Automatic Dependent Surveillance-Broadcast (ADS-B) Advanced Applications: Merging and Spacing Effort

ASAS-TN2 Fourth Workshop
ASAS: A Reality Check
Amsterdam, the Netherlands

Randall Bone

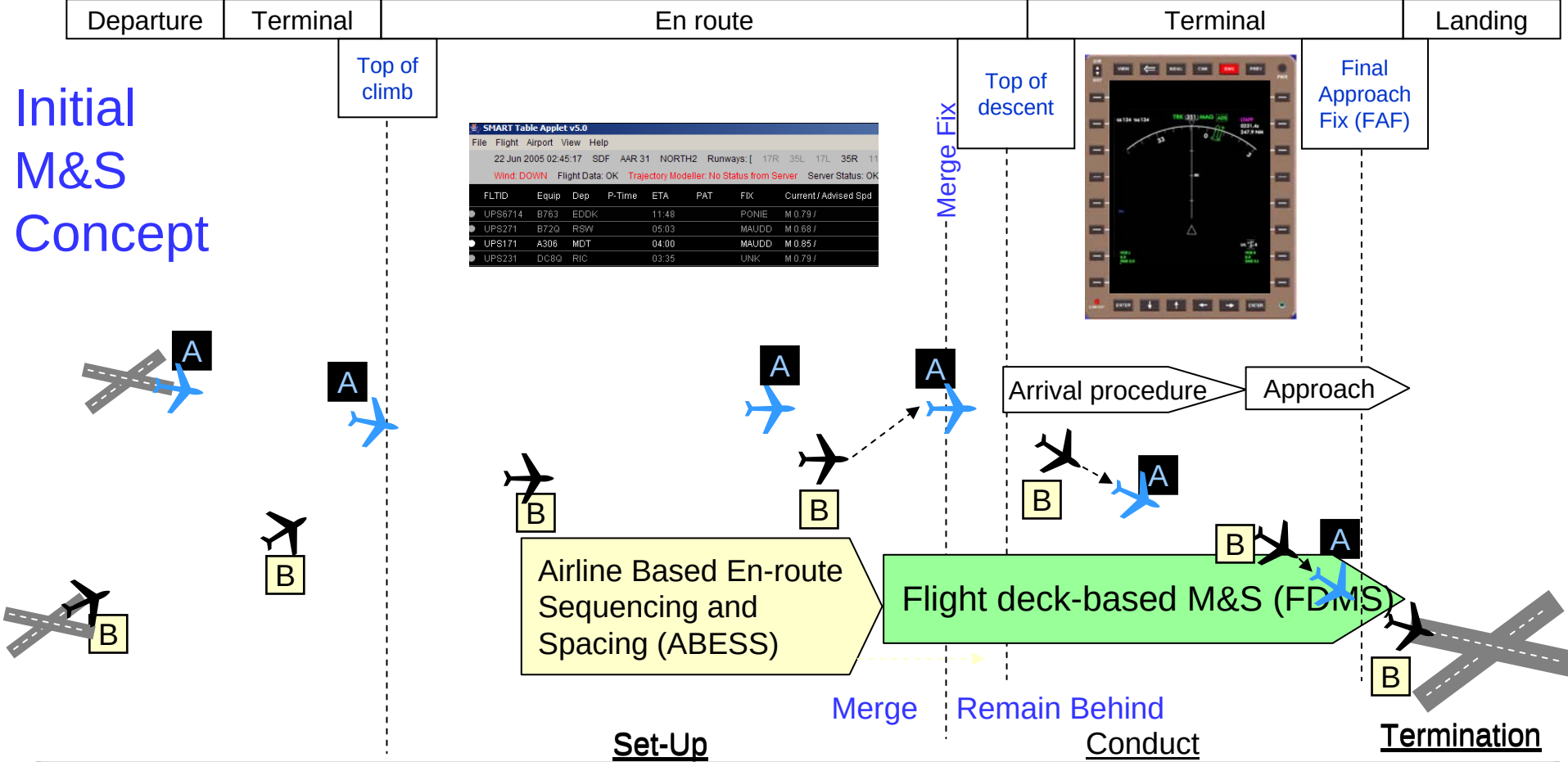
William Penhallegon

April 24, 2007

Outline

- Merging and Spacing (M&S) Concept and Activities
- MITRE Flight Deck-Based Merging and Spacing (FDMS) Human-in-the-loop (HITL) Simulations
- Future Activities

Merging and Spacing (M&S) Concept and Activities



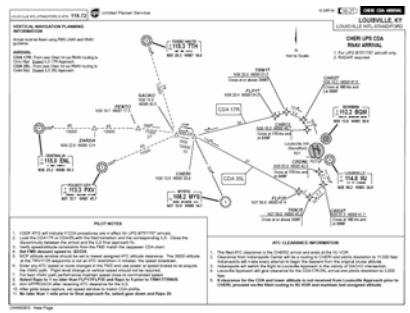
Goal	Strategic arrival sequence and spacing at merge fix and setup for FDMS.	Fine-tuned arrival and landing spacing.
Airline operations center (AOC) role	Use new tool to provide speed advisories via Aircraft Communications Addressing and Reporting System (ACARS) targeting spacing at merge fix.	No new tasks.
Flight deck role	Fly speed provided by AOC until transition to FDMS.	Start flying FDMS speeds and continue until the FAF. At FAF, fly planned final approach speed until landing. Continually monitor for annunciated failures / conditions.
ATC Role	Ensure safe separation as well as to monitor operation with interventions as necessary for spacing or conflicts.	Ensure safe separation as well as to monitor operation with interventions as necessary for spacing or conflicts.

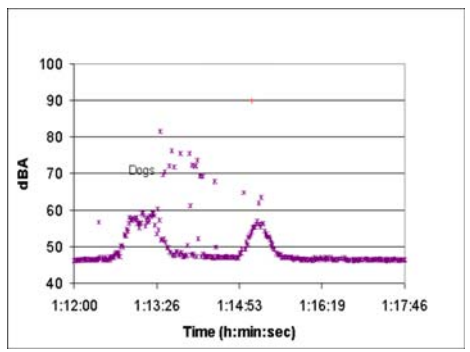
FDMS Concept Development

- Being developed by FDMS Development Group
- Led by Federal Aviation Administration (FAA) Surveillance and Broadcast Services Program Office
- Participation from Airbus, Airline Pilots Association, Aviation Communication & Surveillance Systems (ACSS), Boeing, CENA, Eurocontrol, FAA, Honeywell, Independent Pilots Association, MITRE, NASA, VOLPE, UPS etc.
- Initial concept is being developed as a spacing application for low density airspace as well as one merge fix, one arrival, and one approach to one runway
  - Benefits expected
    - Reduced: High speed / high altitude vectoring, communication, controller workload, fuel burn, time and distance flown
    - Increased: Accuracy and consistency in arrival spacing and traffic awareness
- Later implementations are being planned for and considered in early development activities
  - Higher density, multiple merges, multiple airlines, ATC utilizes spacing / sequencing tool, etc.

UPS Related Activities

- UPS 757 / 767 aircraft currently equipped with ADS-B and a Cockpit Display of Traffic Information (CDTI) for traffic awareness
- UPS plans to implement Continuous Descent Arrivals (CDAs) in 2007
- Want to build from traffic awareness and CDAs
- FDMS is initially planned in UPS late-night, low density environment
  - Ideal test bed due to low density, one airline operations
- ACSS is building flight deck equipment with the intent to implement FDMS in 2007





Sample Past / On-Going Efforts On Similar Concepts

- Eurocontrol
  - Co-Space / Sequencing and Merging
- NASA
  - Terminal Arrival: Self-Spacing for Merging and In-Trail Separation / Concept Element-11
  - Trajectory-Oriented Operations With Limited Delegation (TOOWiLD)
  - Airborne Precision Spacing (APS) / Airborne Merging and Spacing for Terminal Arrivals (AMSTAR)
- FAA / RTCA
  - Initial and final approach spacing
- Package 1

Development Activities for Operational Approval

- Concept, display, and safety and performance requirements
  - Application Description v1.5 released April 2007
  - Preliminary Hazard Assessment v2 released April 2007
- Simulations and demonstrations for human factors evaluation and proof of concept
  - Three Human-in-the-loop (HITL) simulations complete. One is being planned.
  - Demonstrations conducted for ACSS, UPS, and FAA
- Algorithm performance testing / validation / fast time simulation
  - Fast time analysis on-going
  - Flight tests on-going
- Procedures
  - Being examined in simulations
- Training requirements
  - Under development by UPS
- Avionics procurement and installation
  - On-going with UPS and ACSS
- Operational approval activities
  - On-going with FAA, UPS, and ACSS

MITRE Flight Deck-Based Merging and Spacing (FDMS) Human-in-the-loop (HITL) Simulations

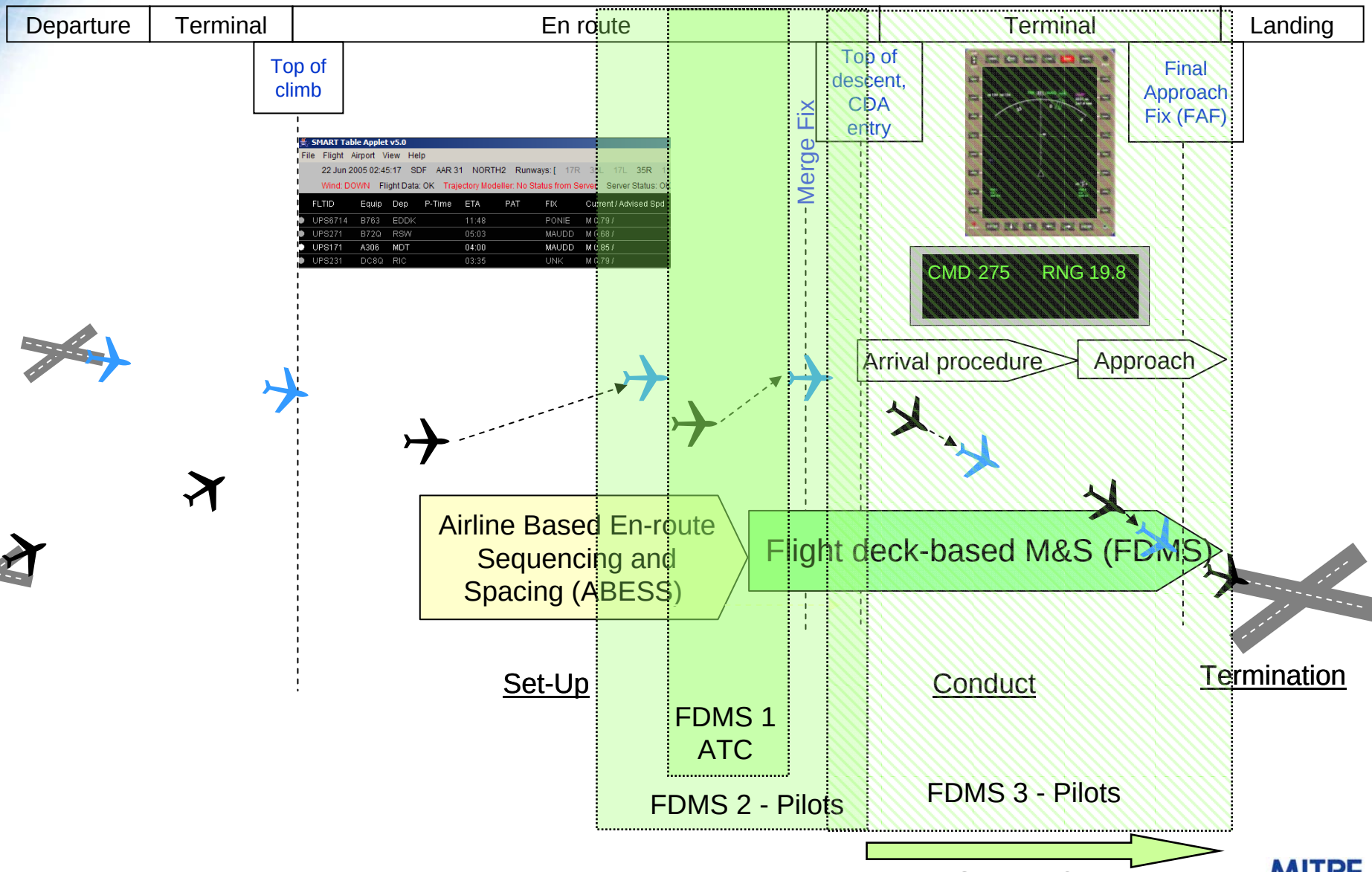
Simulation Purpose

- Provide an initial validation of the FDMS application description
- Evaluate FDMS acceptability
  - Controller monitoring and interventions
  - Information requirements
  - Cockpit display locations, formats, and symbology
  - Communications
  - Workload
- Continue to mature procedures, roles, and responsibilities during nominal and non-nominal operations

Simulation Overview

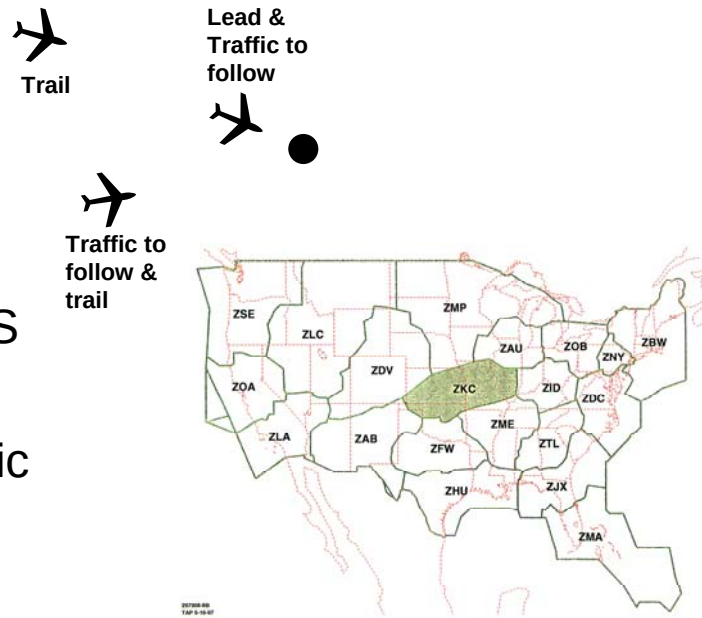
- Three simulations completed
- One simulation is being planned for May 2007
- Simulations either focus on ATC or flight crew but not both in same simulation
- All simulations used flight deck-based speed changes based on Eurocontrol / Co-Space derived algorithm
- Flight crew simulations used UPS / ACSS planned cockpit implementation
- No new controller tools were introduced

Simulation Domains



FDMS Simulation 1 – Design

- Domain
  - En route, merge environment
- Purpose
  - Continue concept maturation and validation
  - Evaluate en route ATC acceptability of FDMS
- Procedure
  - One controller per day controlled FDMS traffic under five scenarios and then completed questionnaires
- Participants
  - Eight current or recently retired en route controllers (some from Kansas City Center)
- Simulation environment
  - Kansas City Center airspace
- Scenarios
  - Baseline, FDMS “nominal”, and FDMS “non-nominal” (overtake, suspension, complete termination)

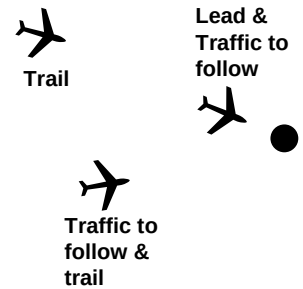


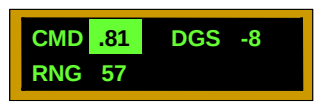
FDMS Simulation 1 – Results and Conclusions

- FDMS is generally acceptable
  - Based on feedback from topics such as situation awareness, communications, workload, and efficiency
- FDMS compared to current day operations had…
  - Lower workload
  - Fewer controller instructions / interventions
    - No increase in number of speed instructions
  - Less communications
  - Reduced time in sector
- Non-nominal situations were sufficiently resolved
  - Detected overtake and resolved overtake, suspension, and termination
- Sufficient information was available from current equipment
  - Knowledge of sequence may have been helpful
- Some concerns about complacency expressed but no problems realized
  - No separation violations
- Future work needs to clearly define procedures and intervention strategies

FDMS Simulation 2 – Design

- Domain
  - En route, merge and in-trail environment
- Purpose
  - Continue concept / procedure maturation and validation
  - Evaluate pilot acceptability of FDMS during merge
- Procedure
  - One pilot per day flew FDMS as pilot flying under eight scenarios and then completed questionnaires
- Participants
  - Ten current air transport pilots
- Simulation environment
  - ATM Lab flight deck simulator with Electronic Flight Bag (EFB) CDTI, Traffic alert and Collision Avoidance System (TCAS) only display, and ADS-B Guidance Display (AGD)
- Scenarios
  - Baseline, FDMS “nominal”, FDMS “non-nominal” (e.g., overtake, incorrect aircraft identified as the aircraft to follow), no CDTI for participant, and new AGD fields

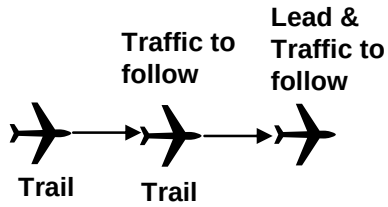




FDMS Simulation 2 – Results and Conclusions

- FDMS was acceptable and desirable
  - Based on feedback from topics such as traffic awareness, workload, communication requirements, and display features
- FDMS increased workload slightly over current operations
  - Remained acceptable
- FDMS improved operational efficiency
- Non-nominal situations were sufficiently resolved
  - Detected wrong traffic to follow and convergence conditions
- AGD location acceptable and the specific EFB / CDTI location suboptimal but acceptable
  - Time estimated to be split about evenly between CDTI and AGD
  - Time spend looking at the CDTI should be reduced
- Current flight crew coordination procedures were sufficient
- The target interval was delivered at the merge fix, on average across the scenarios by the algorithm, within about two seconds
- Flight crew needs to have spacing parameters that support trust in the algorithm and understanding of its functionality
- Clear procedures need to be defined for non-nominal conditions
  - Speed responsibility after disengagement needs clarification
  - Procedures for resolving incorrect identification of traffic to follow need clarification

FDMS Simulation 3 – Design



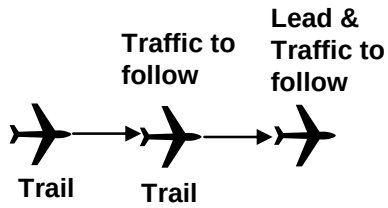
- Domain
  - En route to landing, remain behind
- Purpose
  - Continue concept / procedure maturation and validation
  - Evaluate pilot acceptability of FDMS during descent to landing
- Procedure
  - One pilot per 1.5 days flew FDMS as pilot flying during CDAs under eight scenarios and then completed questionnaires
- Participants
  - Nine current air transport pilots
- Simulation environment
  - ATM Lab flight deck simulator with EFB CDTI, TCAS only display, and AGD
- Scenarios
  - Baseline, FDMS “nominal” (3 times, one under high workload), FDMS “non-nominal” (i.e., disengage / re-engage, overtake / speed cap), no CDTI for participant, CDTI on navigation display

FDMS Simulation 3 – *Preliminary* Results and Conclusions

- In general, FDMS was acceptable and desirable
  - Based on feedback from topics such as traffic awareness, workload, communication requirements, and display features
- On average, FDMS had same workload as current operations
  - Terminal operations were not as workload intensive as was predicted
  - FDMS was acceptable from en route to Final Approach Fix (FAF)
- FDMS improved operational efficiency
- Non-nominal situations were sufficiently resolved
  - Some variability on replies related to when to act on non-nominal
- AGD location acceptable and the specific EFB / CDTI location suboptimal but acceptable
- Current flight crew coordination procedures were sufficient
- Less time was spent viewing the CDTI versus AGD
  - Based on defining the flight crew procedures as following speed commands and detecting and acting upon annunciated failures
- Flight crew needs to have sufficient training in the algorithm and its functionality
  - Acceptable number of speed commands needs to be implemented

FDMS Simulation 4 – Planned Design

- Domain
  - En route to landing, remain behind
- Purpose
  - Continue concept / procedure maturation and validation
  - Evaluate controller acceptability of FDMS during descent and in the terminal area
- Procedure
  - One en route controller and one terminal controller per 2 days controlling FDMS traffic under ~ 9 scenarios and then completing questionnaires
- Participants
  - Approximately 20 current or recently retired en route and terminal controllers planned
- Simulation environment
  - Indianapolis Center and Louisville Terminal airspace
- Scenarios
  - Baseline, FDMS “nominal”, and FDMS “non-nominal” (overtake, spacing error, suspension, and complete termination)
  - Varying levels of phraseology introduced



Future Activities

Future Activities

- Completion of simulations, application description, and preliminary hazard analysis
  - Including recommended communications and procedures
- On-going flight tests
- ACSS certification of equipment
- UPS operational approval
- Field demonstration planned for by UPS in late August 2007
- Validation activities
- Initiation of activities for later implementations
  - Advanced algorithm
  - Multiple arrival streams

For More Information…

- On MITRE FDMS simulation activities and more detailed results, contact…
  - Randy Bone at bone@mitre.org
- On FDMS in general and FAA flight deck application activities under the Surveillance and Broadcast Services Program Office, contact…
  - John Marksteiner at john.marksteiner@faa.gov

CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT

The views, opinions and/or findings contained in this report are those of The MITRE Corporation and should not be construed as an official Government position, policy, or decision, unless designated by other documentation.

MITRE