

Precision Scheduling and Spacing

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NASA's precision scheduling and spacing research has matured to show the high potential of merging efficient flows in high density operations

- » Precision scheduling and efficient delay distribution minimizes early descent from enroute altitude and low-altitude vectoring
- » Precision merging and spacing control improves throughput
- » Enables the extended use of flight path optimization based procedures

FAA/NASA/Industry collaboration is needed to accelerate implementation of ADS-B applications in a way that achieves the full benefit of NextGen operations to those that equip in high density airspace

Integrated precision scheduling and spacing will to offer immediate and systematic benefits to airlines in many environments, even with different equipage levels and traffic densities

Purpose of Briefing

- Share status with airspace users and stakeholders of some exciting relevant research for reducing delays and improving high density NextGen operations
- Encourage future discussions on the potential to accelerate precision scheduling and spacing research into the National Airspace System
- Propose collaborative effort to evaluate key aspects of research in operational environment

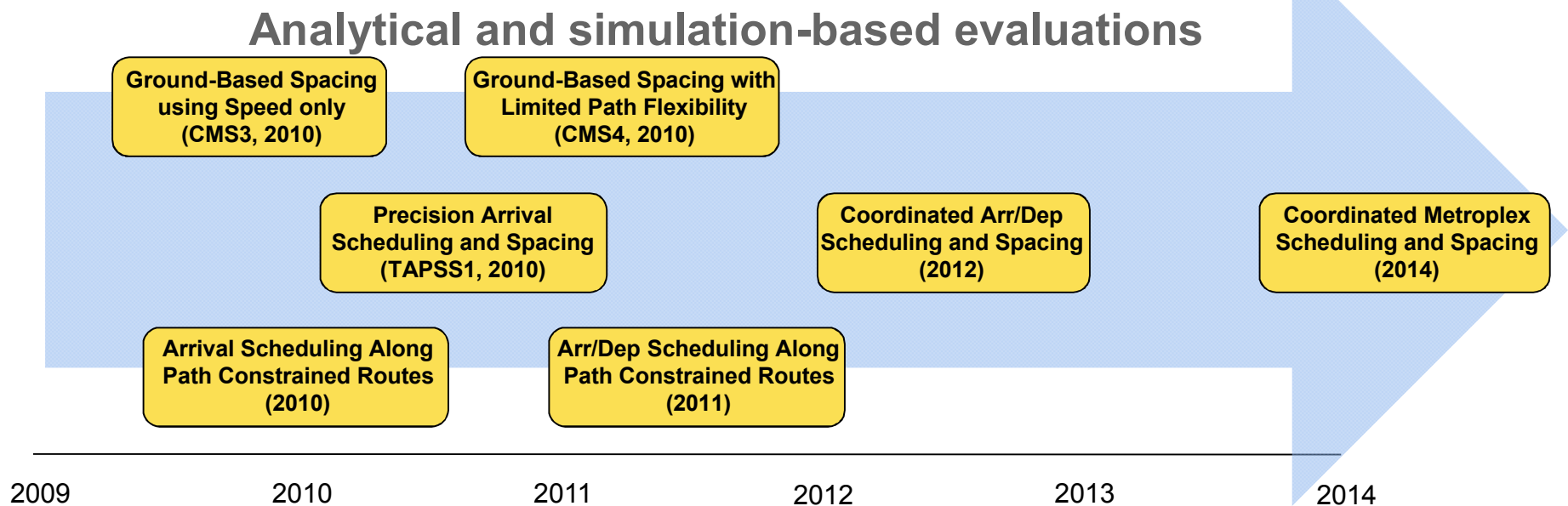
Outline

- Current NASA research plans
 - » Precision Scheduling
 - » Airborne spacing
- Proposal
 - » Opportunity
 - » Approach
 - » Modifications
 - » Benefits
- Discussions/Questions

Research Plans: Precision Scheduling

Time-Based Scheduling in High-Density Terminal Airspace

- NextGen Airspace Systems Program, Concepts and Technology Development Project, Super Density Operations Research Focus Area

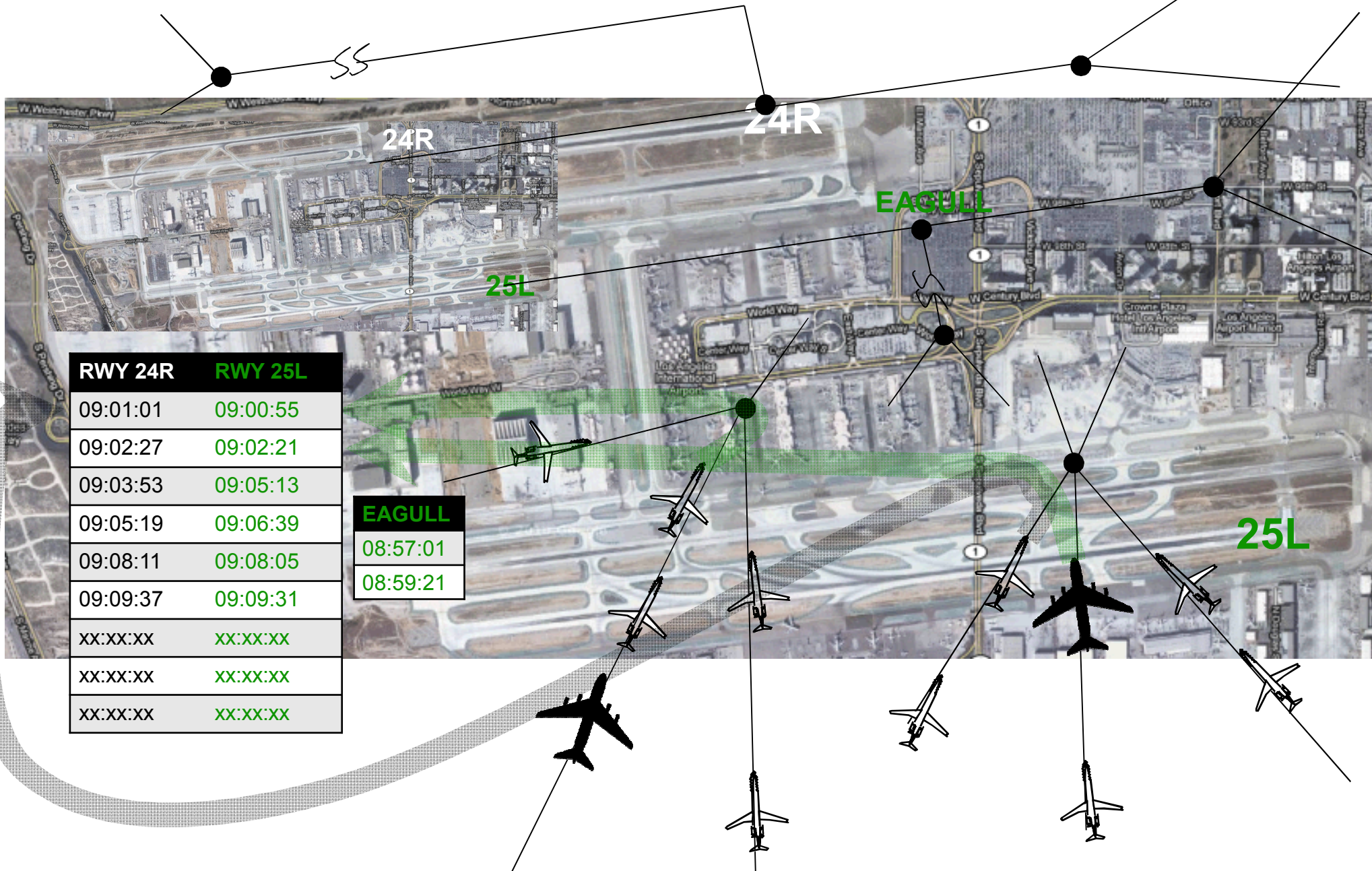


- Work with FAA TBFM Project via the Efficient Flows into Congested Airspace (EFICA) Research Transition Team (see Advanced Scheduling for Congested Terminal Airspace Research Transition Product)

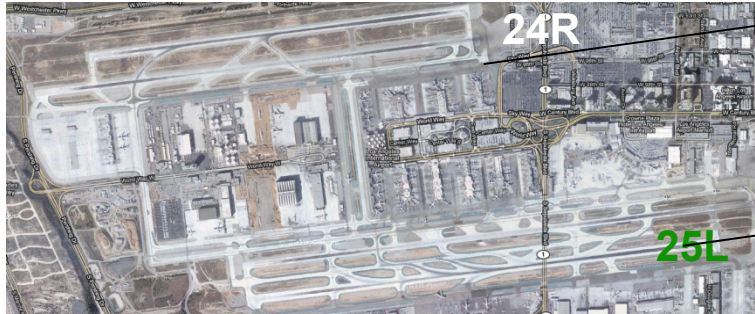
Precision Scheduling & Control Requirements

- Structured airspace with defined routing from en-route airspace through the terminal airspace to primary, secondary, etc... landing runways
- Accurate 4-D predictions with nominal, fast and slow speed profiles
- Defined reference points/locations for application of control
 - Meterfix in Center airspace
 - Mergepoints in terminal airspace
 - Final Approach Fix
 - Runway Threshold
- Accurate surveillance and wind-field information
- Define separation constraints and associated planned excess spacing buffers

Terminal Area Precision Scheduling

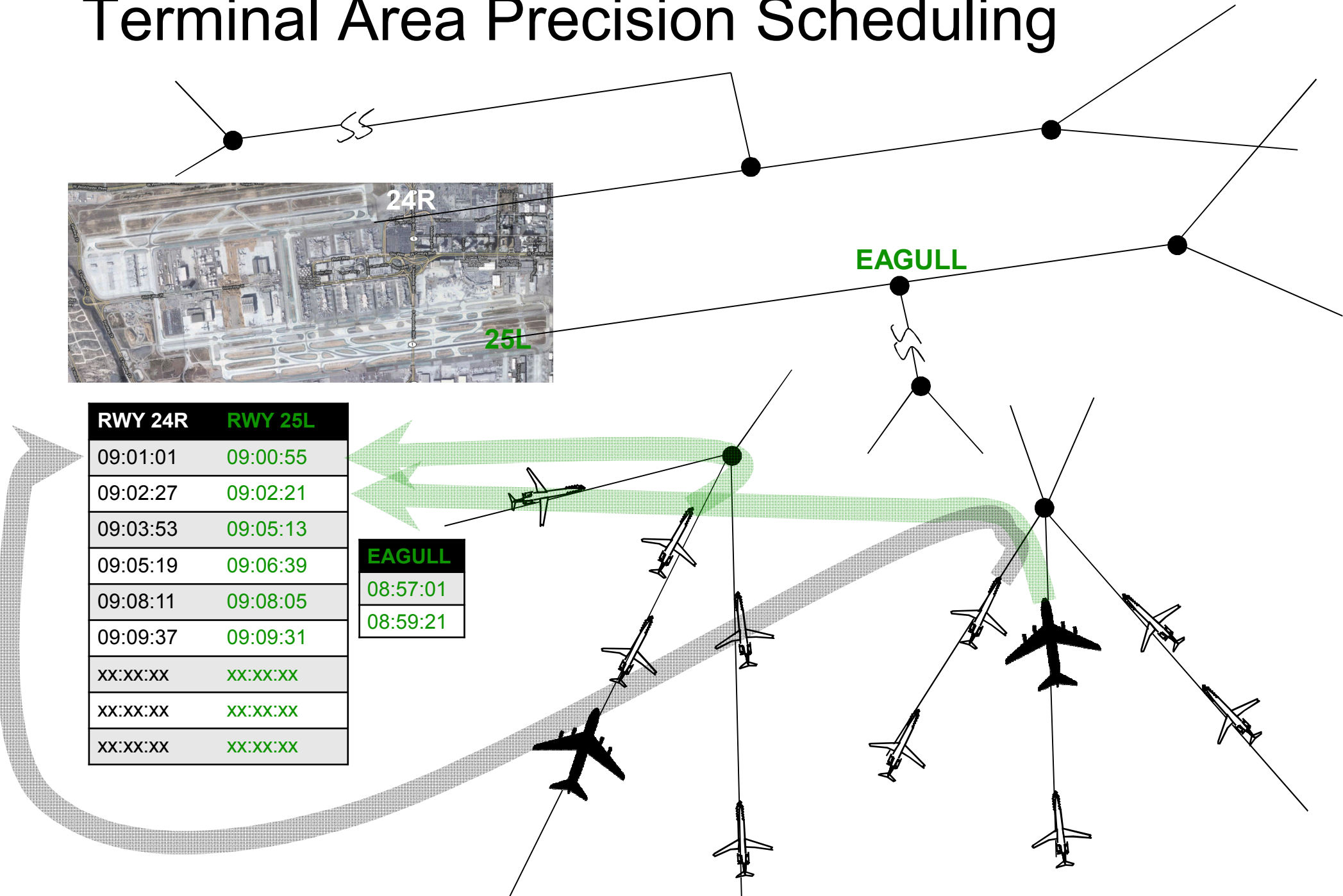


Terminal Area Precision Scheduling



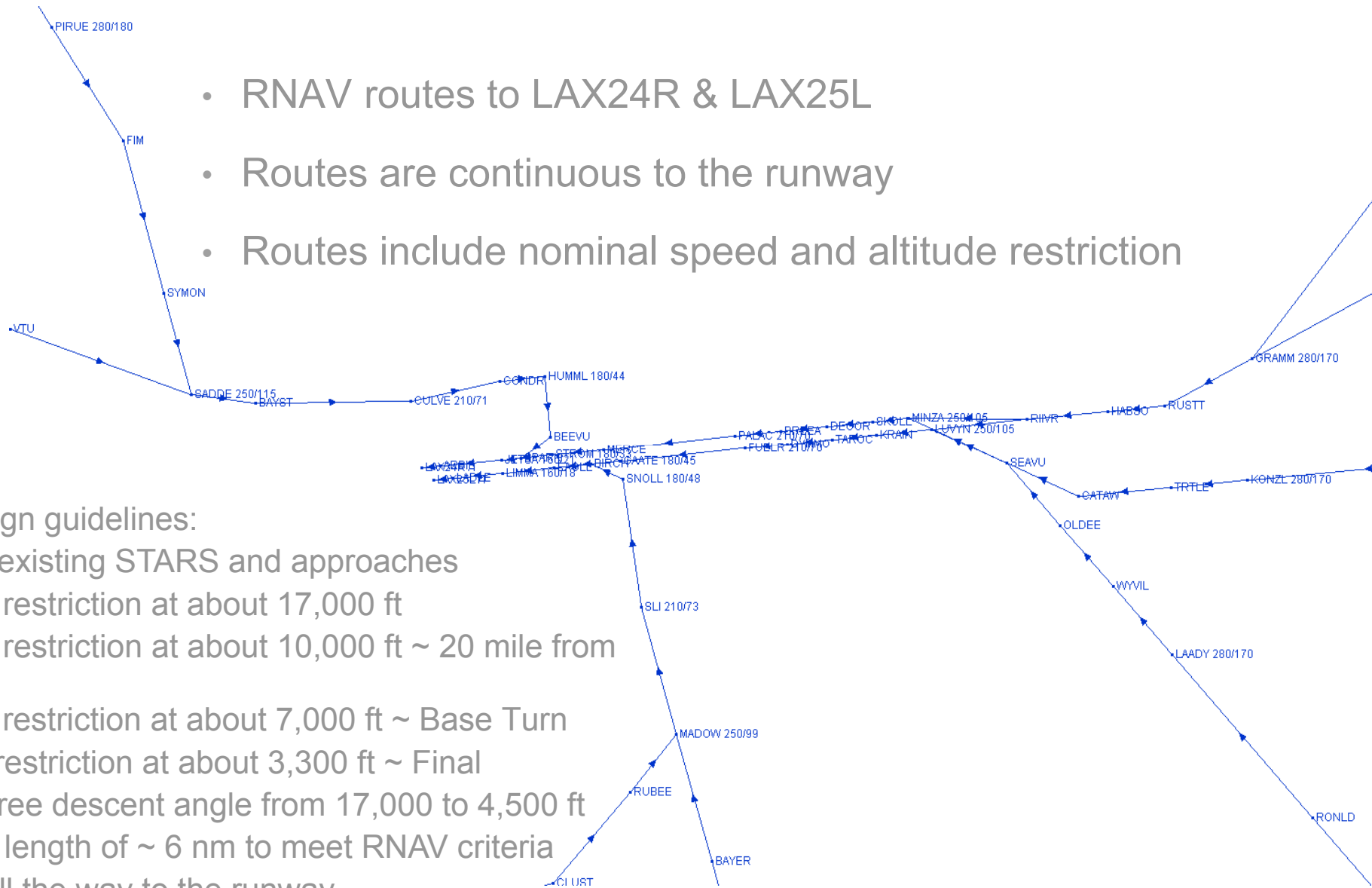
RWY 24R	RWY 25L
09:01:01	09:00:55
09:02:27	09:02:21
09:03:53	09:05:13
09:05:19	09:06:39
09:08:11	09:08:05
09:09:37	09:09:31
XX:XX:XX	XX:XX:XX
XX:XX:XX	XX:XX:XX
XX:XX:XX	XX:XX:XX

EAGULL
08:57:01
08:59:21



Hypothetical & current Optimized Profile Descent RNAV approaches and procedures into LAX

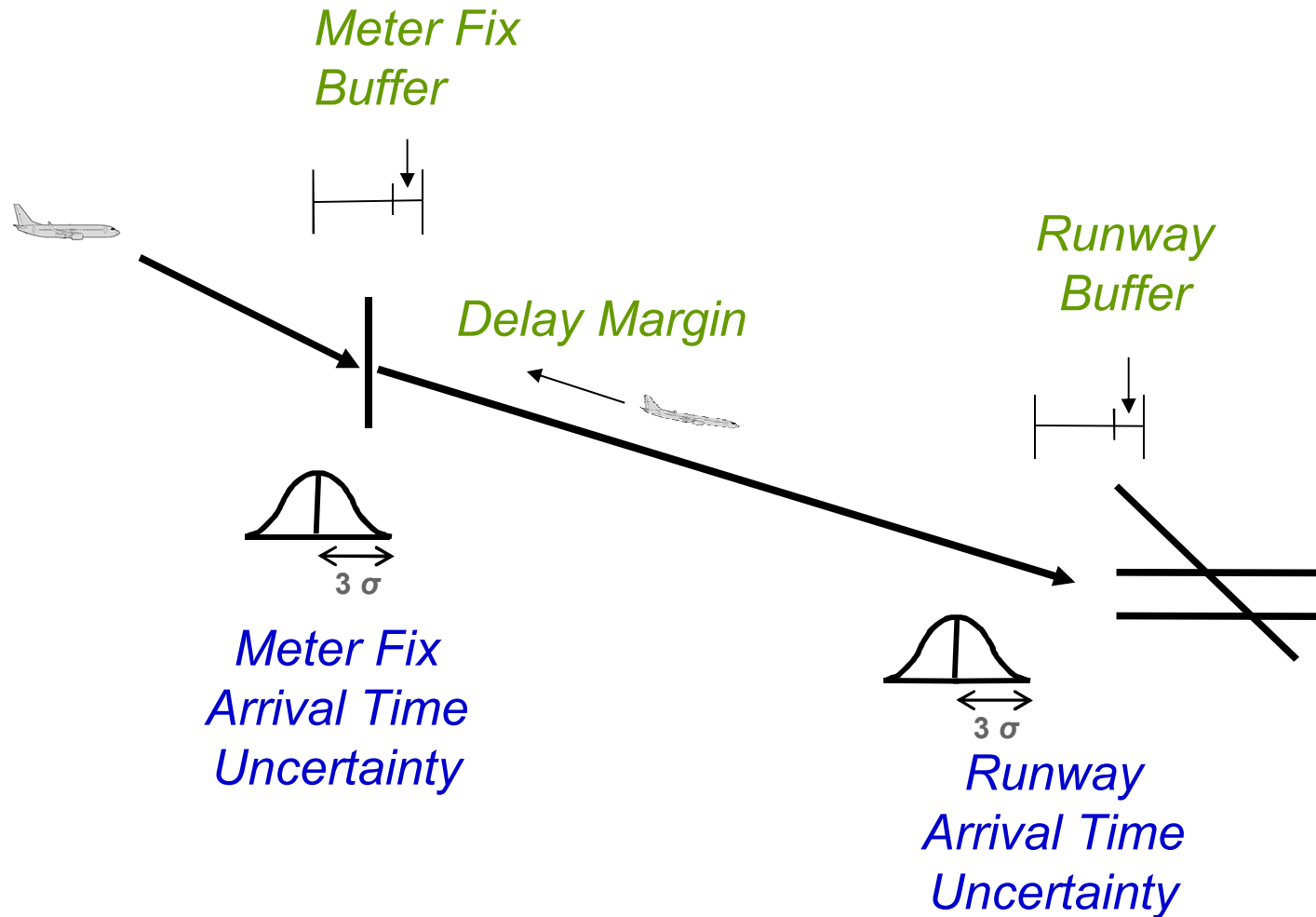
- RNAV routes to LAX24R & LAX25L
- Routes are continuous to the runway
- Routes include nominal speed and altitude restriction



Route design guidelines:

- Base on existing STARS and approaches
- 280 knot restriction at about 17,000 ft
- 250 knot restriction at about 10,000 ft ~ 20 mile from THD
- 220 knot restriction at about 7,000 ft ~ Base Turn
- 180 knot restriction at about 3,300 ft ~ Final
- ~2.4 degree descent angle from 17,000 to 4,500 ft
- Base leg length of ~ 6 nm to meet RNAV criteria
- Routes all the way to the runway

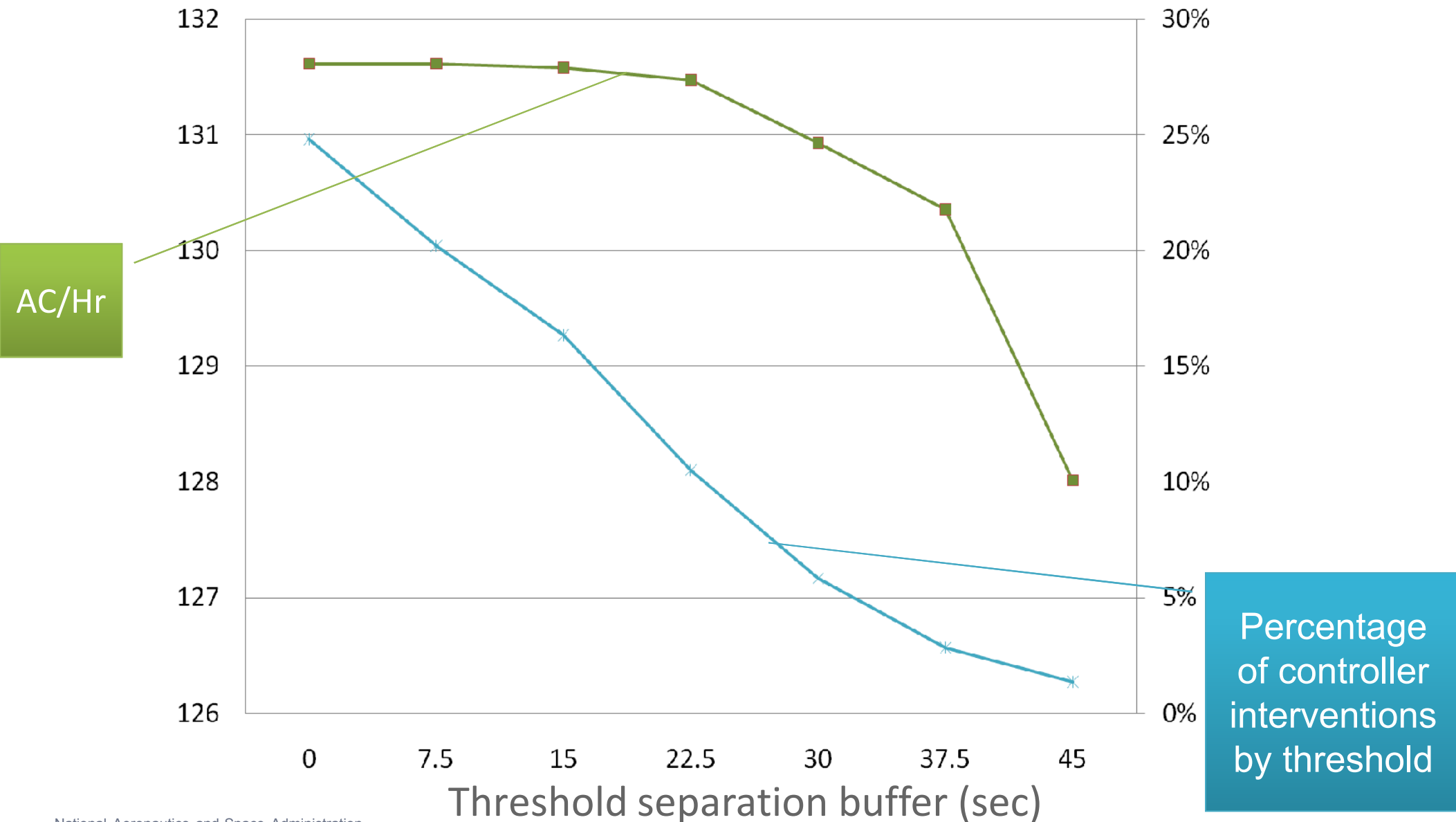
Analytical Stochastic Terminal Area Simulation



<i>Stochastic variables</i>		<i>Control variables</i>	<i>Range</i>	<i>Set</i>
σ_{mf}	30s	Meter fix buffer	0-60s	10s
σ_{rwy}	15s	Runway buffer	0-45s	Variable
		Delay margin	5-25%TTF	60 Sec

Monte Carlo Stochastic Terminal Area Scheduling Simulation Results

Throughput, Controller intervention and threshold buffer trade-space



Concept for using Precision Scheduling with RNAV Approaches and or OPD Arrival Routes

Precision time-based scheduling provides efficient runway assignment and procedure, arrival sequence and time constraints for aircraft.

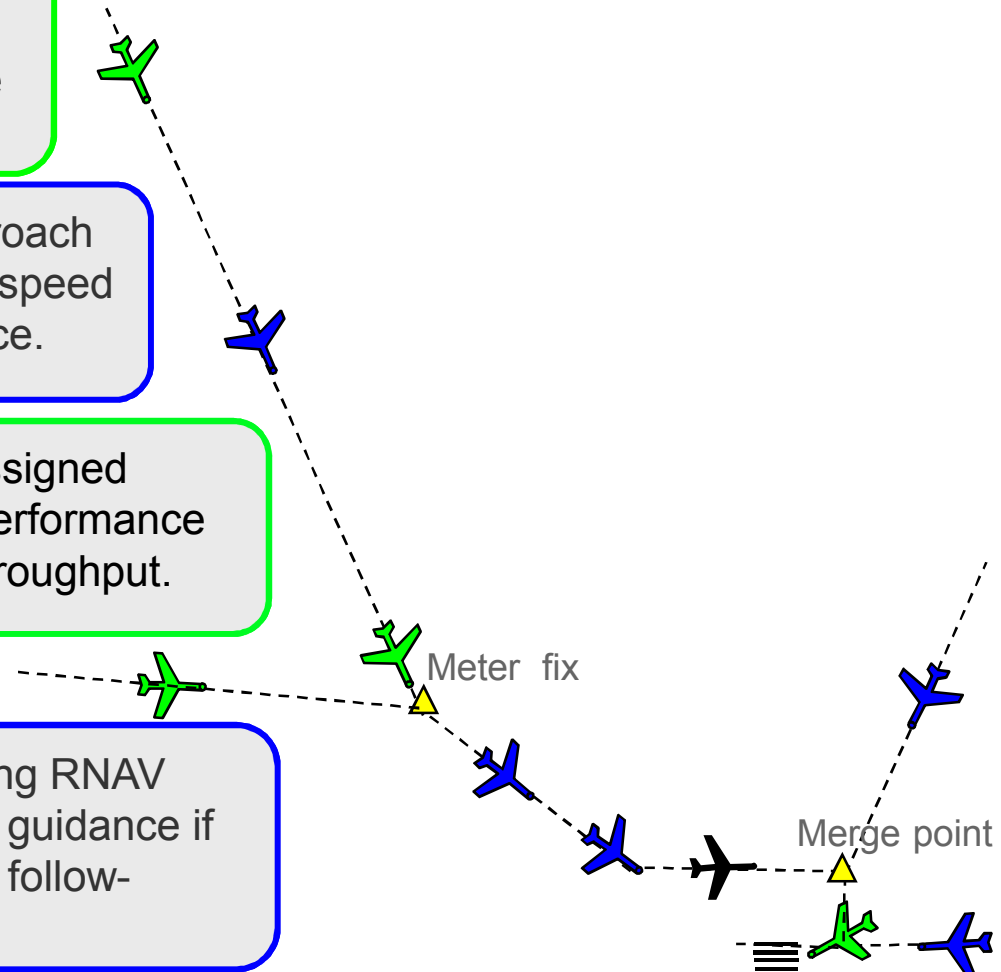
The concept is compatible with aircraft equipped for Required Time of Arrival (RTA) and/or Interval Management (IM).

En route controllers assign runway and use speed, path-stretch to deliver aircraft so they are metered for descending on the RNAV approach/ OPD profile at the meter fix.

Flight crews fly VNAV descents along RNAV approach routes, and for IM equipped aircraft use onboard speed guidance to meet RTA and follow-behind sequence.

Terminal controllers clear the aircraft for the assigned runway and use speed advisories to resolve performance errors at merge-points to maximize runway throughput.

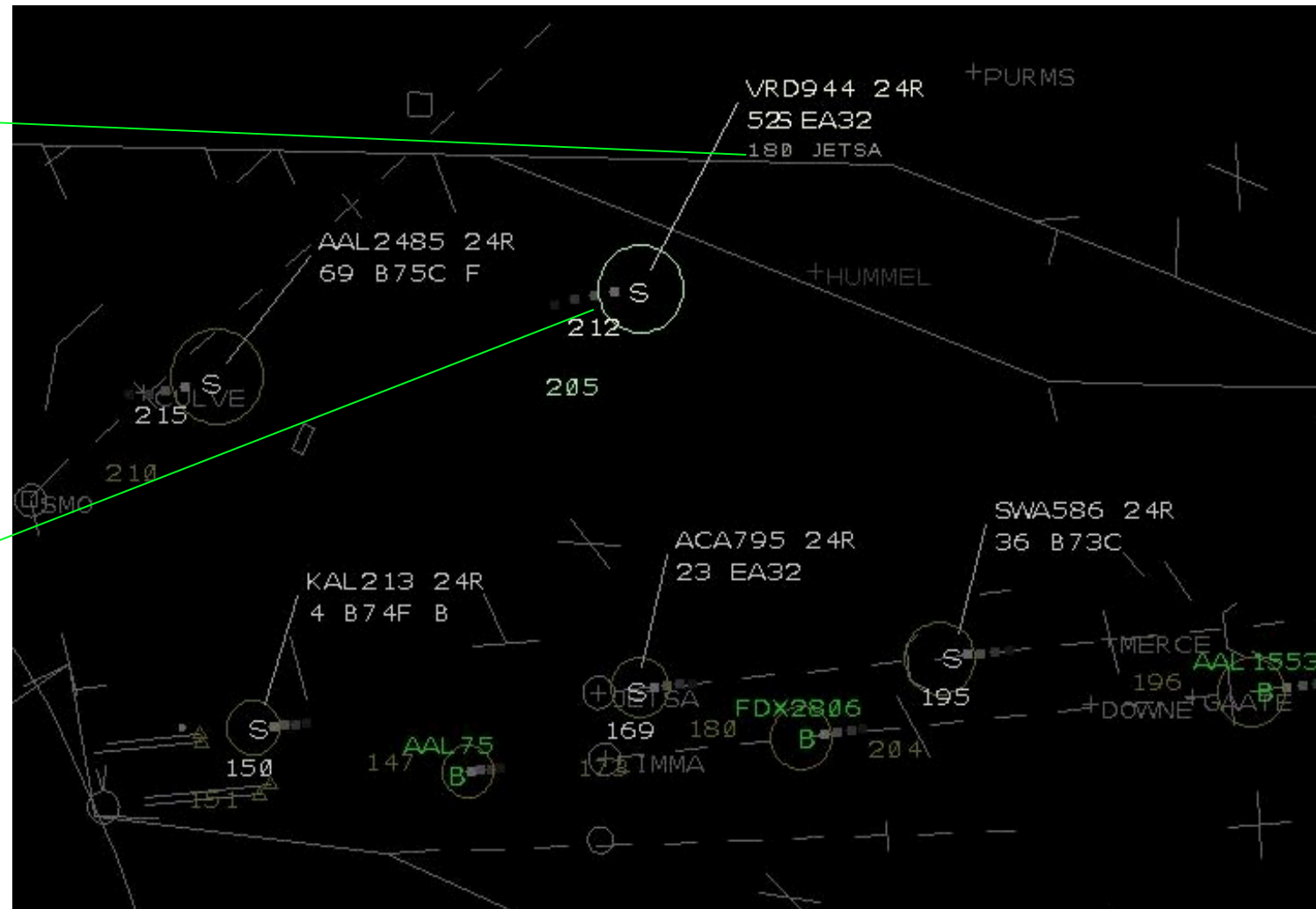
Flight crews continue VNAV descents along RNAV approach routes, and use onboard speed guidance if IM equipped to achieve updated RTA and follow-behind sequence.



Terminal Display with Speed Advisory

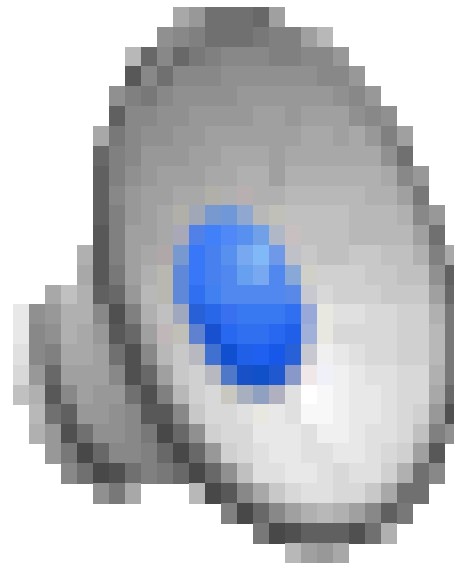
The speed advisory is displayed if the ETA-STA difference is 5 seconds or greater.

The slot marker circles show where the aircraft should be if it flies the nominal RNAV arrival procedure through the forecast wind field

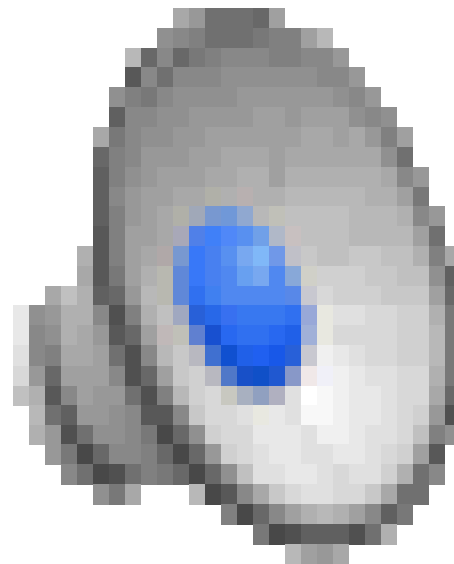


Controller display showing the slot marker circles of desired aircraft position based on each aircraft's nominal 4D trajectory.

Terminal Area Precision Scheduling System Simulation (Controller Positions)

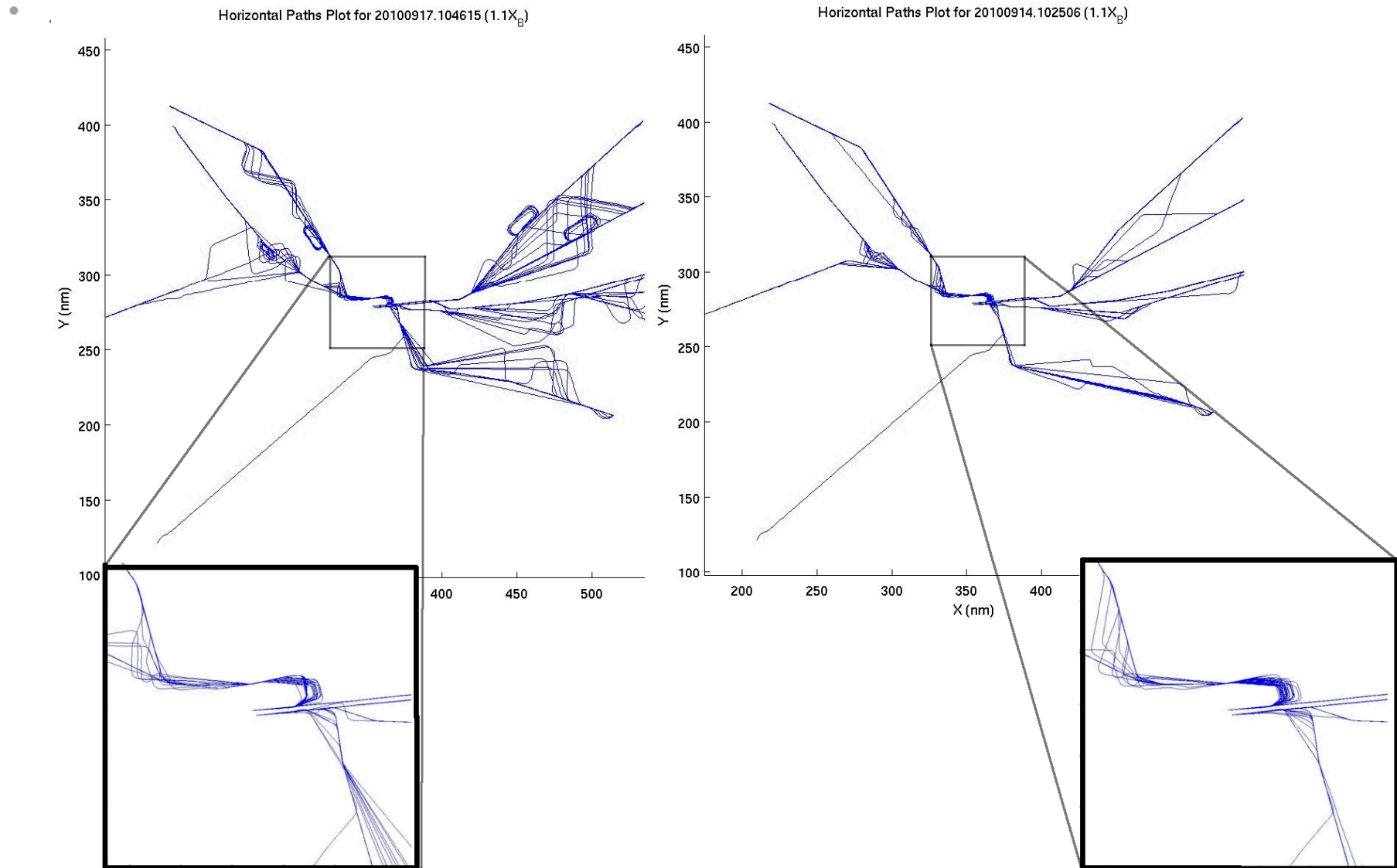


Terminal Area Precision Scheduling System Simulation (Pilot Positions)



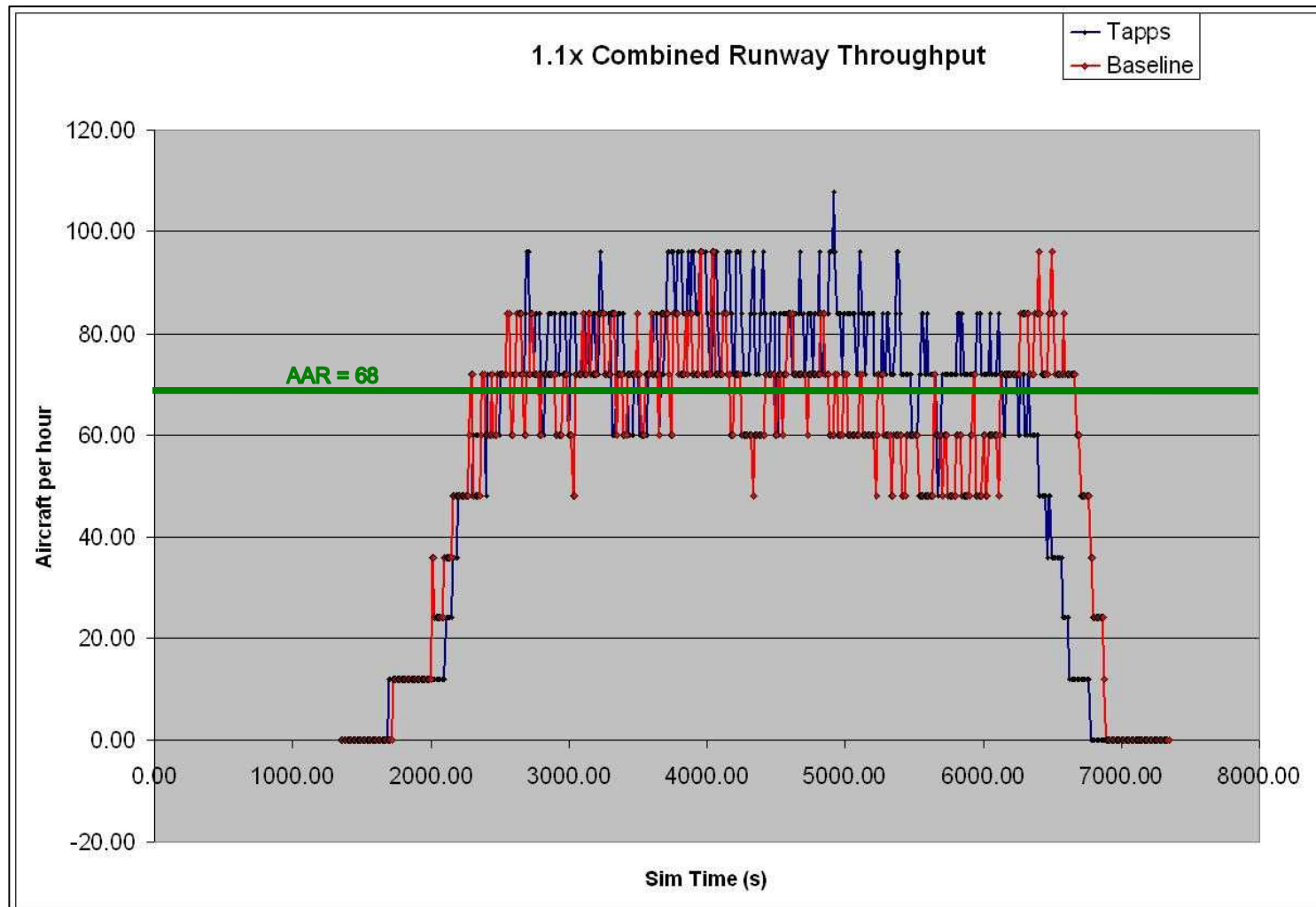
TAPSS Simulation Results

- 10% increase to the 2004 JPDO Baseline



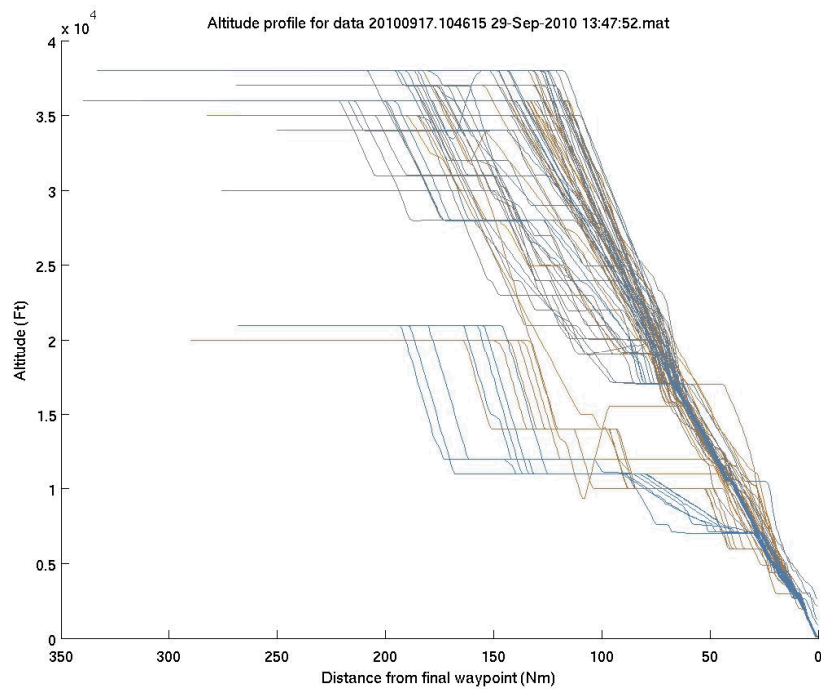
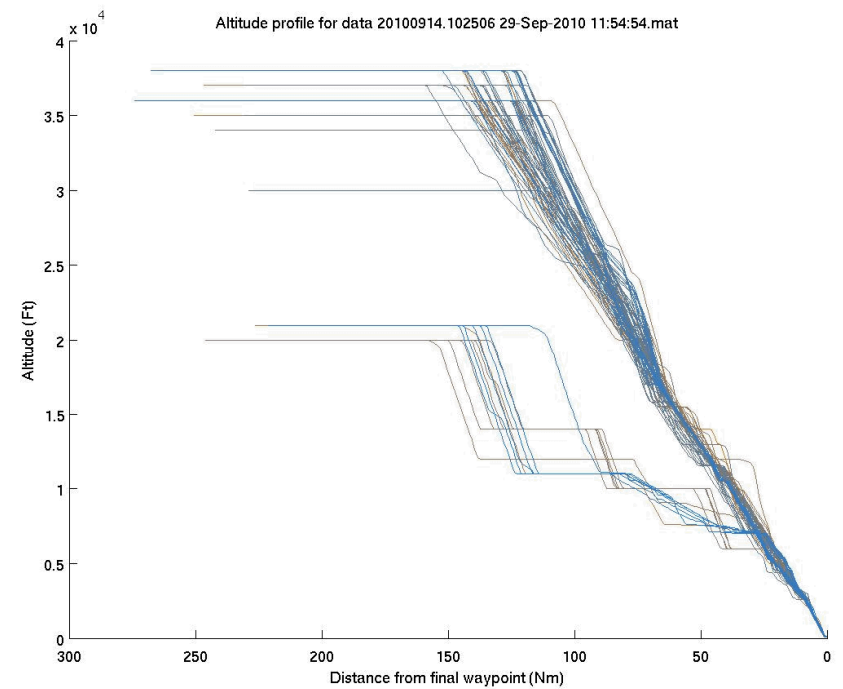
TAPSS Simulation Results

- 10% increase to the 2004 JPDO Baseline
- Runway throughput, ODP profiles



TAPSS Simulation Results

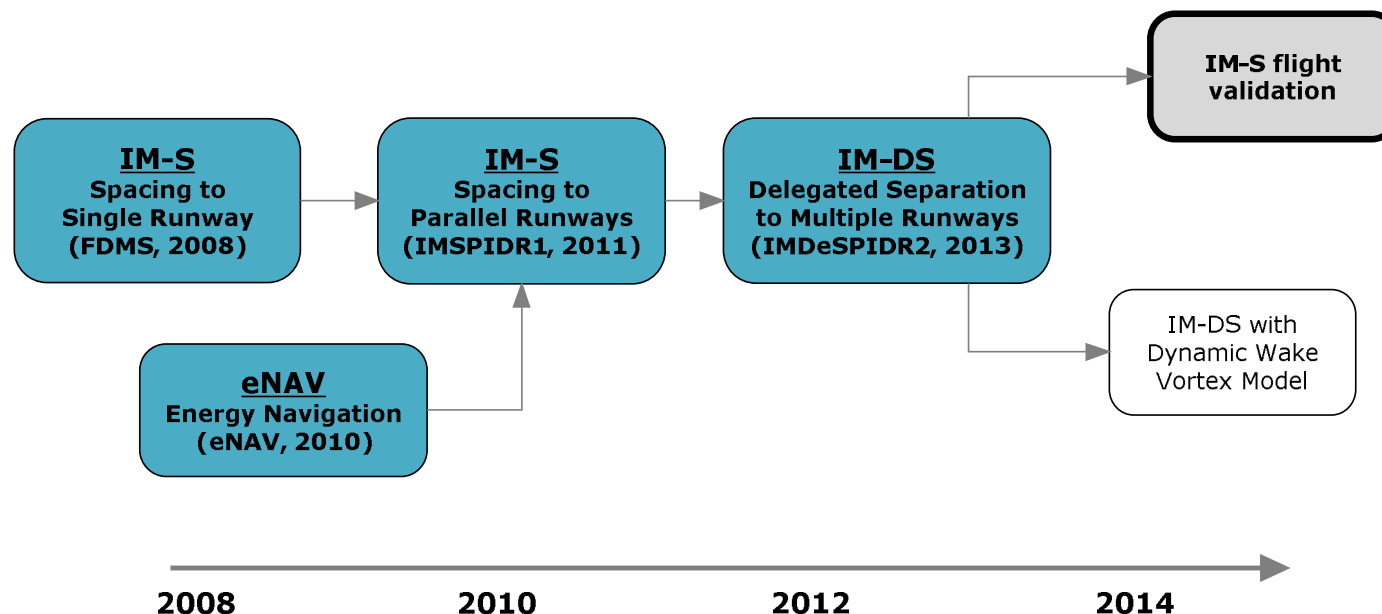
- 10% increase to the 2004 JPDO Baseline
- Descent profiles



Research Plans: Airborne Spacing

Spacing (Interval Management) in High-Density Terminal Airspace

- NextGen Airspace Systems Program, Concepts and Technology Development Project, Super Density Operations Research Focus Area



- Work with FAA SBS Office; IM Workgroup contains many members and partners
FAA AIWP document captures roadmap and timeline (Version 2, June 2010)
 - Application #6, Flight-Deck Based Interval Management-Spacing (IM-S)
 - Application #8: Flight-Deck Based Interval Management-with Delegated Separation (IM-DS)
 - Application #14: Flight-Deck Interval Management-Delegated Separation with Wake Risk Management

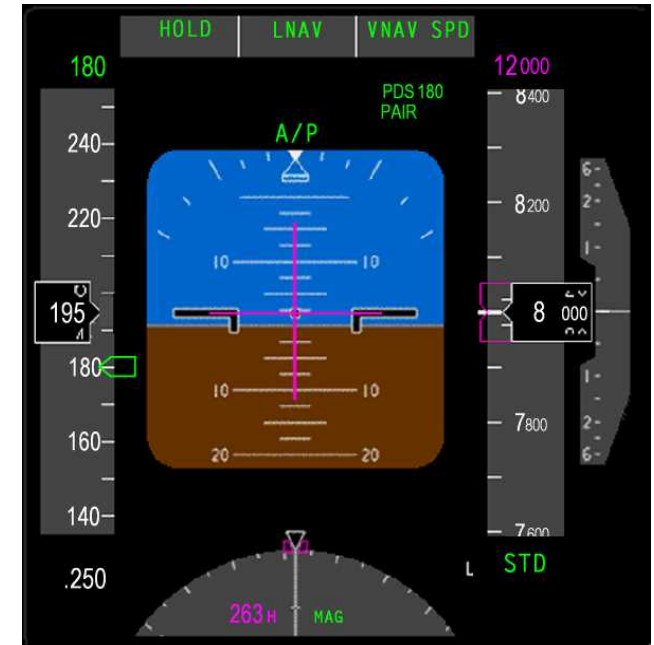
Airborne Spacing: Concept

Philosophy: Aircraft a resource for accomplishing airline and ATM goals

- Flight crew can position aircraft very precisely when required
 - Precise spacing at a specific point to achieve high throughput when needed
 - Smaller deviations from aircraft optimized trajectory for less fuel consumption
- Each flight crew achieves assigned spacing interval behind lead aircraft
 - Flight crew follows guidance from onboard software (use ADS-B information)
 - Additional benefit of reduced need for vectors to maintain separation
- Workload and acceptability
 - Flight crew: not a significant change. The fly arrival and approach as usual, speed from spacing algorithm on aircraft instead of voice from controller
 - Controller: ground software devises schedule and spacing between aircraft; workload for tactical tasks is reduced
- Compatible and enhance Current-Day Operations
 - OPDs, Tailored Arrivals, 3D PAM, ITF (oceanic), Green Skies, RNP at ATL
 - Spacing even possible for low-density airspace without advanced ground scheduler

Airborne Spacing: Algorithm

- Trajectory based, allows for aircraft on different RNAV routes with altitude and speed constraints
- Computes lead & ownship ETA at threshold
- Calculates speed guidance to achieve desired relative ETA over remainder of the route
- Corrects speed if necessary to prevent separation violations (delegated separation)
- Relative spacing enables smaller spacing buffer, increasing throughput during high-density ops



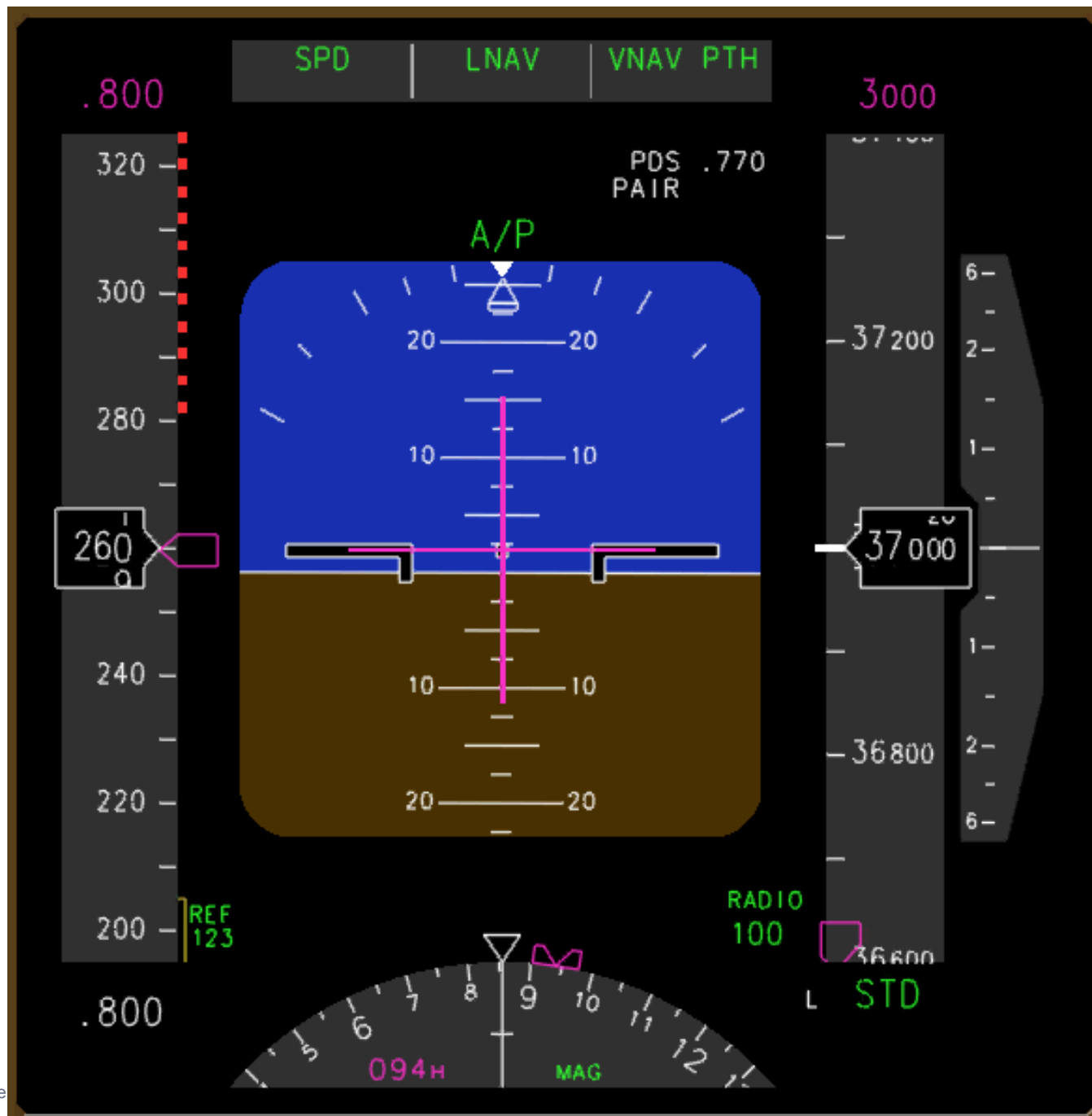
Lead ETA = 14:22:15

Ownship ETA = 14:23:30

- **assigned spacing interval: 90 sec**
- **15 seconds early at threshold**
- **Slow down 5 knots**

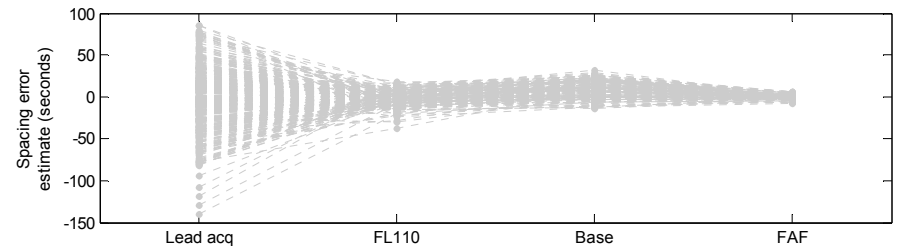


Airborne Spacing: Pilot Action

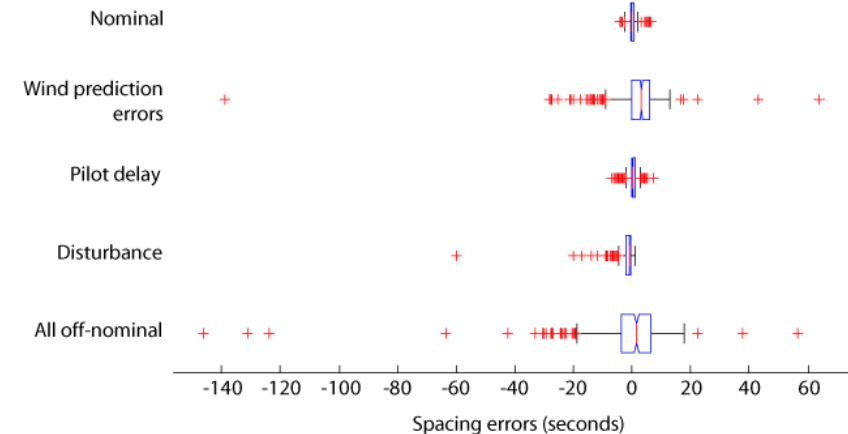
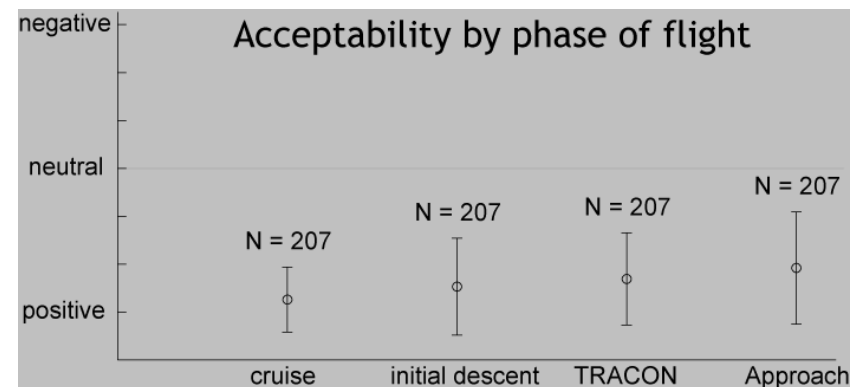


Airborne Spacing: Research Results

- Langley, MITRE, Ames Research
- Just Langley results include:
 - 2006 batch study:
 - arrival stream steady
 - gradual reduction of spacing error
 - 2008 batch study and pilot experiment:
 - high precision crossing runway with wind error, pilot delay, schedule disturbance, and off nominal events
 - pilots rated procedure as very acceptable and with low work load
 - 2009 batch study:
 - RTA and airborne spacing possible in same arrival stream
 - airborne spacing very robust to schedule deviations



Test condition



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Proposal: The Opportunity

- NASA
 - Re-baseline its research plans to focus on the demonstration
 - Enhanced TMA and controller-based automation technology to providing a precise time-based schedule using efficient procedures for arrivals into LAX and enhanced procedures for aircraft capable of spacing
 - Maturing airborne spacing technology with multiple RTA and Interval Management capabilities has been vetted with avionics manufacturers
- FAA
 - ADS-B milestones met on time 5 years straight; major government investment
 - avionics standards established; international procedures being developed (RTCA)
 - Capability incentives: RVSM airspace, Gulf of Mexico helicopter operations
 - ADS-B IN opportunities are being encouraged for implementation by 2020
- Users
 - Work with FAA and NASA to evaluate operational benefits and refine concept
 - Participate in precision scheduling and spacing evaluation; use experience to develop international harmonized procedures and set avionic standards

Proposal: The Approach

- Conduct limited operational evaluation of precision scheduling technologies enhanced with flight deck interval management at LAX
 - Develop RNAV approach procedures from altitude to the runways
 - Develop FAA facilities to support a limited operation evaluation
 - Upgrade the operational TMA and associated controller workstation automation for LA Center and SoCAL TRACON
 - Equip a limited number of aircraft to participate in flight evaluation
 - Leverage current aircraft equipment, require ADS-B IN and onboard interval management software
 - Ensure relevance of combined procedures and technologies for NAS-wide application (arrival, departure, enroute, oceanic)
 - Have broad airspace users and operator collaboration
- Characterize the behavior of precision scheduling and spacing
- Users/Manufacturers conduct cost benefit analyses for broad NAS application with highly relevant operational data.

Proposal: Potential Benefits

- Higher throughput and more fuel efficient operations
 - Reduced vectoring to ensure safe separation (fuel saving)
 - Throughput increase during high-density operations possible by reduced excess separation buffer at runway threshold
 - Compatible with OPDs
- Accelerated technology demonstration of a major NextGen capability for high density operations
- Reduced ATC-pilot communication required, especially during busy or complex operations
- ADS-B IN applications enables other operational benefits: ITF, runway incursion warning, CAVS, traffic awareness with alerts
- Distributed system architecture for failure resilient operations

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Discussion/Questions



Topics for Discussion

- Understanding of airlines' plans and opportunities for implementing NextGen
- Other potential use cases for ADS-B applications in high density airspace
- Benefits achievable with limited ADS-B OUT equipage
- Perspective on airborne equipage and ROI requirements
- Thoughts on specialized potential flight crew and controller training
- Top level risks to consider