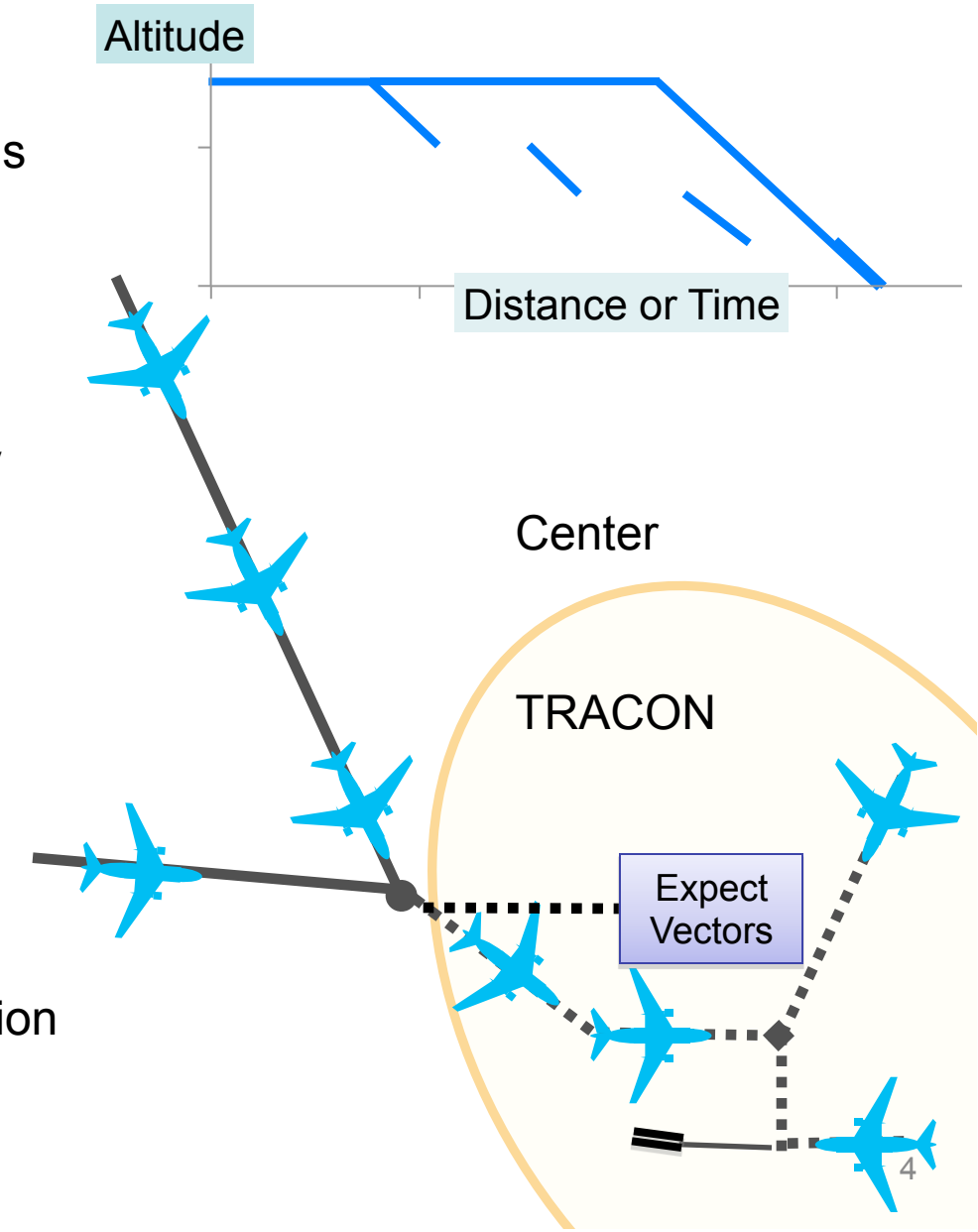
Current Barriers: Limitation of cognitive workload to develop optimal solutions on multiple dimensions (efficiency, throughput)

NASA ASP Discriminator: Develop air/ground concepts and technologies for developing precision schedule and delivery for gate-to-gate operations for NextGen and beyond.

ASP Strategy: Deliver/transfer products to enable changes in NAS – integrated and bite-sized

Background

- Flight Management Systems (FMS) enable fuel-efficient descent operations when routing is known from cruise to landing
- Most terminal areas lack published routing procedures with the necessary level of detail
- Once aircraft initiate fuel-efficient descent operations, interference compromises any fuel savings
- Routine interference with fuel-efficient aircraft procedures is the norm during moderate to heavy periods of congestion



NASA's Recent Terminal Area Research

- Developed the Terminal Area Precision Scheduling and Spacing (TAPSS) for NextGen operations supporting both throughput increases and fuel savings, eliminating vectoring in the terminal area
- Enhanced to support near-term mixed arrival procedures of NextGen performance-based navigation and current vectored operations
- Advanced terminal automation technologies evaluated over a wide number off-nominal terminal operations
  - Missed-approach operations required an extra coordination position to maintain automation integrity during saturated conditions
- Swenson, et. al. "*Design and Evaluation of the Terminal Area Precision Scheduling and Spacing System*" ATM2011 Seminar
- Thipphavong, et. al "*Efficiency Benefits Using the Terminal Area Precision Scheduling and Spacing System*" ATIO 2011
- Martin, et. al. "*Effects of Scheduling and Spacing Tools on Controller's Performance and Perceptions of their Workload*" 30 DASC 2011
- Mercer, et. al. "*Resolving Off-Nominal Situations in Scheduled-Based Terminal Area Operations: Results from a Human-In-The-Loop Simulation*" ICAS 2012

Motivation

- Missed-approaches offer the following challenges to arrival automation
  - Can happen at any time
  - Un-planned aircraft to the arrival plan
  - Urgency and immediate attention required

- Automation design considerations
  - Limit the effect on the schedule within the TRACON
  - Maintain the reduced vectoring on final provided by the TAPSS
  - Not require extra coordinating position

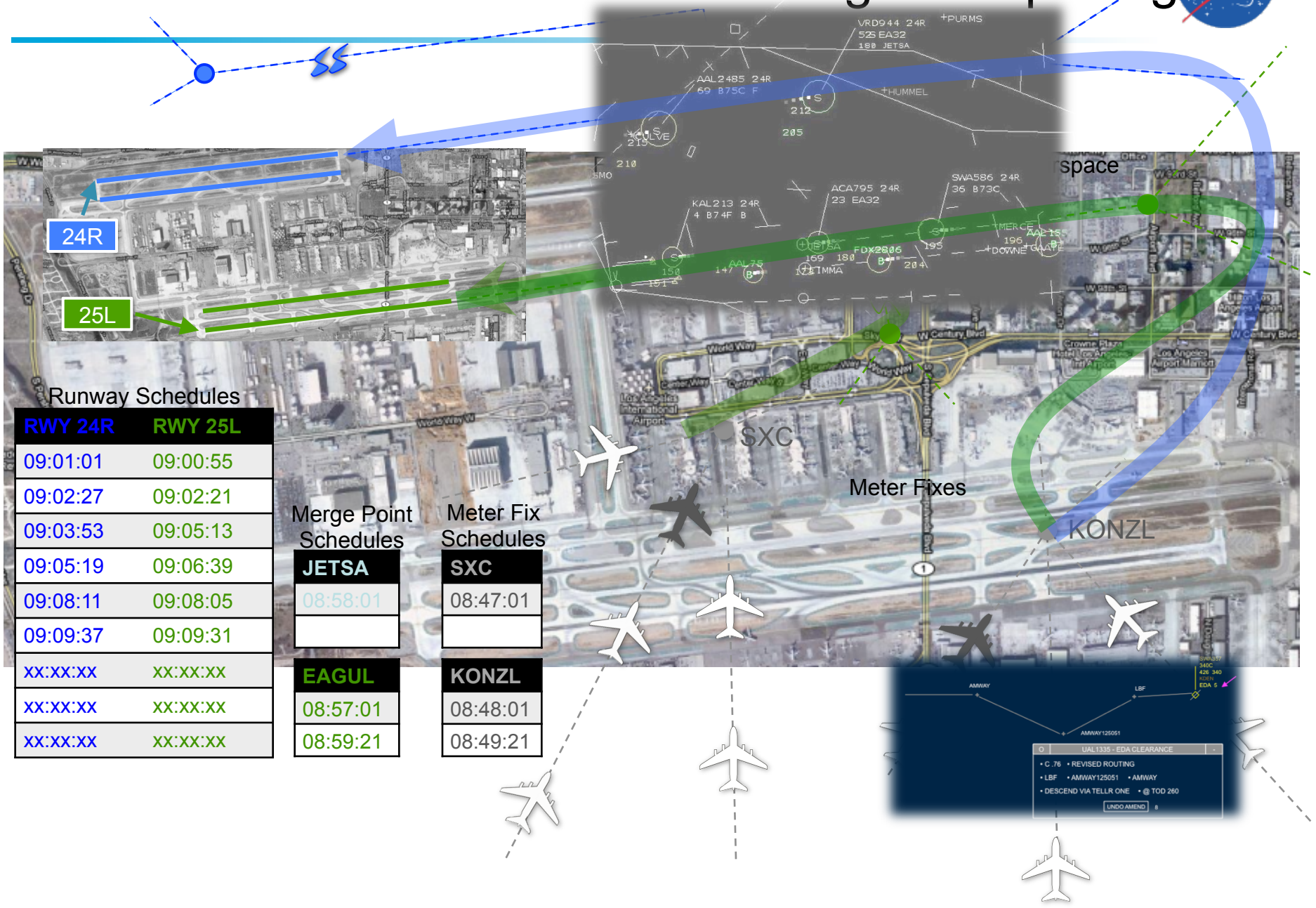
Objective

Enhance the TAPSS system for off-nominal operations

Evaluate the system performance of the enhanced automation

Evaluate the efficacy of using the TAPSS system in a mixed aircraft capability environment

Terminal Area Precision Scheduling and Spacing



Runway Schedules

RWY 24R	RWY 25L
09:01:01	09:00:55
09:02:27	09:02:21
09:03:53	09:05:13
09:05:19	09:06:39
09:08:11	09:08:05
09:09:37	09:09:31
xx:xx:xx	xx:xx:xx
xx:xx:xx	xx:xx:xx
xx:xx:xx	xx:xx:xx

Merge Point Schedules

JETSA
08:58:01

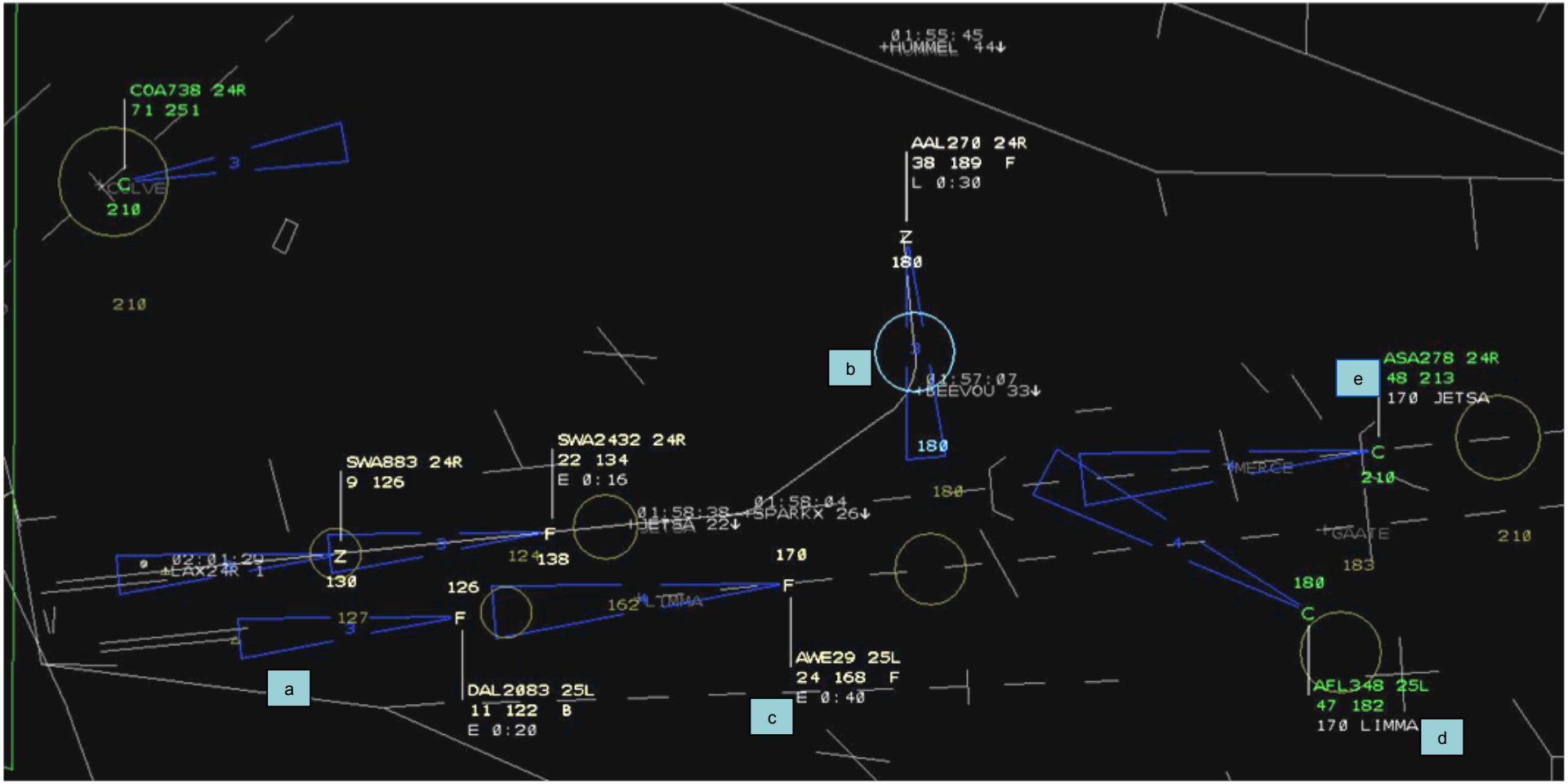
EAGUL
08:57:01
08:59:21

Meter Fix Schedules

SXC
08:47:01

KONZL
08:48:01
08:49:21

TAPSS Controller Tools



a. Spacing cones
b. Slot marker
c. Early/late indicator
d. Fix
e. Aircraft

Missed-approach procedures

- Manual or current operations
  - Fly runway heading and climb to 2000 ft
  - Turn 15 deg and head to missed-approach fix
  - Contact ATC for further instructions

- Automation based operations
  - Fly runway heading and climb to 2000 ft
  - Intercept and fly missed-approach route
  - Contact ATC for further instructions

Concept of Operations for Missed Approaches

Automated Missed Approach

Pilot flies initial missed-approach procedure

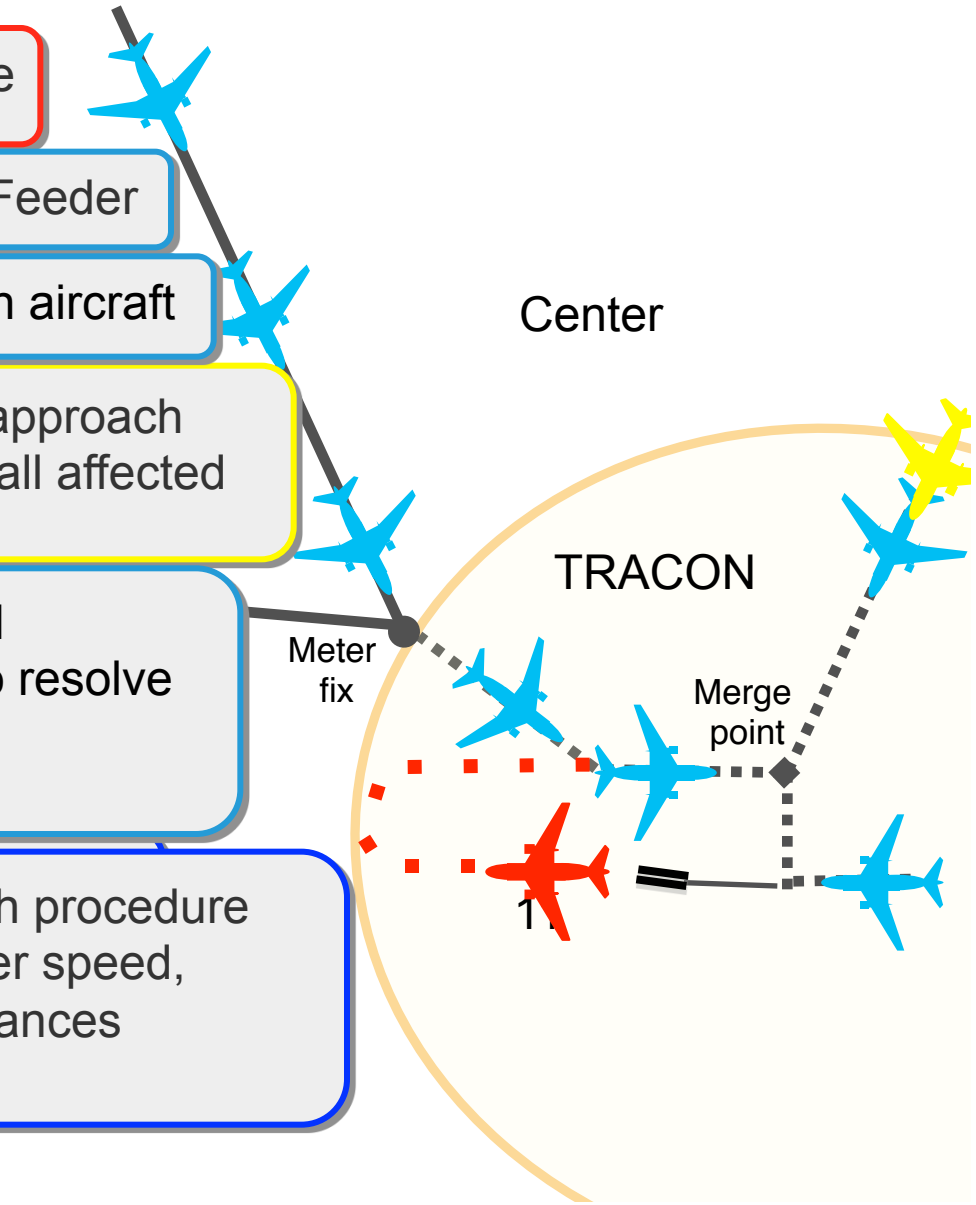
Tower controller transfers control back to Feeder

Feeder controller enters missed-approach aircraft

TAPSS re-schedules using the missed-approach runway time estimate and pushes back all affected runway and merge-point schedules

Feeder and final controllers use speed advisories and improvised vectoring to resolve extra aircraft's schedule

Flight crews enter missed-approach procedure into automation and follow controller speed, vector and/or ascent/descent clearances



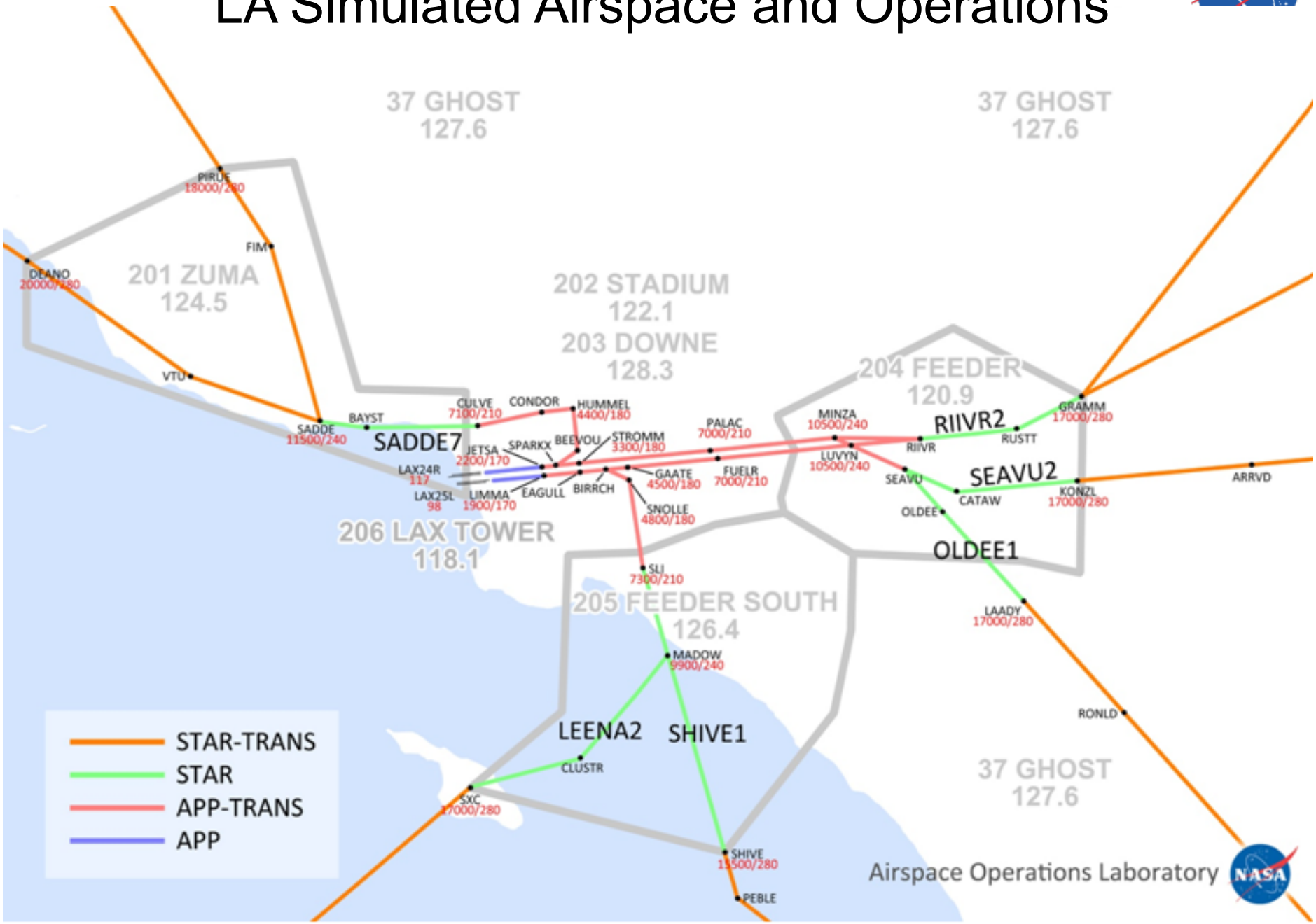
Human in the Loop Simulations

- Airport exceeding 120% current high-demand operations
  - Los Angles high fidelity En-Route & TRACON simulation environment for missed-approach development
  - D-10TRACON only for airspace constrained mid-side airport (Love field DAL) with single RNP route and RNAV-SOP
  - Los Angeles high fidelity En-Route & TRACON simulation environment with early draft OAPM airspace designs
- All controller to pilot interactions via voice communication
- Typical simulations periods 1-2 weeks with 15-30 runs
  - Missed Approaches (October-November 2011)
    - 1 hour 50 minutes with approximately 100 aircraft
    - Each simulation run contained 2-4 missed approaches
    - Controllers only provided with instructions on Con-Ops
    - Retired FAA controller participants
  - Mixed navigation capability RNP and RNAV simulations with FAA
    - D-10 (March 2012), Draft OAPM LAX (Sept 2012)
    - 30-40 minutes with approximately 60 aircraft
    - Current day con-ops vs Automation assisted
    - FAA-NATCA controllers from D-10, N-90, C-90, PHL, SoCal, MIA, DET

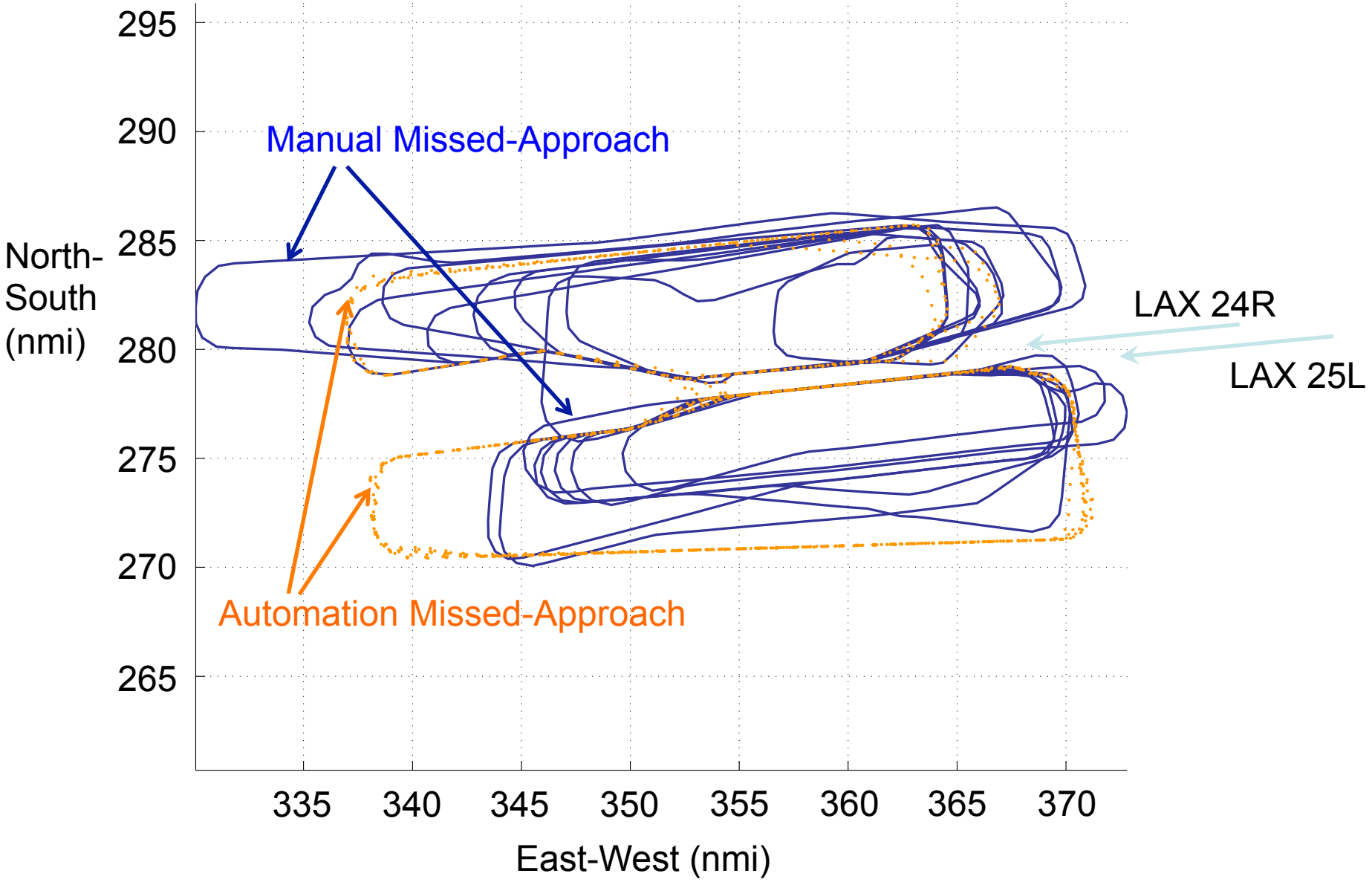
Human-in-the-loop simulation

Missed Approach Simulations using TAPSS

LA Simulated Airspace and Operations



Missed-Approach Tracks

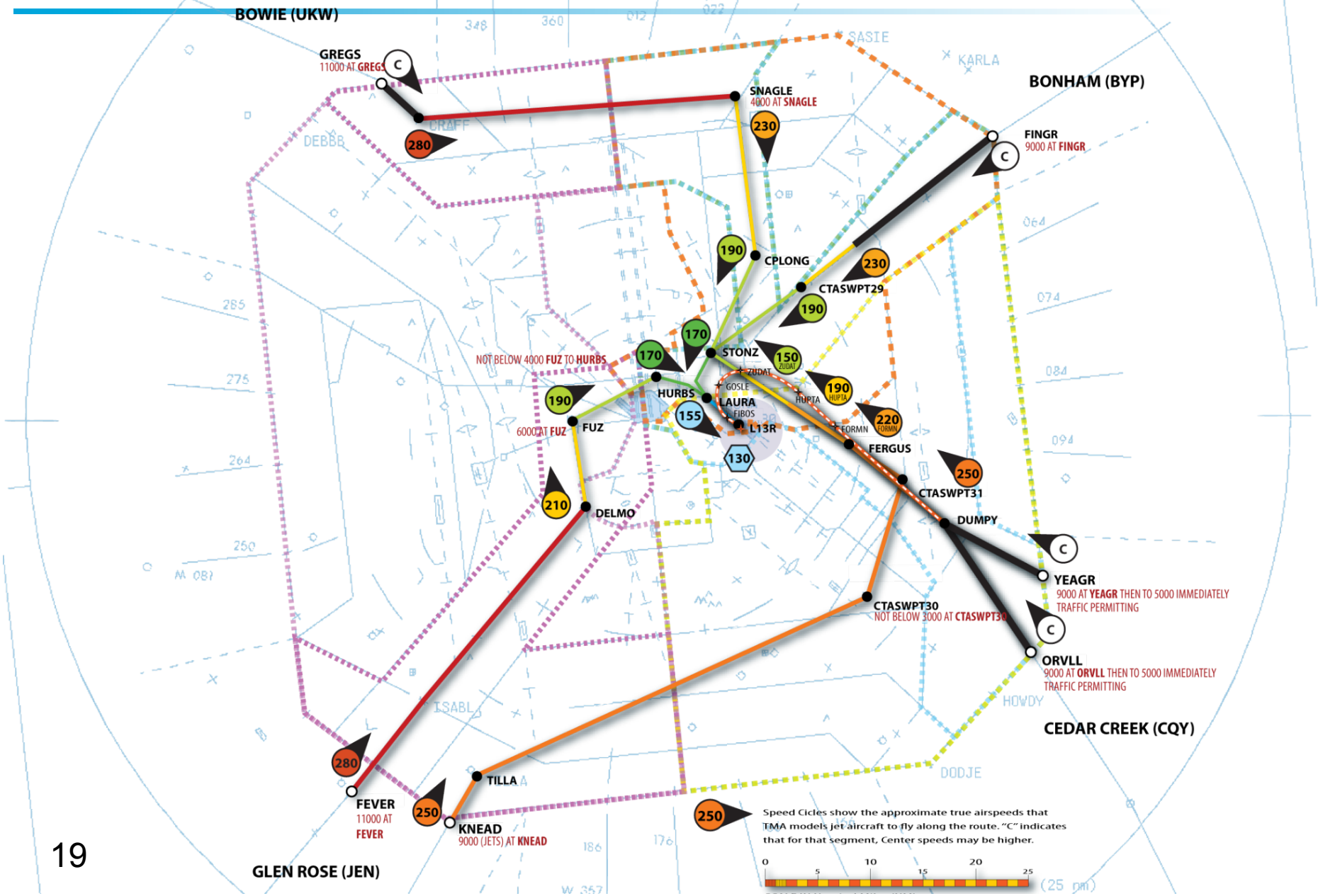


Missed Approach Study Summary

- The Terminal Area Precision Scheduling and Spacing system is robust for off-nominal missed-approach operations for up to 4 missed approaches in a 1-hour period
- Throughput and controller workload analyses between the two con-ops and a baseline without missed-approaches were comparable with similar results
- Automation aided missed-approaches show increase in routing consistency
- Results published at the 31st AIAA/IEEE Digital Avionics Systems Conference: "DEVELOPMENT AND EVALUATION OF THE TERMINAL PRECISION SCHEDULING AND SPACING SYSTEM FOR OFF-NOMINAL CONDITION OPERATIONS" Swenson, et. al...

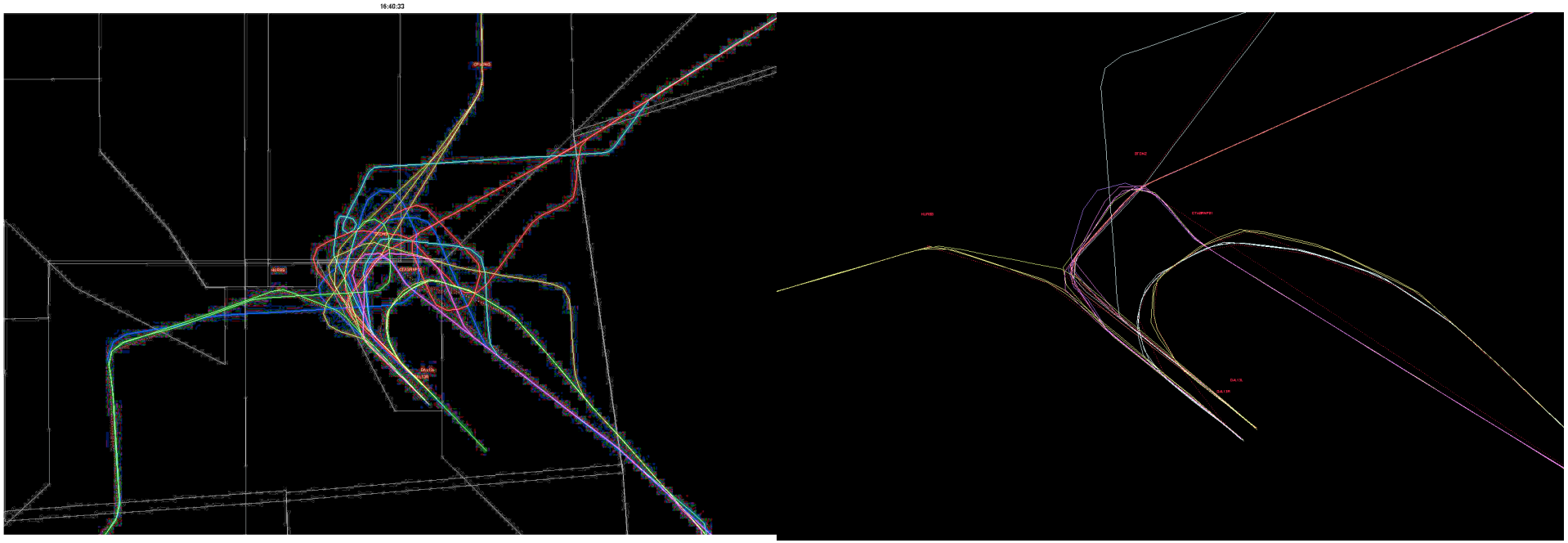
Mixed Aircraft Navigation Capability Simulations at D-10 Love Field

DAL TRACON Routes with RNP RF to 13R/L



Current Procedures vs Automation Assisted

Simulation Radar Tracks for DAL Operations



Current Procedures

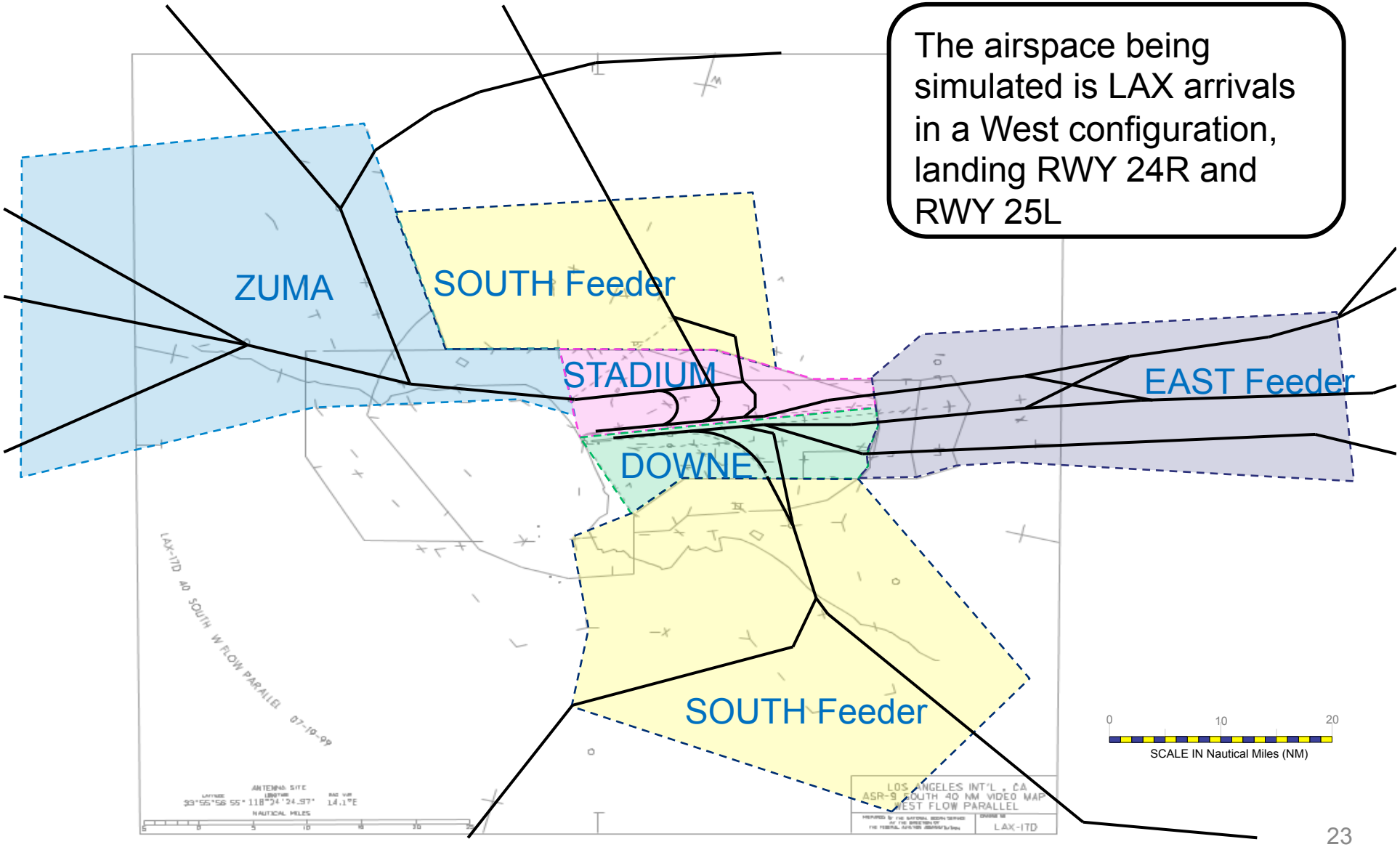
Automation Assisted

Mixed Capability Simulations at D-10 Love Field Study Summary

- The Terminal Area Precision Scheduling and Spacing system greatly assists in the ability to perform advance RNP arrival procedures during heavily congested periods
- Controller preference and RNP compliance conformance highest with full TAPSS controller advisories
- Merging arrival routing procedures a significant factor in an efficient opperations
- Results panned for publication at the 10th UAS/Europe Air Traffic Management Seminar: "DEVELOPMENT AND EVALUATION OF PERFORMANCE-BASED NAVIGATION ARRIVAL WITH TERMINAL PRECISION SCHEDULING AND SPACING SYSTEM" Jung, et. al...

Mixed Aircraft Navigation Capability Simulations using draft OAPM procedures for SoCal

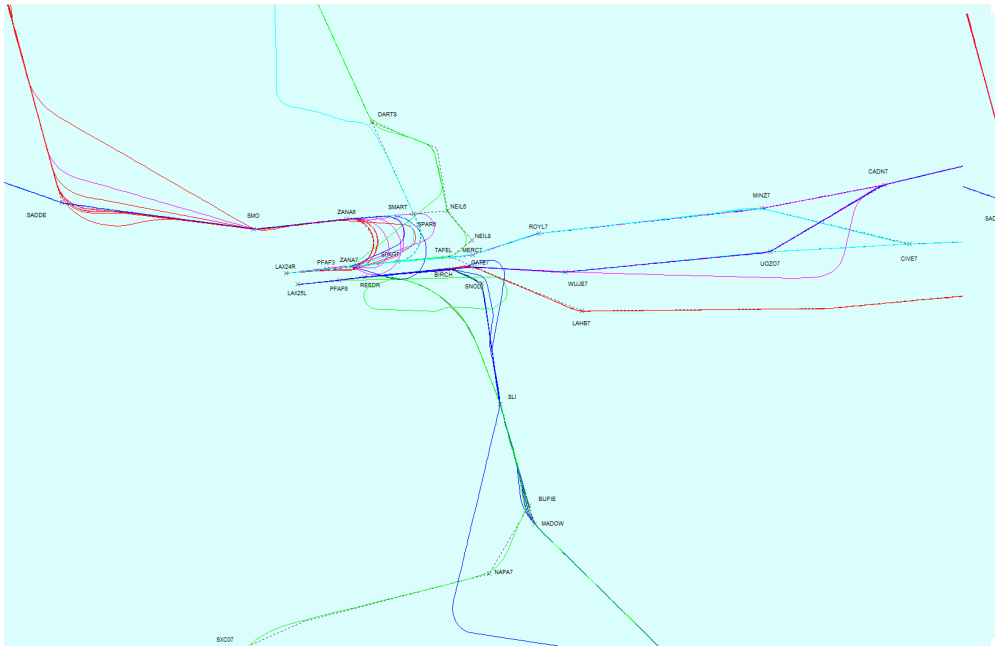
LAX Airspace

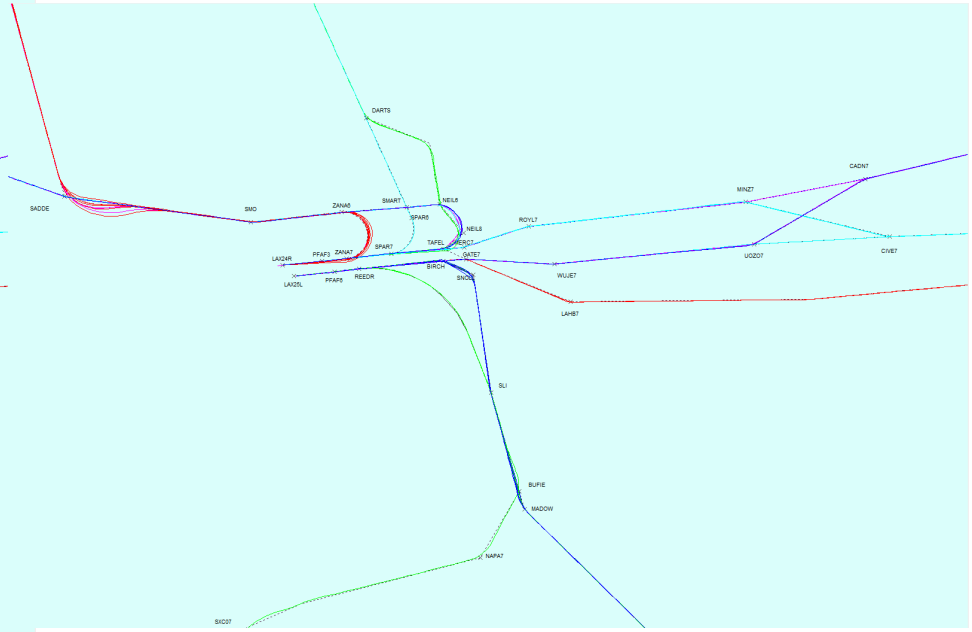


The airspace being simulated is LAX arrivals in a West configuration, landing RWY 24R and RWY 25L

Current Procedures vs Automation Assisted

Simulation Radar Tracks for SoCal Operations with draft OAPM





Current Procedures

Automation Assisted

Mixed Capability Simulations at SoCal Study Summary

- TAPSS system greatly assists in the ability to perform multiple RNP arrival procedures simultaneously with current procedures during heavily congested periods
- Controller preference and RNP compliance conformance highest with full TAPSS controller advisories
- Merging arrival routing procedures a significant factor in an efficient operations
- Results from this simulation are considered anecdotal and only provide insight for future work

Summary

- The Terminal Area Precision Scheduling and Spacing system has demonstrated through research and extensive high-fidelity simulation studies to have benefits in airport arrival throughput, supporting efficient arrival descents, and enabling mixed aircraft navigation capability operations during periods of high congestion
- NASA is currently porting the TAPSS system into the FAA TBFM and STARS system prototypes to ensure its ability to operate in the FAA automation Infrastructure
- NASA ATM Demonstration Project is using the the TAPSS technologies to provide the ground-based automation tools to enable airborne Interval Management (IM) capabilities
- NASA and the FAA have initiated a Research Transition Team to enable potential TAPSS and IM Technology Transfer