R&D to Reduce the Adverse Impact of Weather on Air Traffic Management Decisions

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Friends/Partners In Aviation Weather Vision Forum

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R&D Challenges for Mobility

- Shortfalls associated with the state-of-the-art will have to be overcome to achieve mobility during the decades ahead. Some of the major challenges addressed by the Airspace Systems Program include:
  - Reducing separation distances between aircraft to increase traffic density and determining functions that can be moved to the cockpit to improve operations without compromising safety.
  - Dynamically balancing airspace capacity to meet demand by allocating airspace resources and reducing adverse impacts associated with weather.
  - Increasing airport approach, surface, and departure capacity.
  - Defining appropriate roles for humans (notably air traffic controllers and pilots) in relation to automation, and developing automation that humans can reliably and fluidly interact with, monitor, and, when appropriate, override.

Program Research Focus Areas

NextGen - Airportal

- Safe & Efficient Surface Operations
- Coordinated Arrival/Departure Operations
- Airportal Transition and Integration Management

NextGen - Airspace

- Dynamic Airspace Configuration
- Traffic Flow Management
- Separation Assurance
- Super Density Operations
- Performance-Based Services
- Trajectory Prediction, Synthesis & Uncertainty
- System-Level Design, Analysis & Simulation Tools

- Both projects conduct system-level design and analysis.
- Results of the two projects are integrated to ensure gate-to-gate solutions that are aligned with NextGen needs.

R&D Challenges for Weather Data Integration

- A key component of air traffic management research will be to understand uncertainties due to weather.
- A common weather picture (shared situational awareness) of forecasts and observations from which all weather-related decisions can be made will enable implementation.
- Research areas include:
  – Enhancing situational awareness (in particular enhanced flight deck displays of weather conditions and forecasts).
  – Determining the spatial and temporal resolution and accuracy required to integrate weather information with air traffic management automation systems.
  – Developing real-time verification systems that quantitatively assess the accuracy and reliability of probabilistic weather forecasts including generation of aviation weather parameters: convection, winter storms, icing, turbulence, ceiling, and visibility.
  – Understanding the disparate interpretations of weather information by all stakeholders, and their impact on decision-making processes

Weather Data Integration Research Plan

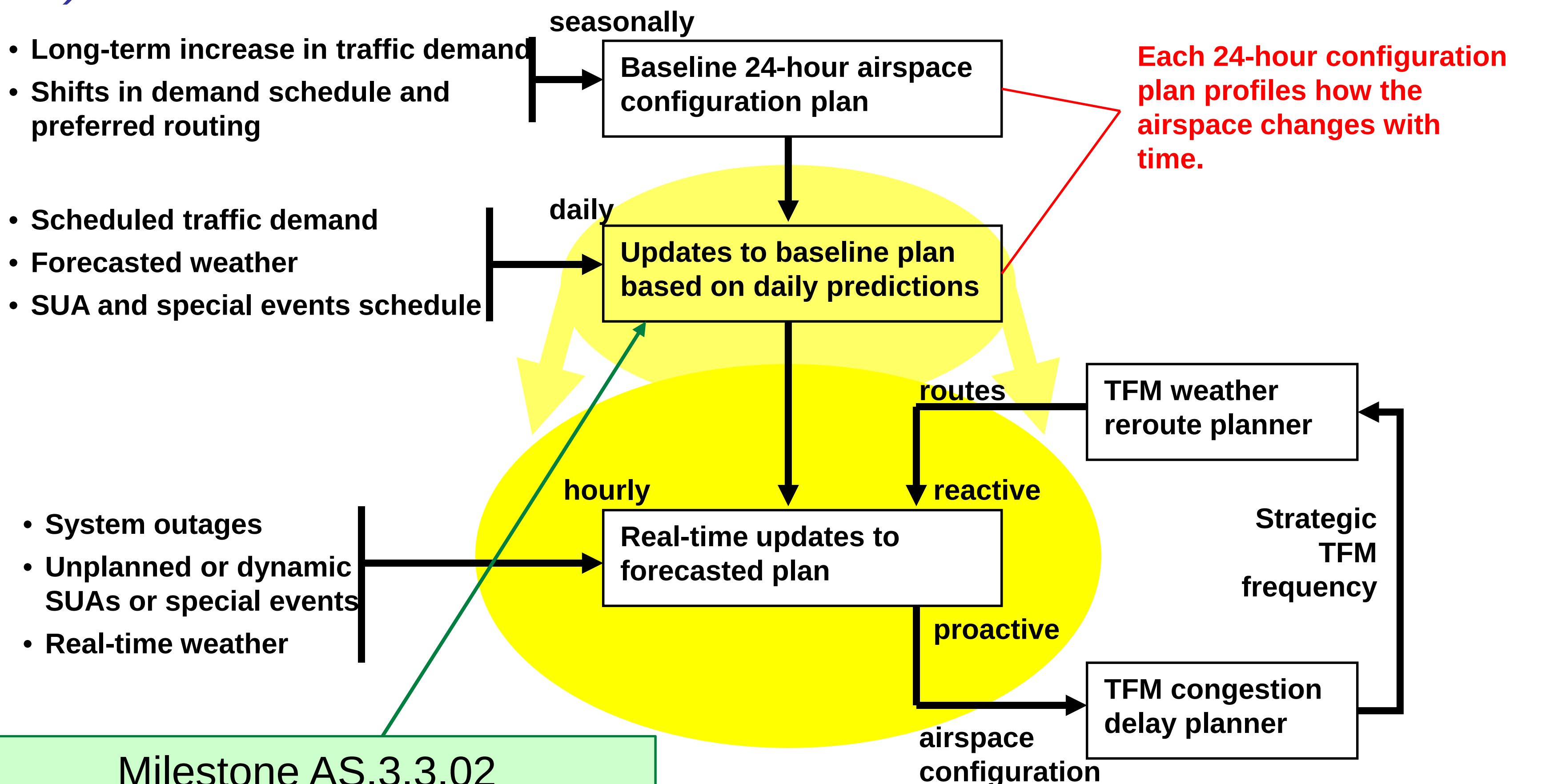
- NASA's Airspace Systems Program conducts weather-related research across the various research focus areas
- Research is also conducted in concert with other Government Agencies and FFRDCs such as,
  - NOAA/NWS Western Region - Support of Research to Correlate Weather and National Airspace Performance
  - MIT Lincoln Lab - Convective Weather Translation Modeling
- In the past two years, more than 12 partnerships were established through NASA Research Announcements (NRA) addressing uncertainty and weather

NRA Partners for Uncertainty and Weather Research

PI Name	Title of Proposal	Organization	Award Date
Michael Ball	DYNAMIC,STOCHASTIC MODELS FOR MANAGING AIR TTRAFFIC FLOWS	University of Maryland	9/30/06
R. John Hansman	OPTIMIZATION OF SUPER-DENSITY MULTI-AIRPORT TERMINAL AREA SYSTEMS IN THE PRESENCE OF UNCERTAINTY	MIT	9/30/06
Steven Landry	ANALYSIS AND DEVELOPMENT OF STRATEGIC AND TACTICAL SEPARATION ASSURANCE ALGORITHMS	Purdue University	9/30/06
Sandip Roy	CONTROL-THEORETIC DESIGN AND NUMERICAL EVALUATION OF TRAFFIC FLOW MANAGEMENT STRATEGIES UNDER UNCERTAINTY	Washington State University	9/30/06
Alexandre Bayen	A UNIFIED APPROACH TO STRATEGIC MODELS AND PERFORMANCE EVALUATION FOR TRAFFIC FLOW MGMT	The Regents of the Univ. CA Berkeley	9/30/06
John-Paul Clarke	APPROACHES TO TFM IN THE PRESENSE OF UNCERTAINTY	Georgia Tech Research Corp.	9/30/06
Jimmy Krozel	Mitigation of Weather Impacts in Dense Terminal Airspace	Metron Aviation, Inc.	11/27/06
Mark Rodgers	The Development of Concepts of Operation and Algorithms to Support Dynamic Airspace Allocation as a Function of Equipage, Traffic Density, and Weather	CSSI, Inc.	8/1/07
Jimmy Krozel	Translation of Weather Information to Traffic Flow Management Impact	Metron Aviation, Inc.	8/22/07
Lara Cook	Modeling Non-Convective Weather Impacts on En Route Traffic Flow Management	Mosaic ATM, Inc.	8/30/07
Daniel Finkelsztein	Weather Scenarios Generator and Server for the Airspace and Traffic Operations Simulation	Raytheon	6/11/08
Mark Peters	Integration of Weather Data into Airspace and Traffic Operations Simulation (ATOS)for Trajectory Based Operations Research	Sensis	7/11/08

Dynamic Airspace Configuration

Dynamic Airspace Configuration (DAC) Information Flow



Milestone AS.3.3.02
Develop an operational framework for dynamic airspace configuration

Dynamic Fixed Posting Including Airspace Playbook Applications

Accomplishments

- Proposed new approach for DAC, using today's FPA concept
  - Create more "FPAs", especially near sector boundaries
  - Share FPAs between sectors dynamically, as needed
  - Do not limit to present FPA layouts
  - Design FPAs that make sense from ATM perspective
- Created initial Airspace Playbook prototype for ZOB/ZID/ZDC
  - Playbook includes 2006 and 2007 convective seasons
  - Focused on Wx/reroute scenarios that impacted ZOB/ZID/ZDC

Who was involved?

- Alexander Klein (ATA), Mark Rodgers (CSSI), Hong Kaing (CSSI)

Lessons Learned

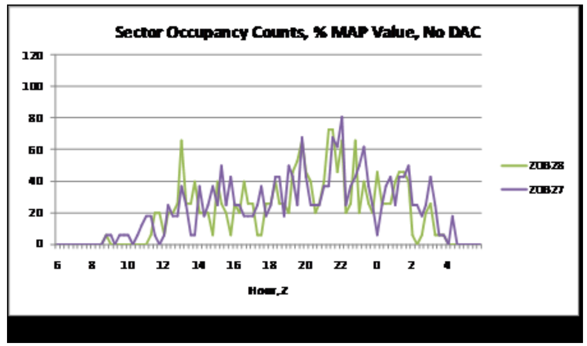
- Controlled sector boundary adjustments in 2D/3D
- Absolute optimum (e.g., completely balanced workload) is <u>not</u> the goal
  - Bring metrics back within required limits
- Easy to retain continuity of DAC process throughout the day
- A bridge from current NAS airspace design to NextGen concepts
  - Uses airspace elements and concepts familiar to current airspace operators and designers
  - Applicable to existing and potential new airspace classes (e.g.,Tubes)

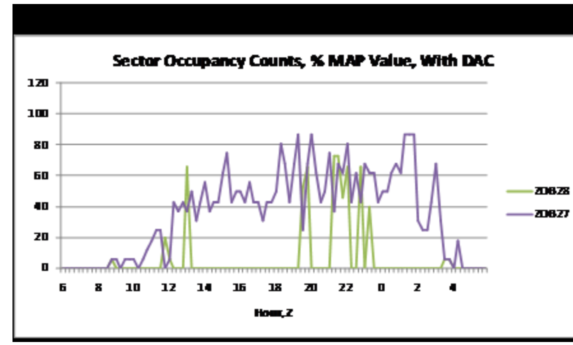
Supported Milestones: AS.3.3.02

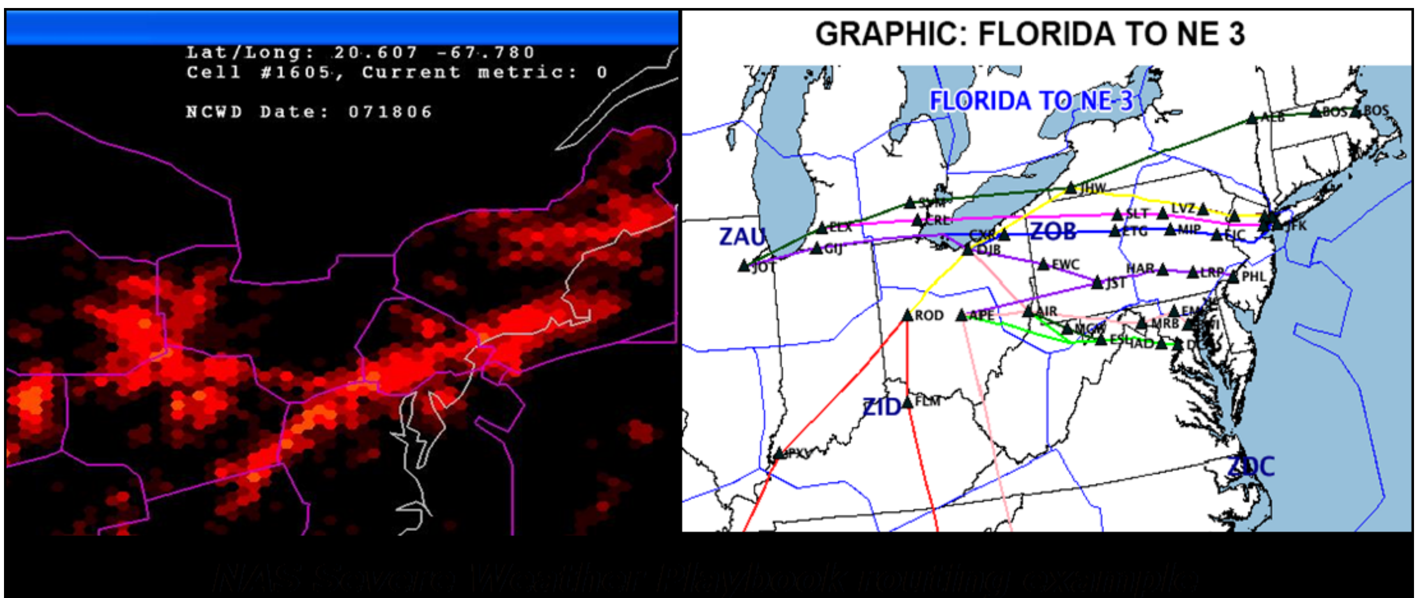
Dynamic Fixed Posting Including Airspace Playbook Applications, cont.

Combining Under-loaded Sectors (Under-loaded vs. Combined sectors)

ZOB Airspace Playbook Example

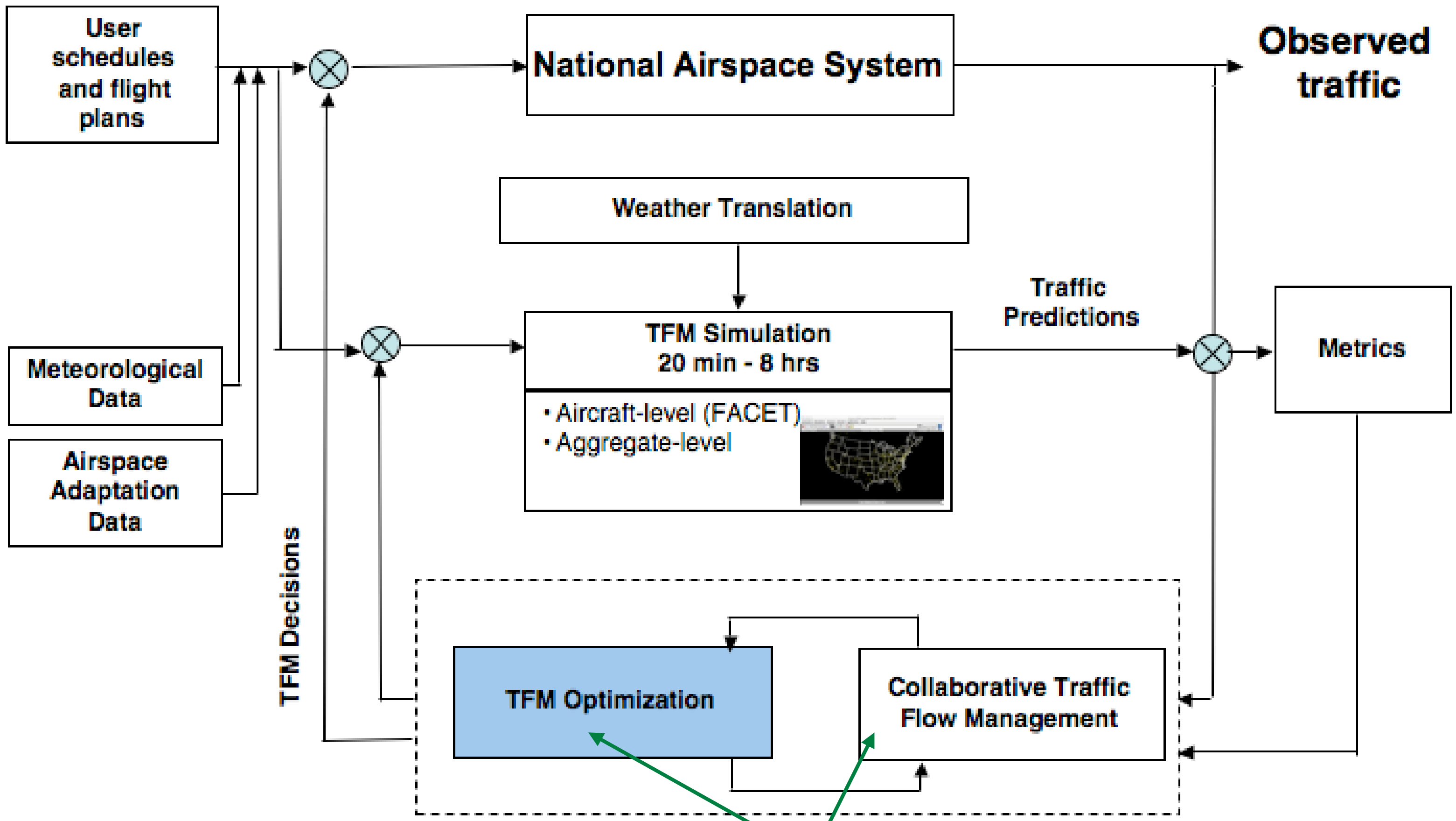






Traffic Flow Management

Traffic Flow Management (TFM) Information Flow



Milestone AS.3.4.01 Develop Traffic Flow Management concepts at national & regional levels

A Model for Determining SFO GDP End Times Using a Probabilistic Forecast of Stratus Clearing

Accomplishments

- Completed study of benefits to be achieved using SFO Stratus Forecast System
  - Translated probabilistic forecast information into optimal GDP end times, using a newly developed stochastic model
  - Gathered actual GDP data
  - Analyzed the reductions in unnecessary ground delay and flights affected using GDP parameters recommended by model
- Developed model to determine SFO GDP end times
  - Generated a cumulative distribution function (CDF) by adding empirical error forecast clearing time
  - 59% (82 minutes) reduction in excess planned GDP minutes
  - Model selected an end time later than clearing time 95% of the time
  - Model selected better end time 90% of the time

Who was involved?

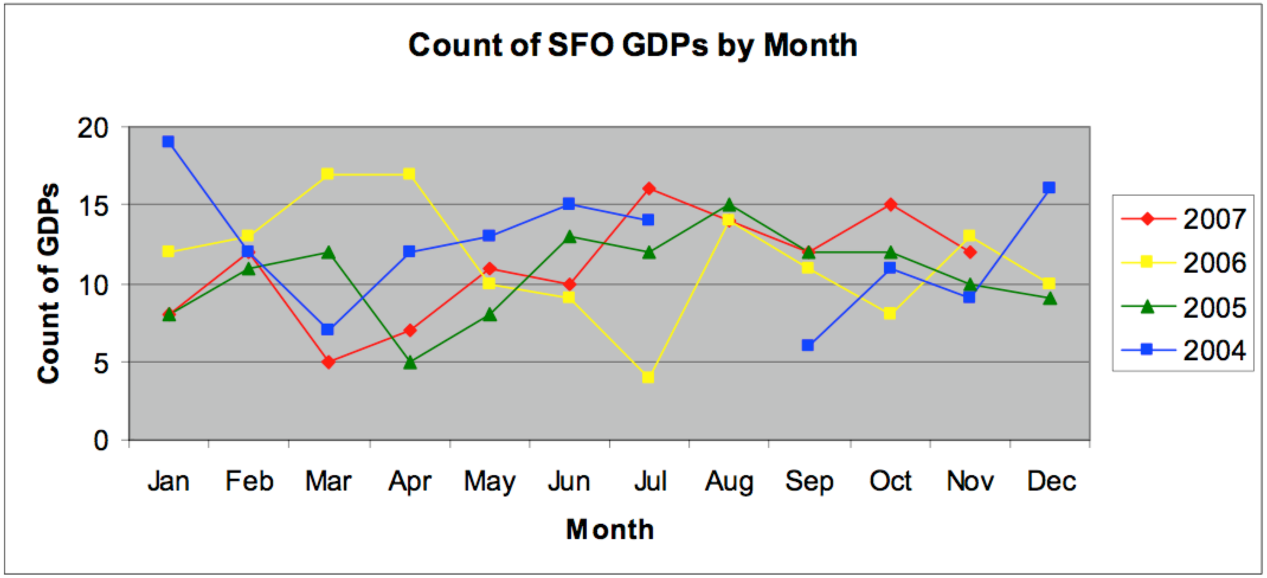
- Lara Cook (Mosaic ATM), Dave Simenauer (Avmet Applications), et al.

Lessons Learned

- One hour resolution is arbitrary and not precise enough to evaluate risks to aviation imposed by forecast error
- With a more precise CDF of forecast error, the risks of forecast error on any proposed GDP can be modeled/simulated

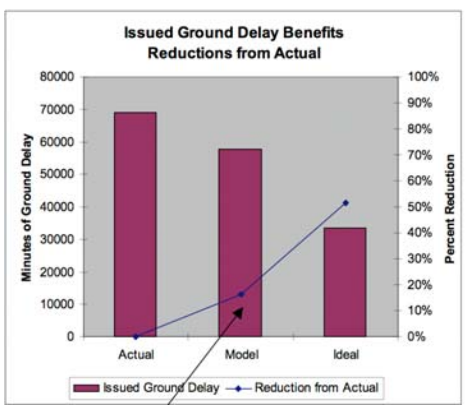
Supported Milestones: AS.3.4.01

A Model for Determining SFO GDP End Times Using a Probabilistic Forecast of Stratus Clearing, cont.

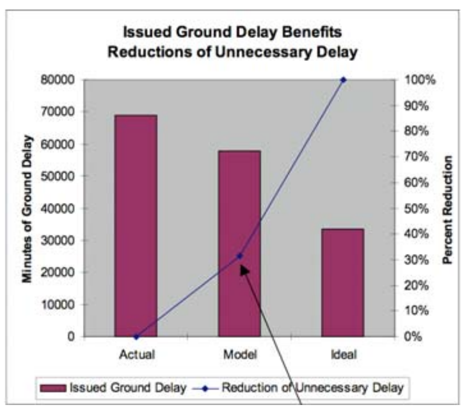


Issued Ground Delay Benefits

(6/10/06 - 8/29/06)



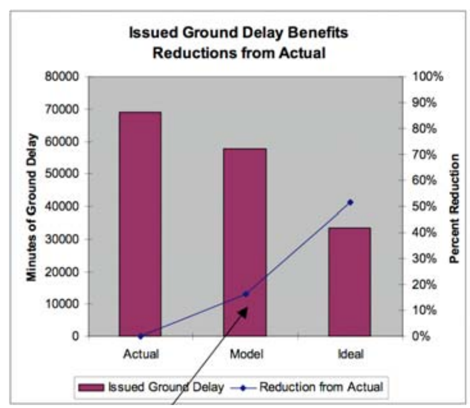
16% reduction in delay



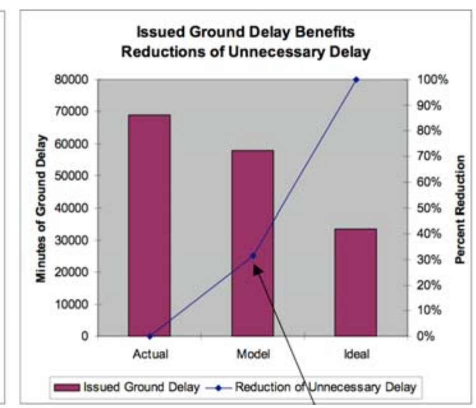
32% reduction in unnecessary delay

Affected Flights Benefits

(6/10/06 - 8/29/06)

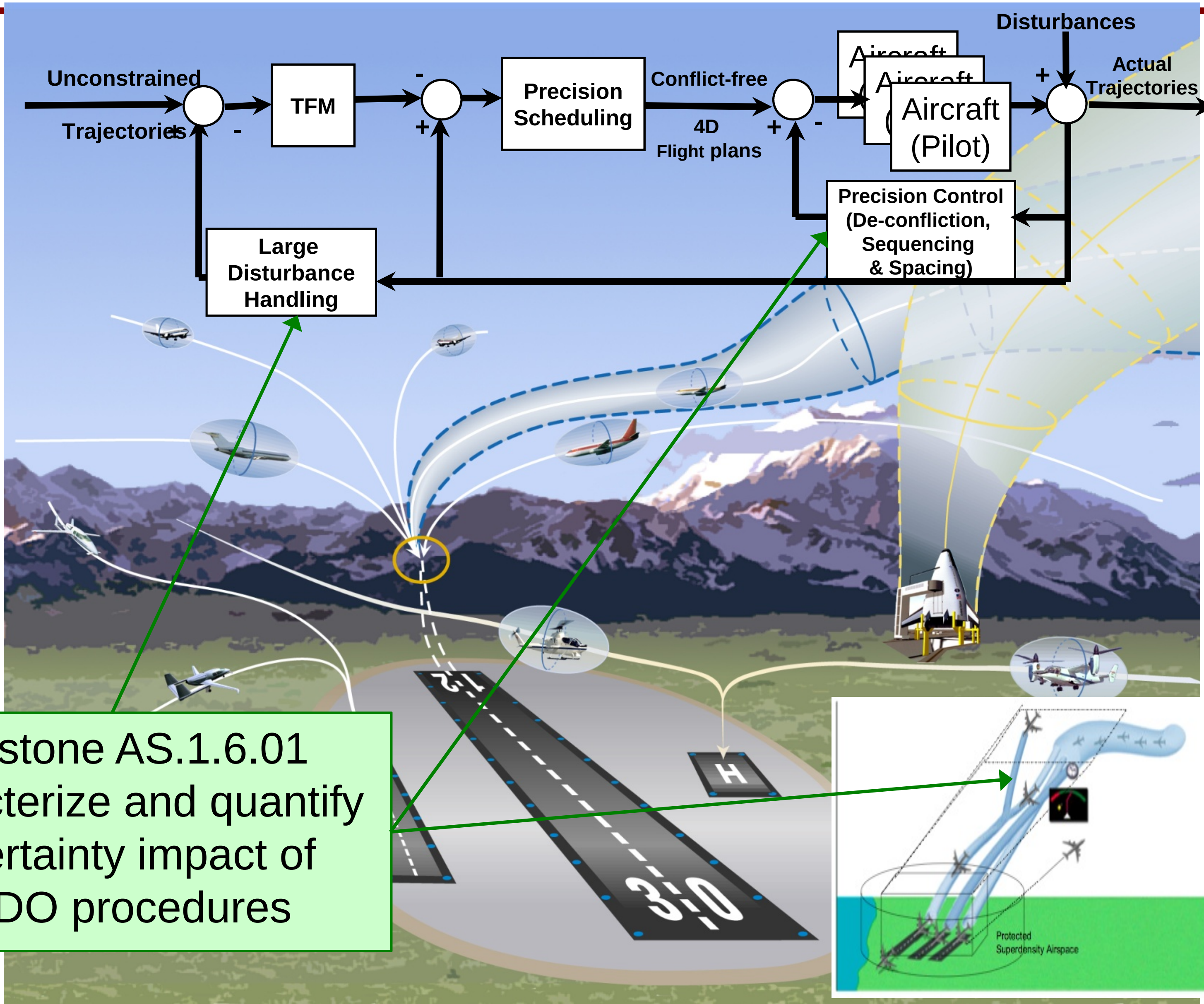


19% reduction in number of flights



41% reduction in unnecessary affected flights

Airspace Super Density Operations



Milestone AS.1.6.01
Characterize and quantify uncertainty impact of ASDO procedures

Optimization of Terminal-Area Operations in the Presence of Uncertainty

Accomplishments

- Developed a framework for arrival/departure scheduling that can optimize a range of objective functions investigating robustness and tradeoffs between metrics (e.g., throughput, delays, fuel burn, fuel costs, etc.)
- Developed approaches to validate and integrate (possibly probabilistic) weather forecasts into the scheduling algorithms
- Investigated implementation issues: controller cognitive complexity studies

Who was involved?

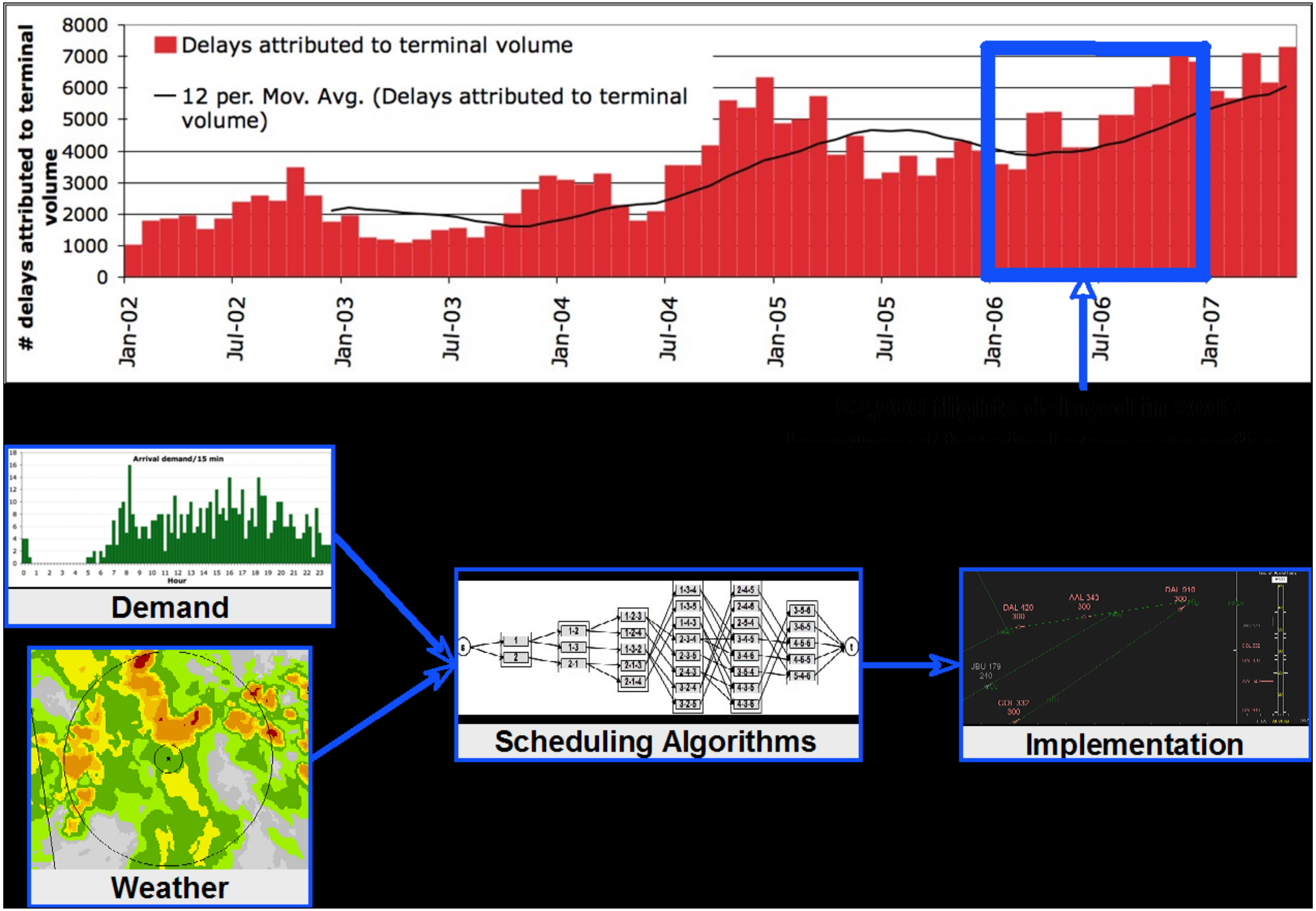
- Hamsa Balakrishnan, John Hansman & Emilio Albuquerque (MIT)

Lessons Learned

- Two types of uncertainty
  - Capacity-side: Uncertain estimates of the possible arrival times of an aircraft at the runway due to the variability in weather, availability of routes, etc.
  - Demand-side: Aircraft may not arrive at the runway or metering fix at the scheduled time because of trajectory uncertainty
- Solutions
  - Robust runway scheduling in the presence of demand and capacity uncertainties
  - Controller cognitive complexity studies and recommendations
  - Probabilistic forecasts using deterministic convective weather forecasts
  - Reduce surface emissions

Supported Milestones: AS.1.6.01

Optimization of Terminal-Area Operations in the Presence of Uncertainty, cont.



Concluding Remarks

- Based on community feedback at our March 2007 Foundational Technical Interchange Meeting, the Program has infused our capacity-focused research portfolio with R&D focused on uncertainty and weather
- Weather-related R&D is embedded across each of our research focus areas and is carried out with our partners
- NASA, together with JPDO and its member Agencies, will continue to refine our plans for integrating weather into ATM decisions