



Airborne Precision Spacing / Interval Management

***Crew Systems & Aviation Operations Peer Review
Hampton, VA
February 28 – March 1, 2012***

Dr. Bryan E. Barmore
William C. Johnson, Eng.
Crew Systems & Aviation Operations Branch
NASA Langley Research Center
Hampton, VA 23681-2199

bryan.barmore@nasa.gov (757)864-6225
william.johnson@nasa.gov (757)864-3858



Outline



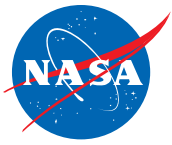
- Problem Statement
- Proposed Solution
- Benefits
- Relationship with Outside Work
- History of Airborne Precision Spacing Development
- Recent Results and Accomplishments
- Future Plans
- Research Team



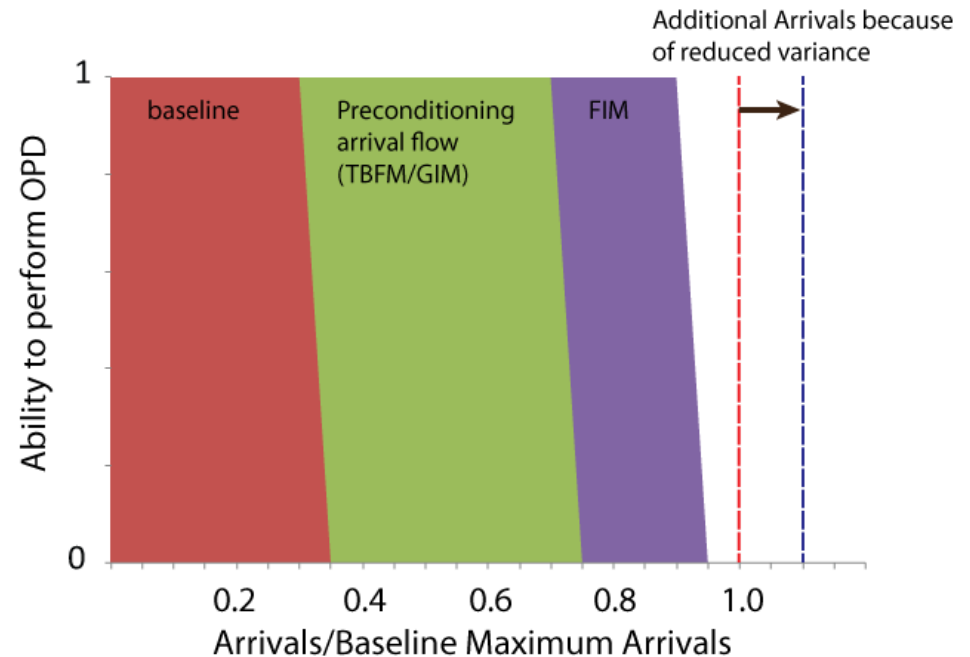
Arrival Problem

- Optimized Profile Descents (OPD) are hard for controllers to predict
 - Leads to tactical maneuvering and level segments
 - Spacing between aircraft increased due to uncertainty
- OPDs can only be used in low demand environments without assistance

Proposed Solution



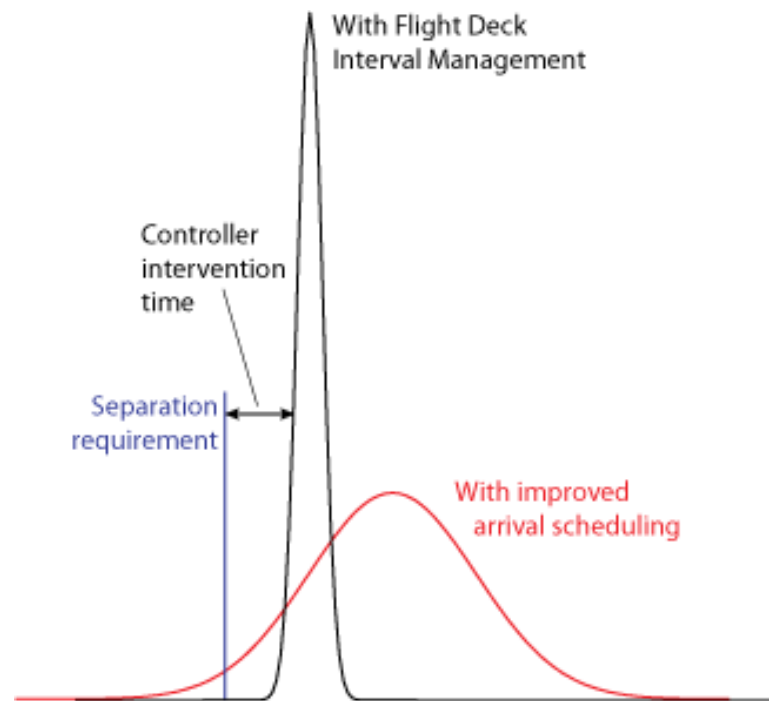
- Allow aircraft to manage inter-aircraft spacing
 - Start with coordinated schedule
 - Flight crew manages speed for relative spacing
 - Speed changes small so aircraft stays on OPD
 - Reduced uncertainty allows for more OPDs



FAA ATO En route and Oceanic Services, "Benefits Basis of Estimate Surveillance and Broadcast Services," August 2007.

Expected Benefits

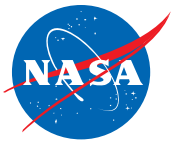
- Increased use of OPD
 - Reduced lateral maneuvering
 - Eliminate level segments
 - No loss of throughput
- Reduced delay
 - Throughput closer to capacity
 - No scheduled delay in terminal area
 - Increased use of arrival routes in terminal area
- Fuel and noise
 - Small speed changes for APS/IM have minimal impact on fuel use and ground noise



Terminology

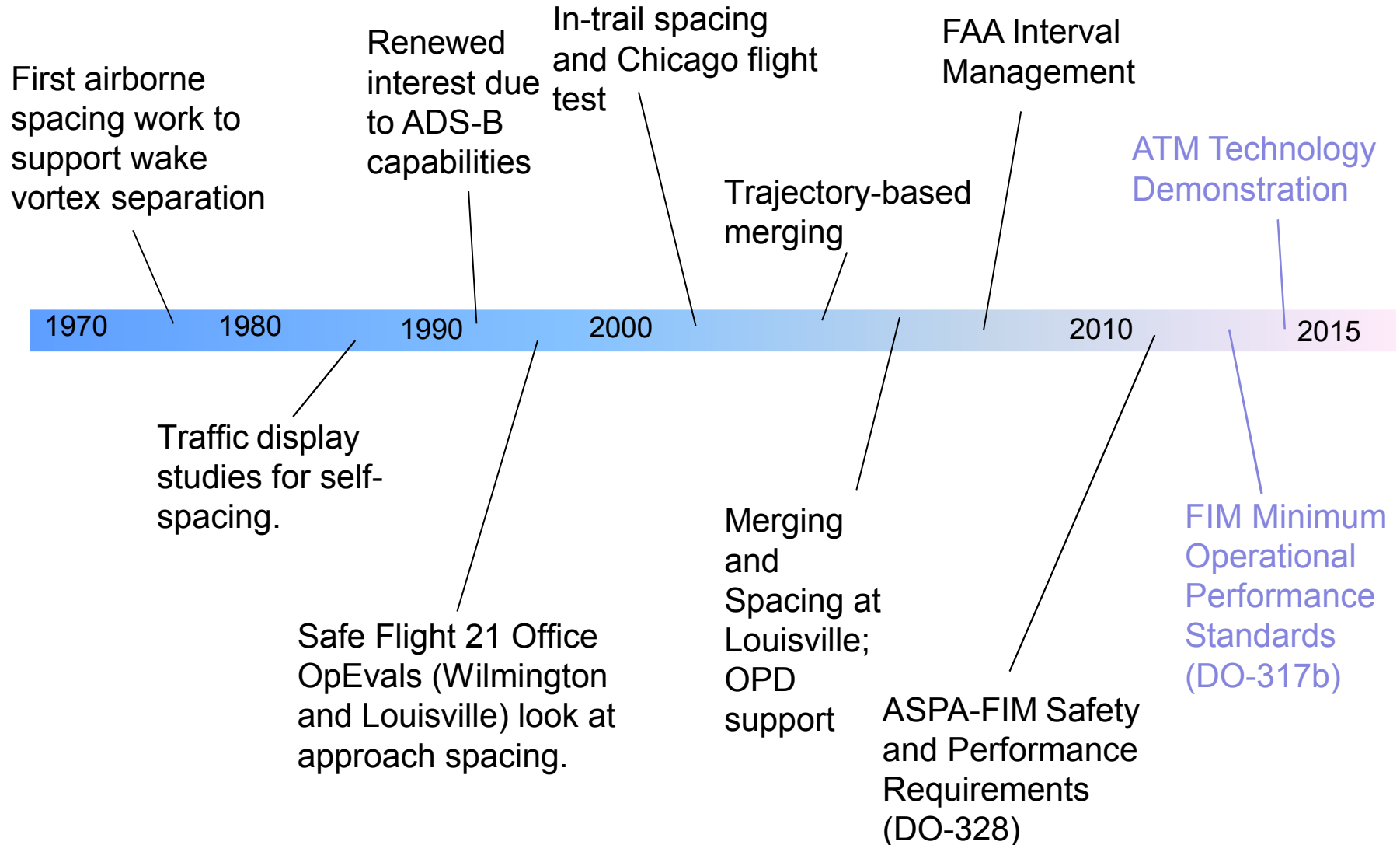
- IM – Interval Management
 - FAA SBS Concept for relative spacing of aircraft
 - Covers all domestic flight regimes
 - Generic functional description; multiple “applications”
- FIM – Flight Deck-based Interval Management
 - Portion of Interval Management allocated to the flight deck
 - Automation and procedures
- APS – Airborne Precision Spacing
 - NASA Concept for research and development
 - Focused on arrival and approach operations
 - Subset of IM

Partnerships and Collaboration



- Close working relationship with FAA
 - SBS Office in particular
- Supporting related RTCA work
 - SC-186 / FIM Standards
 - Safety, Performance and Interoperability Standards
 - Minimum Operational Performance Standards
- Major contributor to FAA / Industry IM Working Group
 - Previously [Flight Deck-based] Merging and Spacing Working Group
- Collaboration agreements with
 - MITRE
 - NLR
 - Boeing

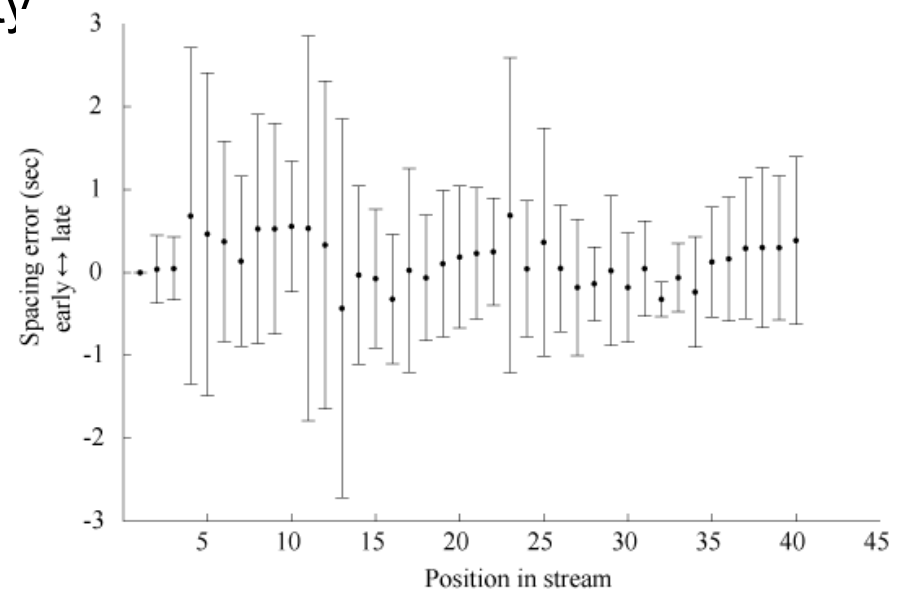
APS History



Past Highlights



- APS/IM operations are feasible and beneficial
- Could increase runway throughput by 10-20%
- Pilot task can be integrated without detrimental workload
- Proof-of-concept trajectory-based spacing tool
- Long strings of aircraft can be stable
- Nominal or reference speed profile prevents extreme variations
 - Promotes acceptability and stability
- Precision of 3-5 seconds is achievable
 - Did not model surveillance errors
- Accounting for planned final approach speeds is critical for expected benefits



Recent Results



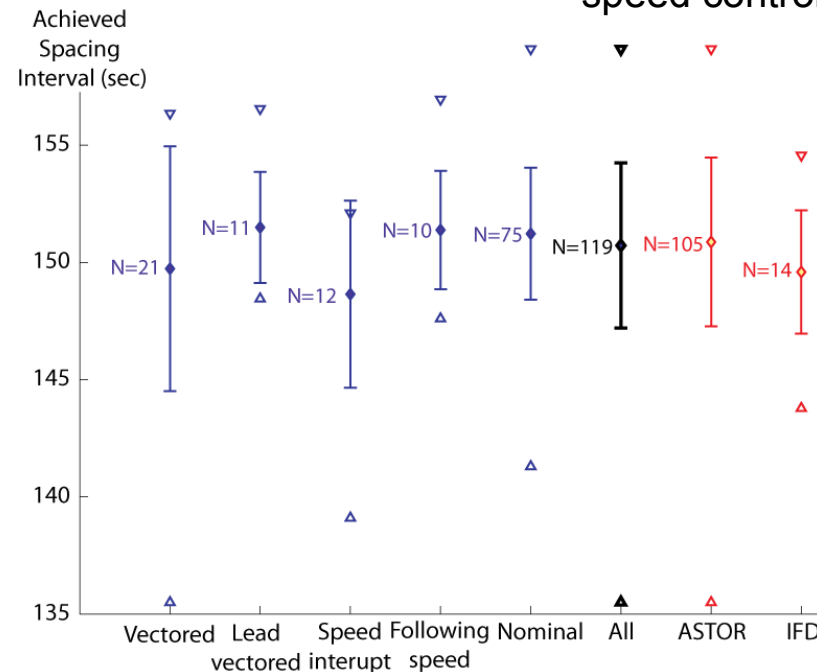
- Worked with FAA and community
- Completed 3 Human-in-the-Loop studies, 4 batch studies
- Developed modeling tool
- Part of team that won 2007 Collier Trophy for ADS-B Implementation
 - Government and industry partnership for the development and deployment of ADS-B technology including enabling applications such as Merging and Spacing



Merging and Spacing



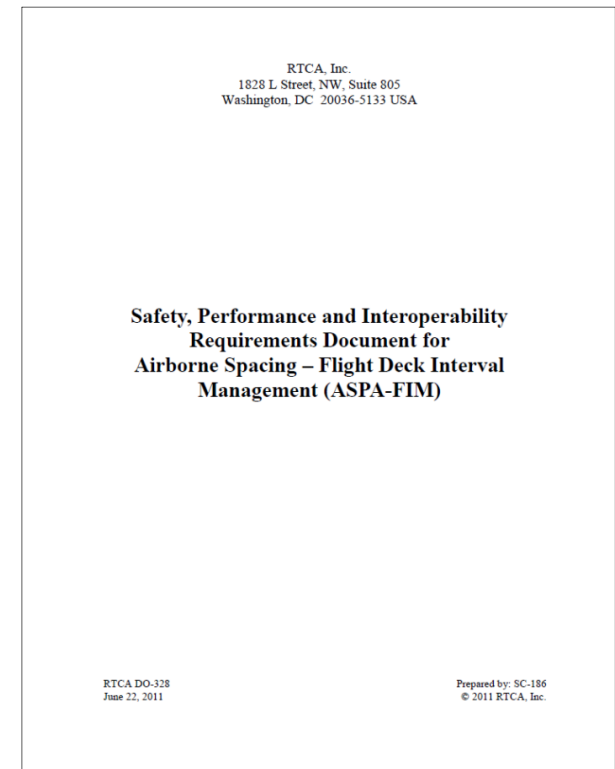
- FAA-led group to implement IM at Louisville Airport (2004-2009)
 - Guidance on long-term concept
 - Trajectory-based approach and spacing tool
 - Worked with ACSS on algorithm and displays
 - Data collection on-board UPS aircraft (8/2010)
- Conducted a human-in-the-loop study
 - Summer 2008
 - Procedures acceptable for interruptions during operation
 - Energy management of IM and OPD can be challenging
 - OPD design should consider speed control (not just for IM)





Transition of Concept to FAA

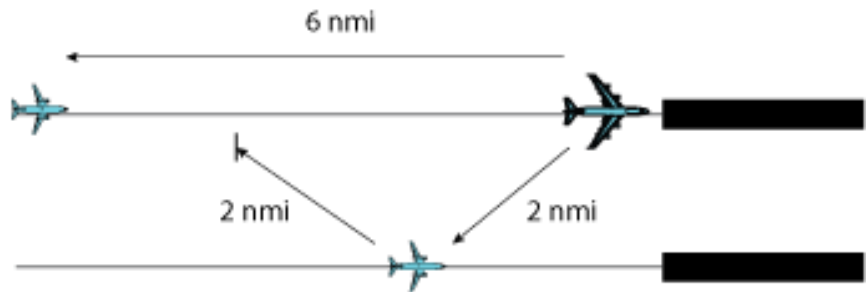
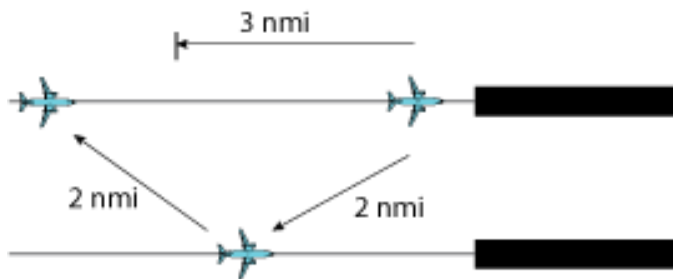
- Major contributors to ASPA-FIM Safety and Performance Requirements
 - RTCA DO-328 / EUROCAE ED-195 (2011)
 - Lead development of OSED (concept description)
 - Contributed to performance analysis
 - Instigated change from limited Sequencing and Merging to FIM
 - Supported datalink (CPDLC) message creation/testing
- Transitioned concept to FAA SBS Office
 - Leading concept development through an interagency agreement



Dependent Runway Operations



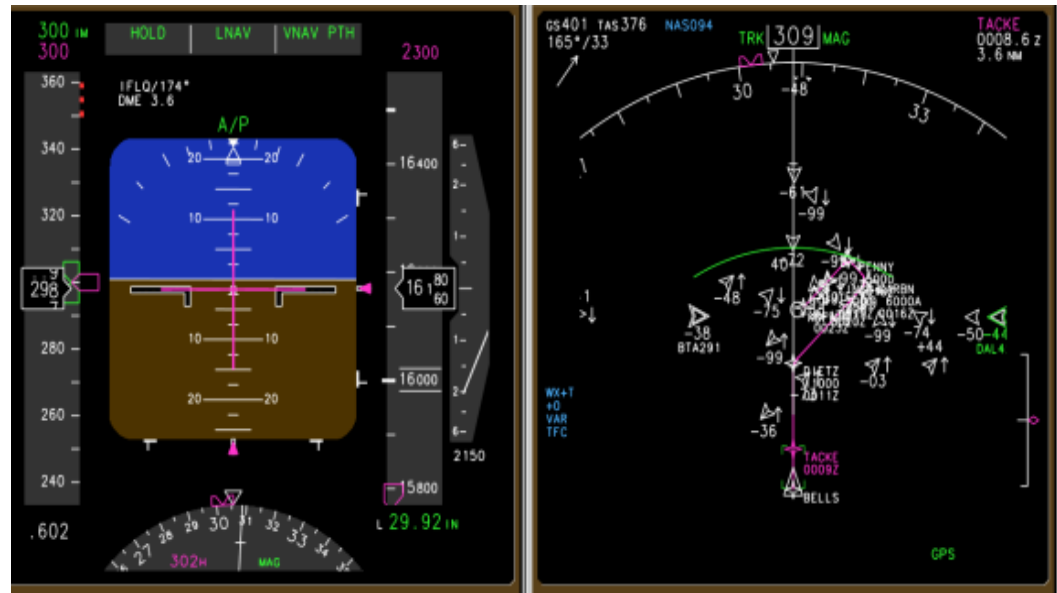
- Suggested that IM could be used for dependent parallel runways
 - Runways separated by 2500 ft or greater can support dependent operations
 - Spacing considers same route and parallel aircraft
 - Deliver aircraft based on both criteria



Dependent Parallel Runways



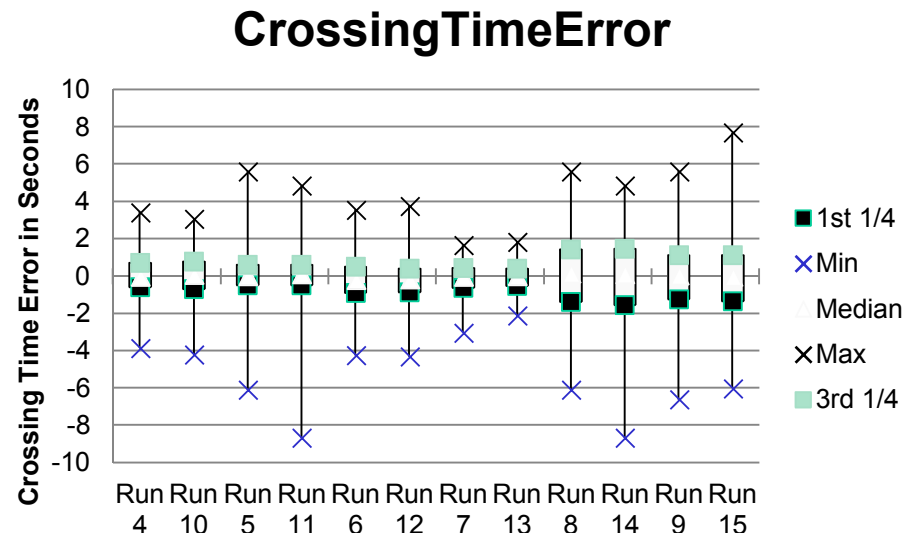
- Developed concept of operations and procedures (2009)
- Modified spacing tool to support operation
- 3 studies (2010 – 2011)
 - Refined spacing goal and criteria
 - Determined need to consider both target aircraft
 - Tested and refined pilot interface
- Facilities
 - Air Traffic Operations Laboratory
 - Cockpit Motion Facility
 - Portable Airspace and Traffic Operations Simulation



Dependent Runway Results



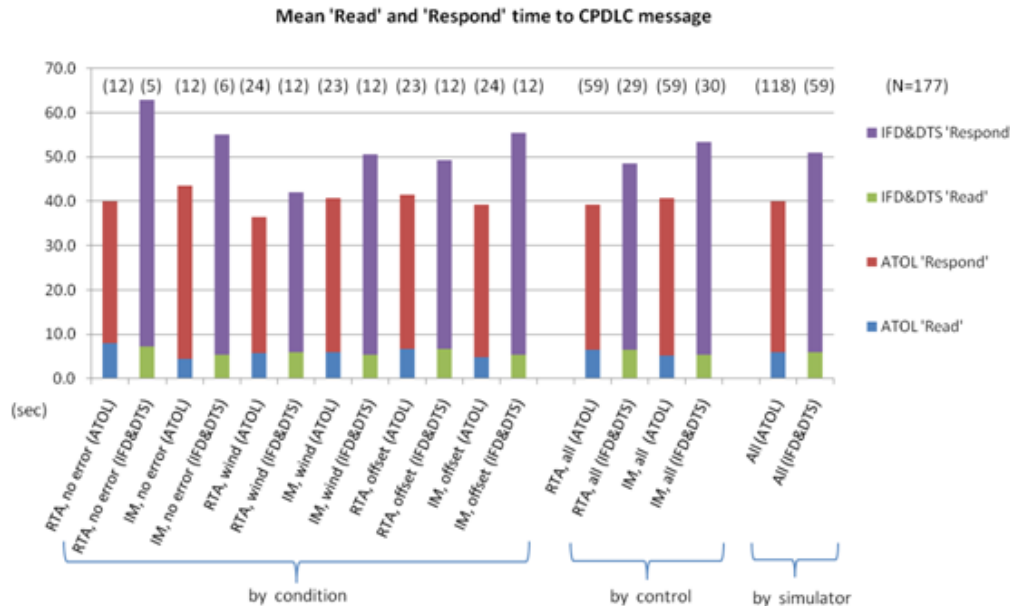
- Clearances are long and require datalink
- Schedule needs to react to actual delivery
- Pilots were generally accepting of operation and found workload to be manageable
 - Concerns about speed changes at low altitude
 - Resulted from trajectory prediction errors due to multiple turns and wind shear
- Not clear the benefits exist to outweigh the complexity of doing this right.



Datalink Results



- Dependent runway study (2011) was used to collect data for datalink standards
 - Measured read and response times
 - As complex of clearance as envisioned for IM
 - Results used for datalink standard (SC-206)



- Winds
 - Conducted in 2009; Air Traffic Operations Laboratory
 - Collected a year's worth of forecasted and recorded winds
 - Selected 8 days covering range of winds
 - Improvement over previous mathematical model for winds
- Use of distance
 - Just completed data collection; Air Traffic Operations Laboratory
 - Not necessarily problem for trajectory-based approach
 - More inline with controller's expectations
 - Corrects for wind and speed errors on the fly
 - Negative feedback on schedule

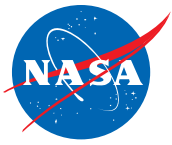
- Fundamental modeling of different control mechanisms (on-going)
 - Rapidly develop and characterize different mechanisms
 - Relative estimated times of arrival (our algorithm)
 - Trajectory-modification
 - Several variations on time-history
 - Can control occurrences of disturbances
 - Useful tool for MOPS analysis
- Most (*not all*) algorithms tested work in nominal conditions
 - Differences are seen in how large of an initial error they can handle
 - State-based algorithms are less susceptible to wind forecast errors
 - But aircraft must be in-trail

Future Plans – Tech Development



- In 2010
 - Elements of NASA research nearing demonstration maturity
 - National R&D Plan, FAA and JPDO Plans updated identifying strong needs for NASA products
 - Stakeholder input and feedback on successes, future goals, and needs align with emerging capabilities
- In 2011
 - OMB and Congress have requested NASA to:
 - Accelerate ATM technology transition, including ADS-B
 - Conduct more relevant flight research emphasizing enhancing aviation safety and airspace efficiency

Future Plans – Tech Development

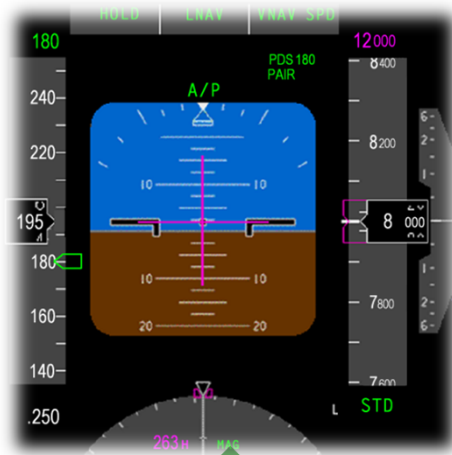


- Air Traffic Management Technology Demonstration – 1
 - Integrating 3 NASA technologies to support advanced arrival operations for the mid-term NAS
 - Flight-deck Based Interval Management w/ASTAR (FIM)
 - Traffic Management Advisor with Terminal Metering (TMA-TM)
 - Controller Managed Spacing (CMS)
 - Partnering with FAA and industry stakeholders
 - Culminates in operational demonstration in 2015

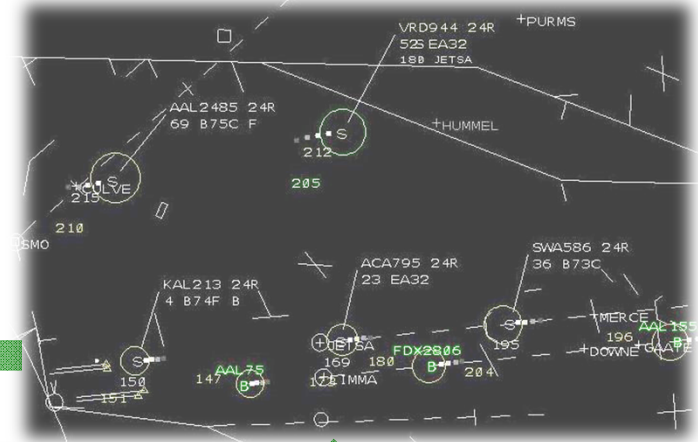
Future Plans – ATD1 Components



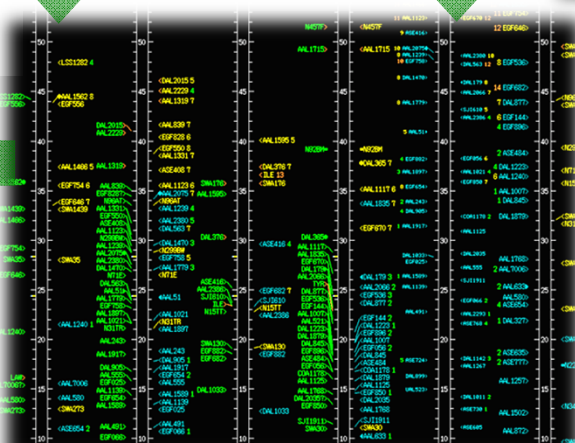
Flight Deck Interval Management (FIM) to Runway Threshold



Controller Managed Spacing (CMS) in Terminal Airspace

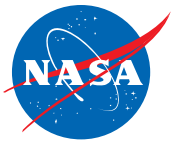


Integrated Arrival Solution



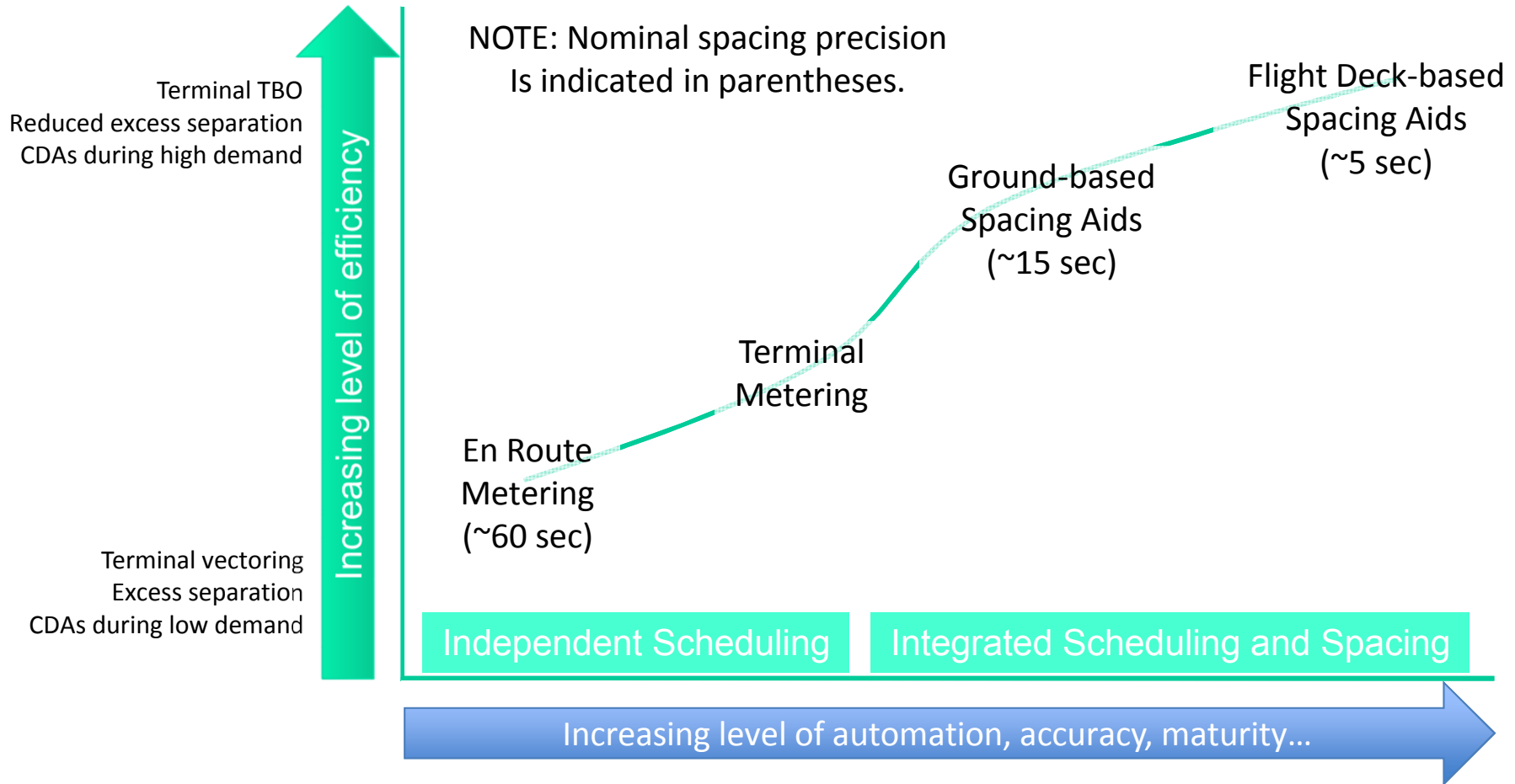
Traffic Management Advisor with Terminal Metering (TMA-TM)

Future Plans – ATD1 Objectives



- Demonstrate consistent and increased use of Performance-Based Navigation (PBN)
 - RNAV/RNP arrival procedures from cruise to touchdown
 - Optimized Profile Descents (OPD) using speed control
 - Simultaneous high throughput and fuel-efficient terminal ops
- Demonstrate ADS-B In Spacing Application
 - Langley ADS-B In merging and spacing algorithm (ASTAR)
- Accelerate transfer of NASA scheduling and spacing technologies for inclusion in late mid-term NAS
 - Terminal metering based upon Ames TMA-TM research
 - Airborne spacing application based upon Langley ASTAR research
 - Controller spacing tools based upon Ames CMS research

Future Plans – ATD1 Ops Context

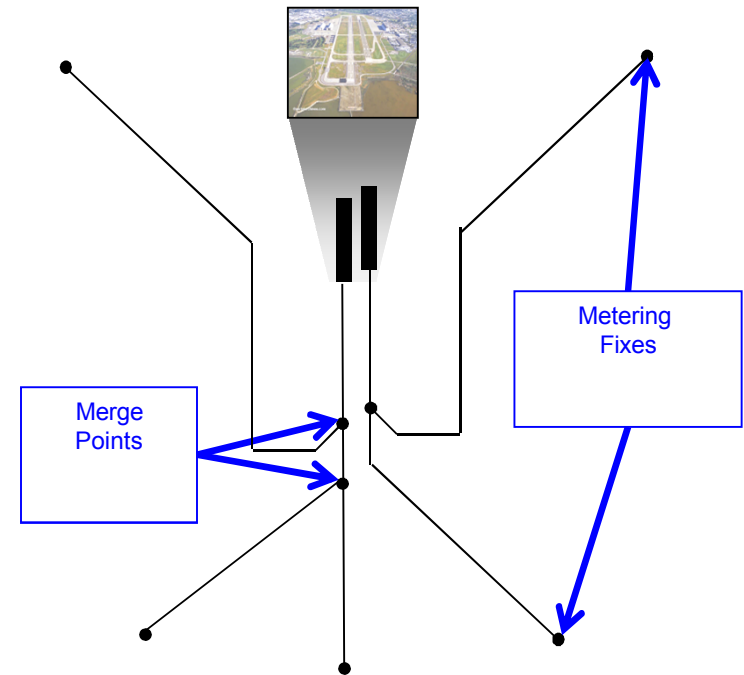


-
- RIVER TWO ARRIVAL**
- NOTE:** DME or RADAR required.
- NOTE:** Expect runway assignment on initial contact with Southern California TRACON. In the event of last communications prior to runway assignment, proceed via ILS RWY 25L.
- LOS ANGELES**
N34° 03' 33.77"
W118° 14' 35.77"
ELEV 336'
- LOS ANGELES TOWER**
N34° 03' 33.77"
W118° 14' 35.77"
ELEV 336'
- LOS ANGELES INTL**
N34° 03' 33.77"
W118° 14' 35.77"
ELEV 336'
- LOS ANGELES R-068**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-069**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-070**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-071**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-072**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-073**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-074**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-075**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-076**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-077**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-078**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-079**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-080**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-081**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-082**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-083**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-084**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-085**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-086**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-087**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-088**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-089**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-090**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-091**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-092**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-093**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-094**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-095**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-096**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-097**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-098**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-099**
N34° 03' 33.77"
W118° 14' 35.77"
- LOS ANGELES R-100**
N34° 03' 33.77"
W118° 14' 35.77"
- HECTOR**
N34° 03' 33.77"
W118° 14' 35.77"
- BUGGA**
N34° 03' 33.77"
W118° 14' 35.77"
- DYFSS**
N34° 03' 33.77"
W118° 14' 35.77"
- HABSO**
N34° 03' 33.77"
W118° 14' 35.77"
- RUSTI**
N34° 03' 33.77"
W118° 14' 35.77"
- PAGSD**
N34° 03' 33.77"
W118° 14' 35.77"
- GRAMM**
N34° 03' 33.77"
W118° 14' 35.77"
- ETINE**
N34° 03' 33.77"
W118° 14' 35.77"
- DIKES**
N34° 03' 33.77"
W118° 14' 35.77"
- NOTICE:** Chart not to scale.
- HECTOR TRANSITION (HEC.RIVR2):** From over HEC VORTAC, via HEC R-203 and PDZ R-046 to RUSTI, then via LAX R-068 to RIVR.
- PEACH SPRINGS TRANSITION (PGS.RIVR2):** From over PGS VORTAC, via PGS R-204 and R-046 to RUSTI, then via LAX R-068 to RIVR.
- WEST GARET INTERCOM:** In the event of last communications prior to runway assignment, proceed via ILS RWY 25L.

Future Plans – ATD1 Scheduling



- Precision route structure to runways
 - Mostly RNAV OPD arrivals
 - Primarily speed control past top-of-descent
- Enhanced TMA Scheduler
 - Terminal metering compatible with Interval Management and RTA operations
- Controller decision support
 - Timelines to meter points
 - TMA information displayed to en-route and terminal controllers

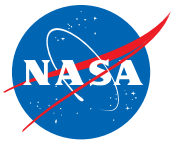


Future Plans – ATD1 Collaboration



- FAA
 - SBS
 - GIM-S IOC
 - MOPS Development
 - Op Evals
 - Phraseology
 - TBFM
 - Extended Metering IOC
 - Speed Advisories
 - Terminal Metering
 - Trajectory Modeling
 - Delay Countdown Timer (DCT)
 - RNP HITL3
 - TAMR
 - Chief Architect
 - William J. Hughes Technical Center
 - Technology Transfer
 - Engagement Team

Future Plans – ATD1 Collaboration



- Industry
 - Raytheon
 - STARS Prototype with CMS Functionality
 - Lockheed Martin
 - TMA Prototype Terminal Metering and Speed Advisories
 - Boeing
 - ASTAR Research
 - SBS/Industry Adhoc Working Group
 - Airlines for America (A4A)
 - RTCA Standards Development

Future Plans – ATD1 IM Activities

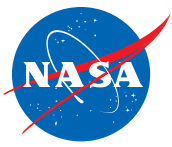


- Develop a Concept of Operations for terminal metering including IM
- Design, build, and integrate a prototype FIM system
- Enhance ASTAR algorithm to support technology development
- Integrate and evaluate FIM with ground automation tools (TMA and CMS)
- Develop recommendations for FIM display and alerting requirements
- Develop, evaluate and refine pilot and controller FIM procedures in a mixed-equipage environment
- Coordinate with the FAA ANG, SBS, TBFM, TAMR, Aircraft Certification and Tech Transfer Offices

Future Plans – ATD1 IM Activities

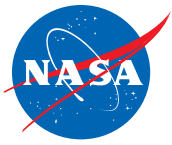


- Identify participating aircraft for demonstration
- Lead technical discussions with aircraft operators, airframe, and avionics stakeholders
- Conduct a series of analyses to support the demonstration (cost, schedule, business, technical)
- Contribute to the FIM MOPS Development
- Participate with industry groups on standards development
- Demonstrate integrated capabilities (TBFM+FIM+GIM, Enroute+Terminal) in an operational environment in FY2015



- Continue fundamental modeling
 - Model more algorithms
 - Test responses to more types of disruptions
 - Answer MOPS questions
 - Collaborate with MITRE and FAA
- Testing of Interval Management with Defined Interval concept
- Connection of IM with other applications
 - IM to (enhanced) visual separation
 - IM to Closely Spaced Parallel Runway Operations
 - Weather rerouting
 - Delegated separation
 - Wake mitigation

Future Plans – FAA support



- Agreement to support MOPS development
 - Starting now through end 2013
 - Participation in RTCA SC186
 - Define Requirements
 - Provide Subject Matter Expertise
- Lead development of IM Conops for SBS Office
 - Define baseline for all of IM through 2020
 - Define IM- Defined Interval
 - Use of IM outside arrival and approach
 - IM to support Closely Spaced Parallel Runway Operations
- Conducting experiment on data placement and attention directing
 - Responding to questions from SBS, AVS and HF
 - Placement of information
 - Notifications and alerts
 - Support MOPS requirements

- After many years of R&D, FAA and industry are moving forward with implementing APS/IM.
 - We have, are and will continue to support this transition
 - ATM Technology Demonstration is NASA Aeronautics highest priority
- We have, and will continue to have, a leading role in defining the future of IM through our concept development, research and prototype development.

Team Composition

- Skill Mix (Example)
 - Air Traffic Management
 - Automated systems design
 - Aviation operation concept and procedure development
 - Avionics systems & architectures
 - Crew/vehicle interaction technologies
 - Electrical Engineering
 - Flight management
 - Flight operations
 - Human/Automation Integration
 - Physical & system modeling
 - Simulation and flight testing
 - Software development
 - Systems Engineering
 - Trajectory generation in the airspace system
- Workforce (Example)
 - ~5-7 FTE (historical average)
 - ~10 WYE (supporting research activities, automation development, and simulation infrastructure development)
 - ATD-1
 - 9 FTE
 - 16 WYE

Questions?



Backup Charts

Basic Slide Format

