Overview of NASA's Next Generation Air Transportation System (NextGen) Research

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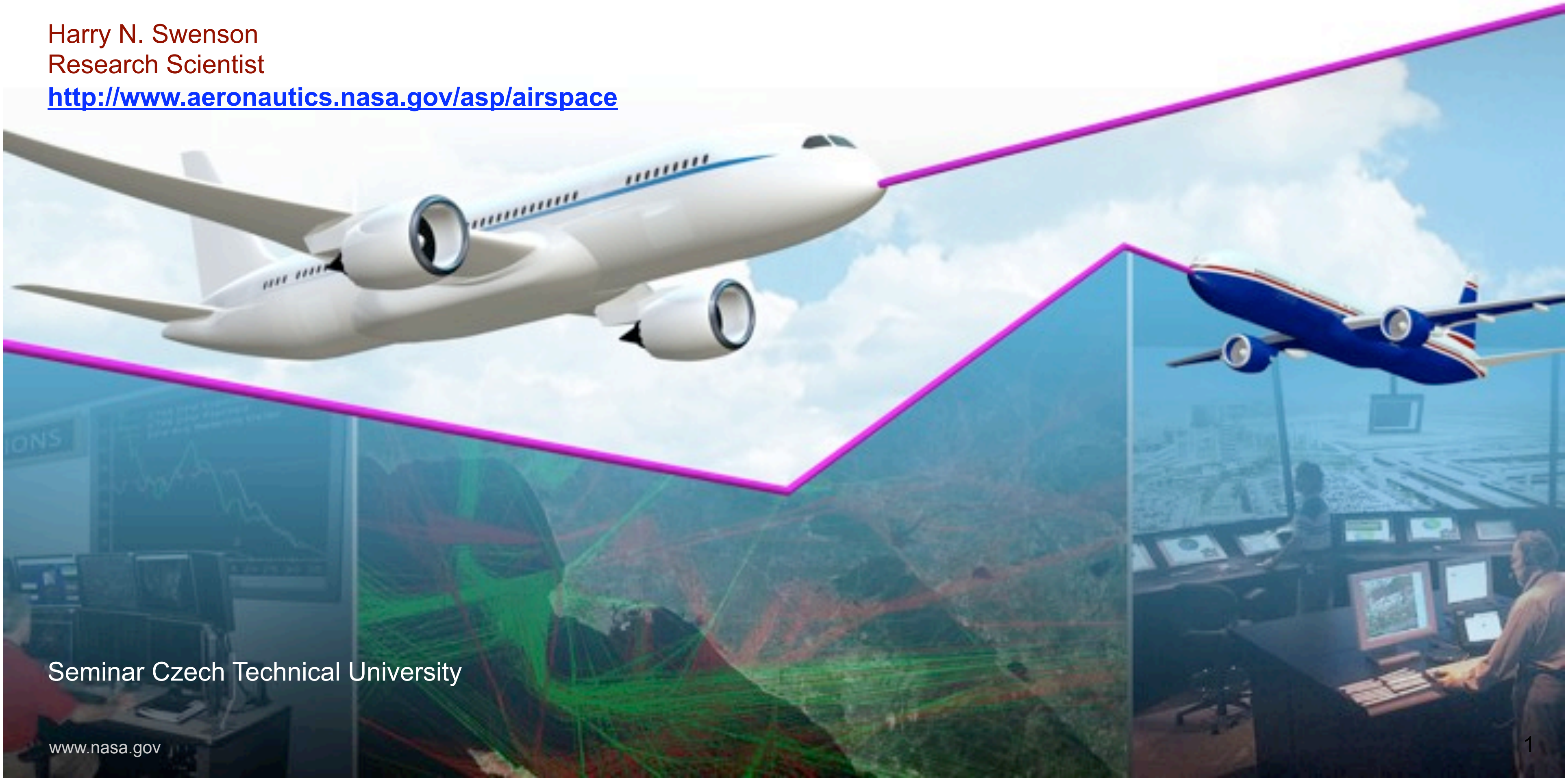


Seminar Czech Technical University

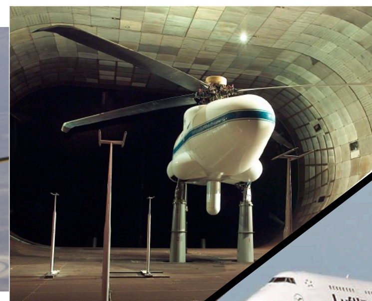
Contents

- NASA's Aeronautics Research Portfolio
- Fundamentals of the Current Air Transportation System
- Air Transportation Research Challenges
- Current Research Highlights and Significant Accomplishments
- Concluding Thoughts

NASA Aeronautics Programs

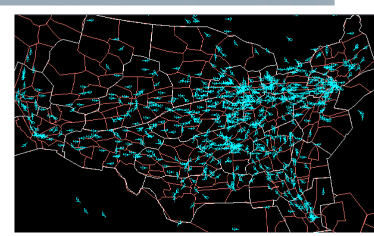
Fundamental Aeronautics Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.



Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.



Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.

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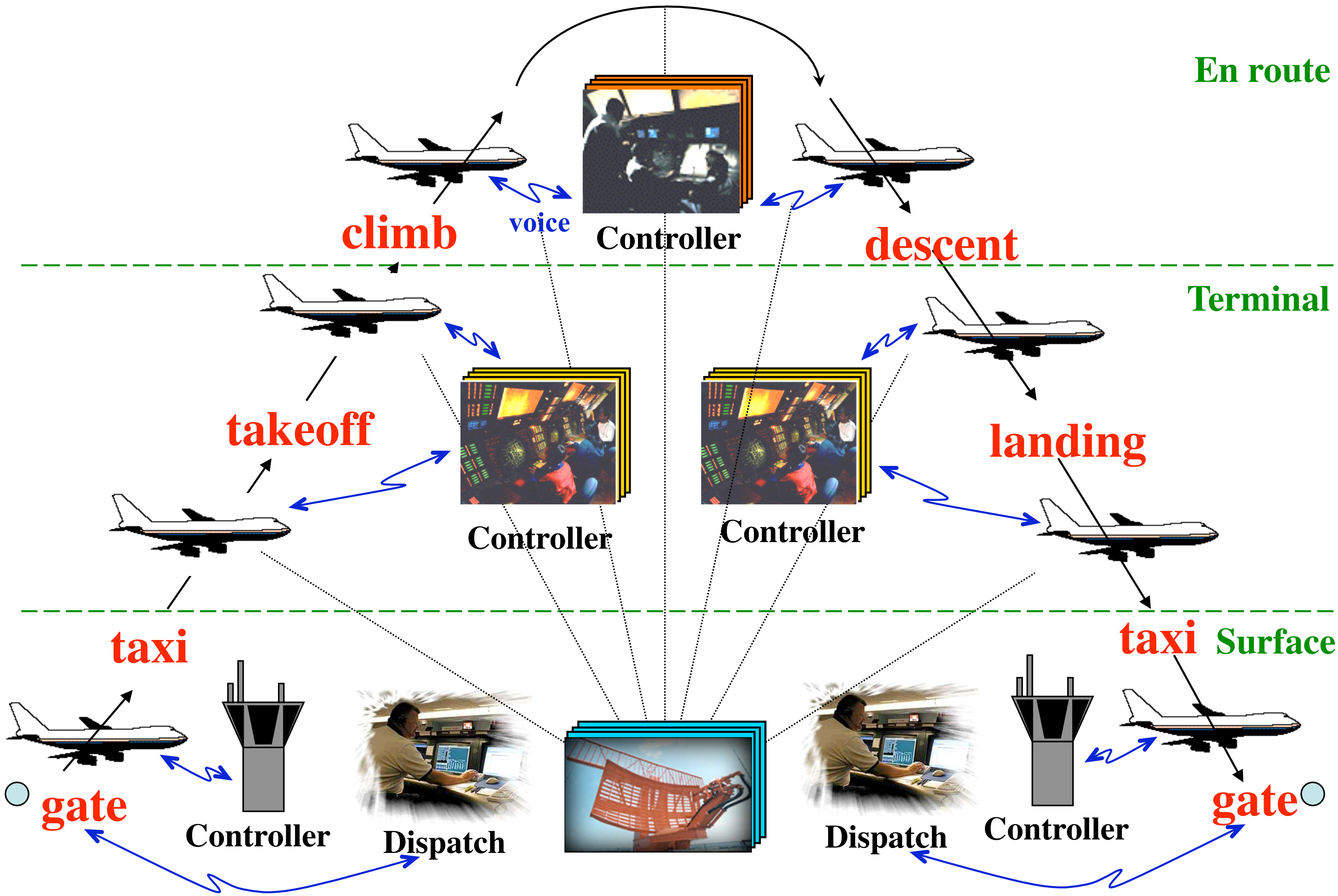
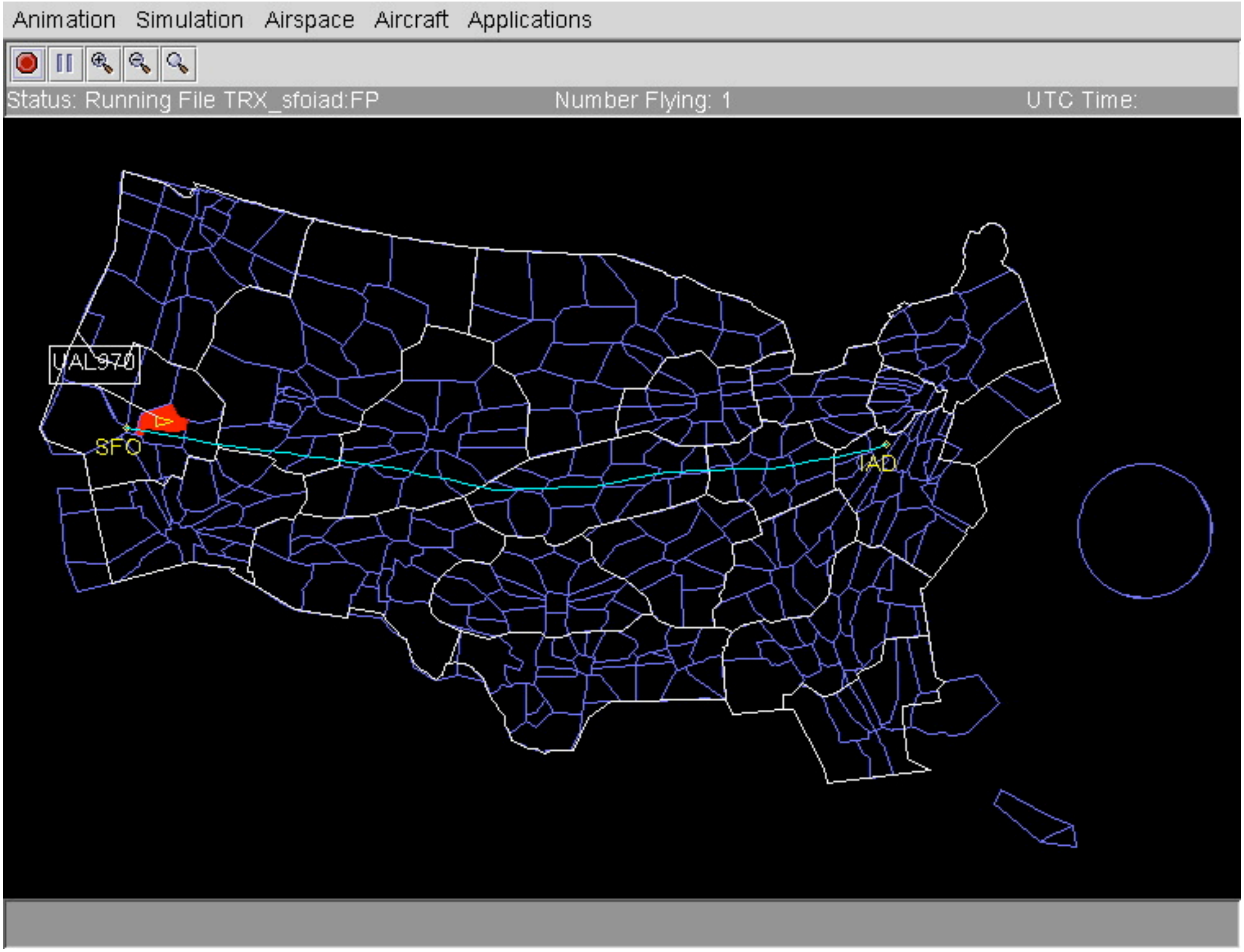
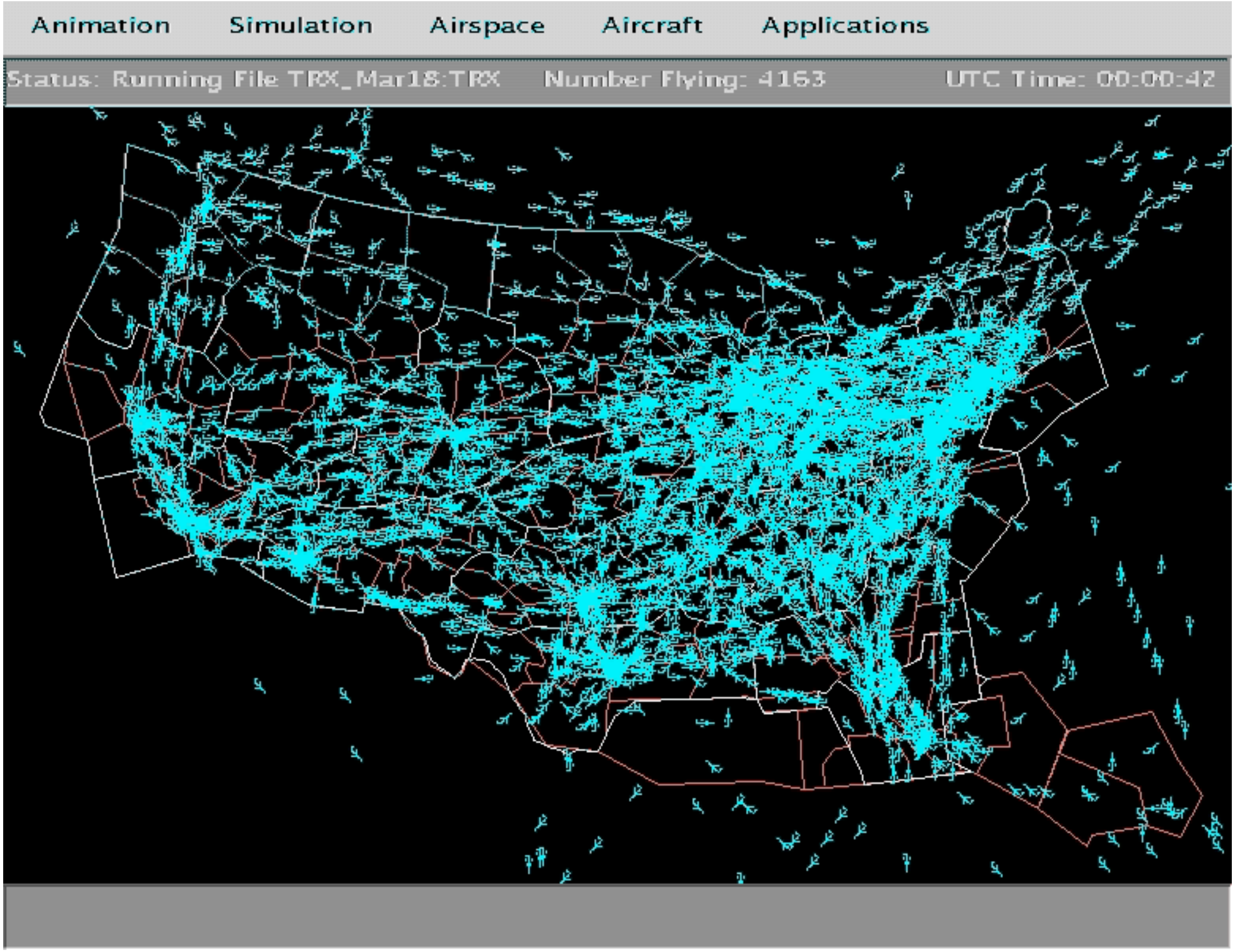
Today Basic Air Transportation Operation



Flight Across the United States Airspace from San Francisco (SFO) to Washington DC (IAD)

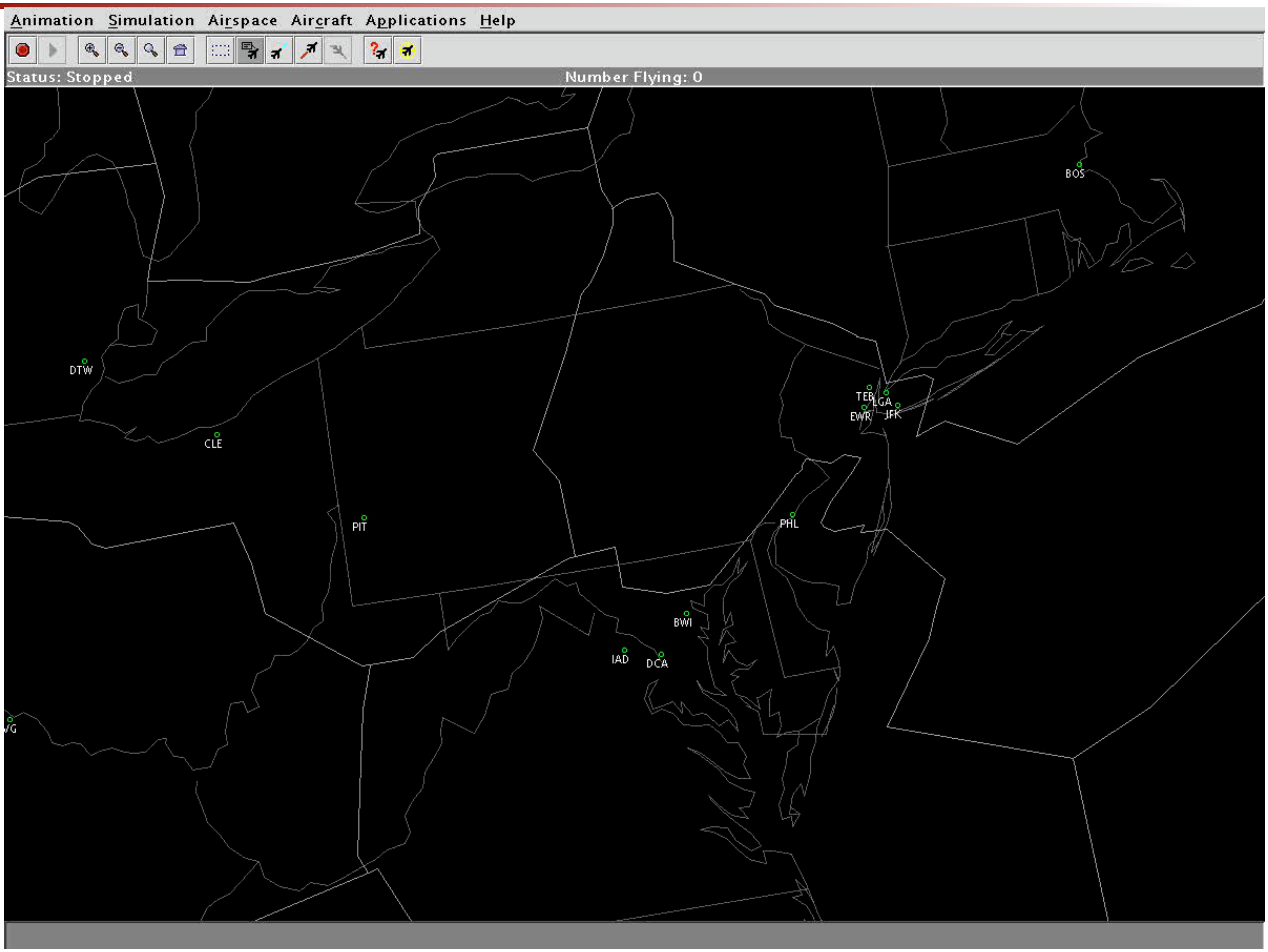


One Day of En-route Operations in the United States (starting at 7 pm Eastern)

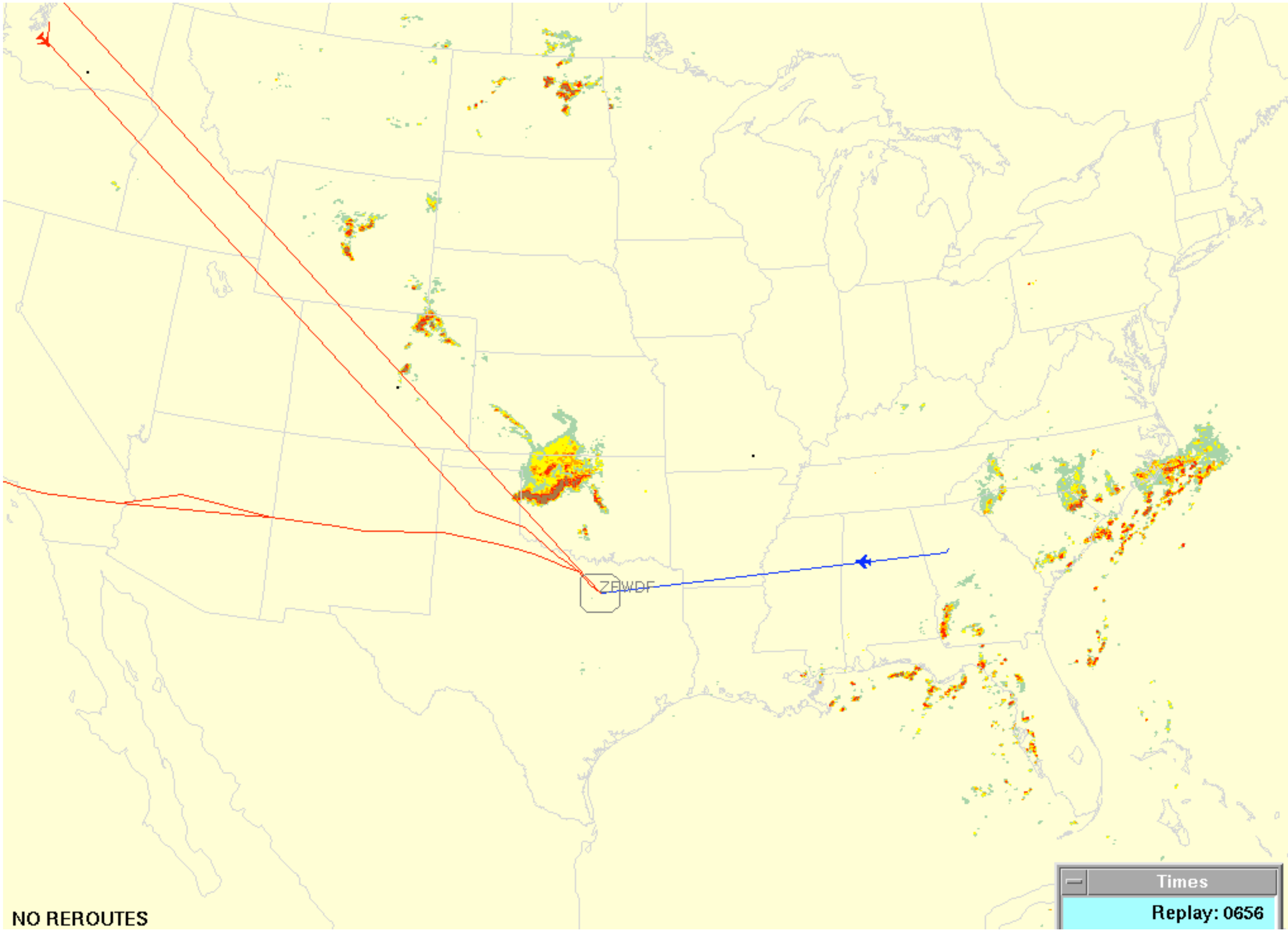


One Day of World Wide Air Transportation Operations

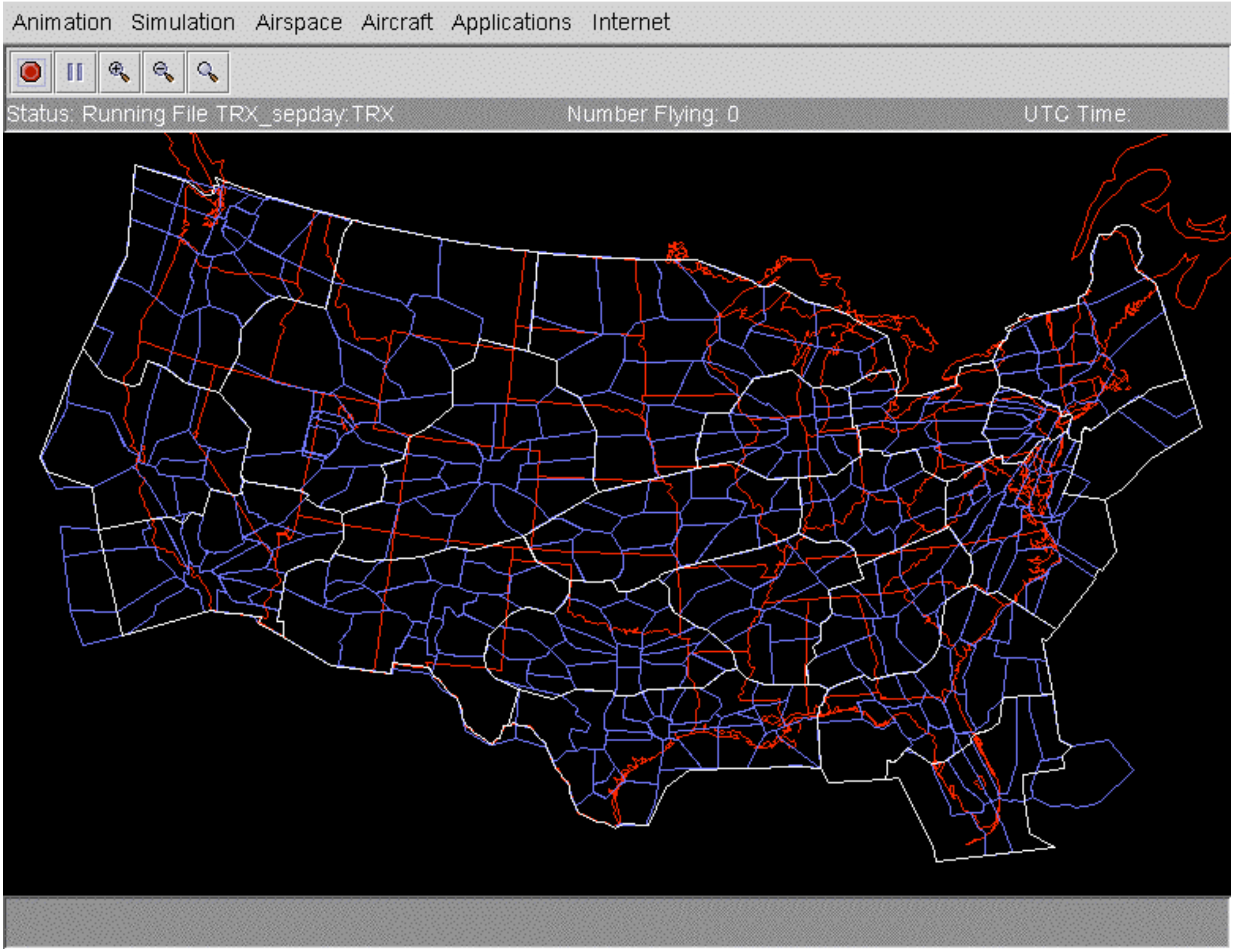
Weather Impacts for Air Transportation Traveling to the New York Area (starting around 7 am local time)



Weather Impacts for Air Transportation Traveling to the Dallas Texas Area (starting around 3 am local time)



Extremely Off-Nominal Conditions
(Look for it aound 13:30 UTC 10:30 am local EDT)

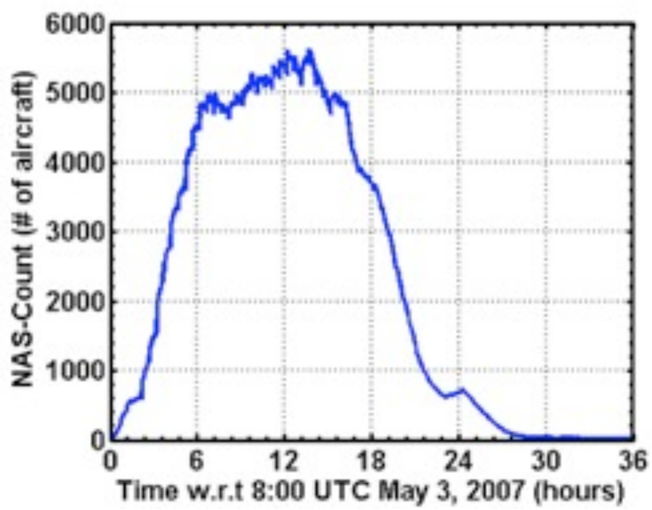


National Airspace System Aggregate Statistics Per Flight

	Time (minutes)	Distance (Nautical-miles)	Fuel Burnt (lbs)
Surface	19	5	474
Climb	16	76	1,911
Cruise	70	465	6,787
Descent	14	68	349

	Min. Time (minutes)	Max. Time (minutes)	Min. Fuel Burnt (lbs)	Max. Fuel Burnt (lbs)
Surface	11	43	274	1,073
Climb	5	56	520	18,704
Cruise	0	1,039	0	375,350
Descent	4	40	175	1,942

	CO_2 (lbs)	H_2O (lbs)	SO_X (lbs)	NO_X (lbs)	CO (lbs)	HC (lbs)
Surface	1,659	650	0.5	7	1.6	0.2
Climb	6,698	2,626	2.1	28	6.4	0.6
Cruise	23,781	9,324	7.5	98	22.6	2.3
Descent	1,223	480	0.4	5	1.2	0.1

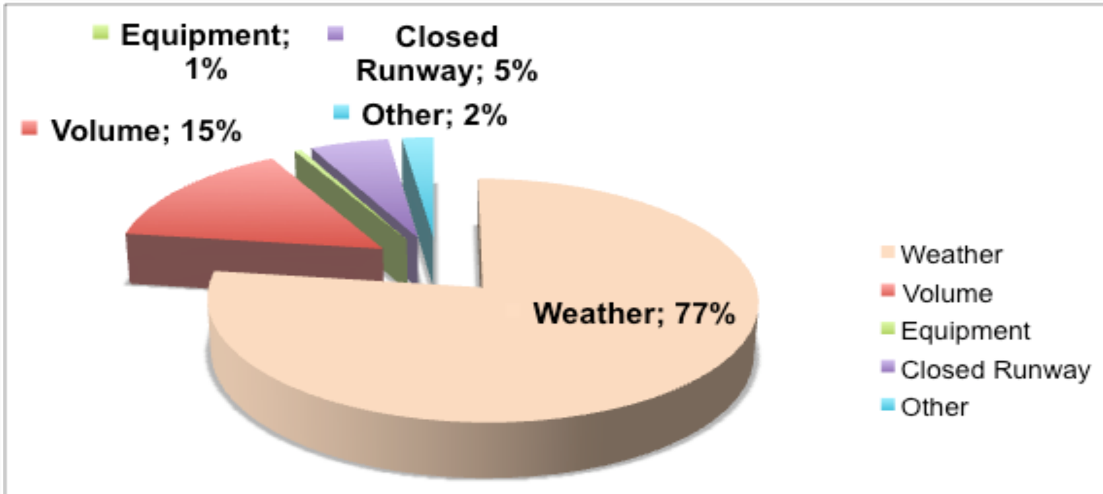


- 24-hours from 8:00 UTC May 3 to 8:00 UTC May 4, 2007.
- High-volume, low-delay day, 56,267 flights (71% jets, 17% turboprops,12% piston).

Complex operations – Multiple facilities, aircraft, people, and equipment
Any improvements need to consider many angles – makes vital R&D

National Airspace System Delays

Period: September'08 – August'09 (Source FAA), Roughly 25% aircraft get delayed

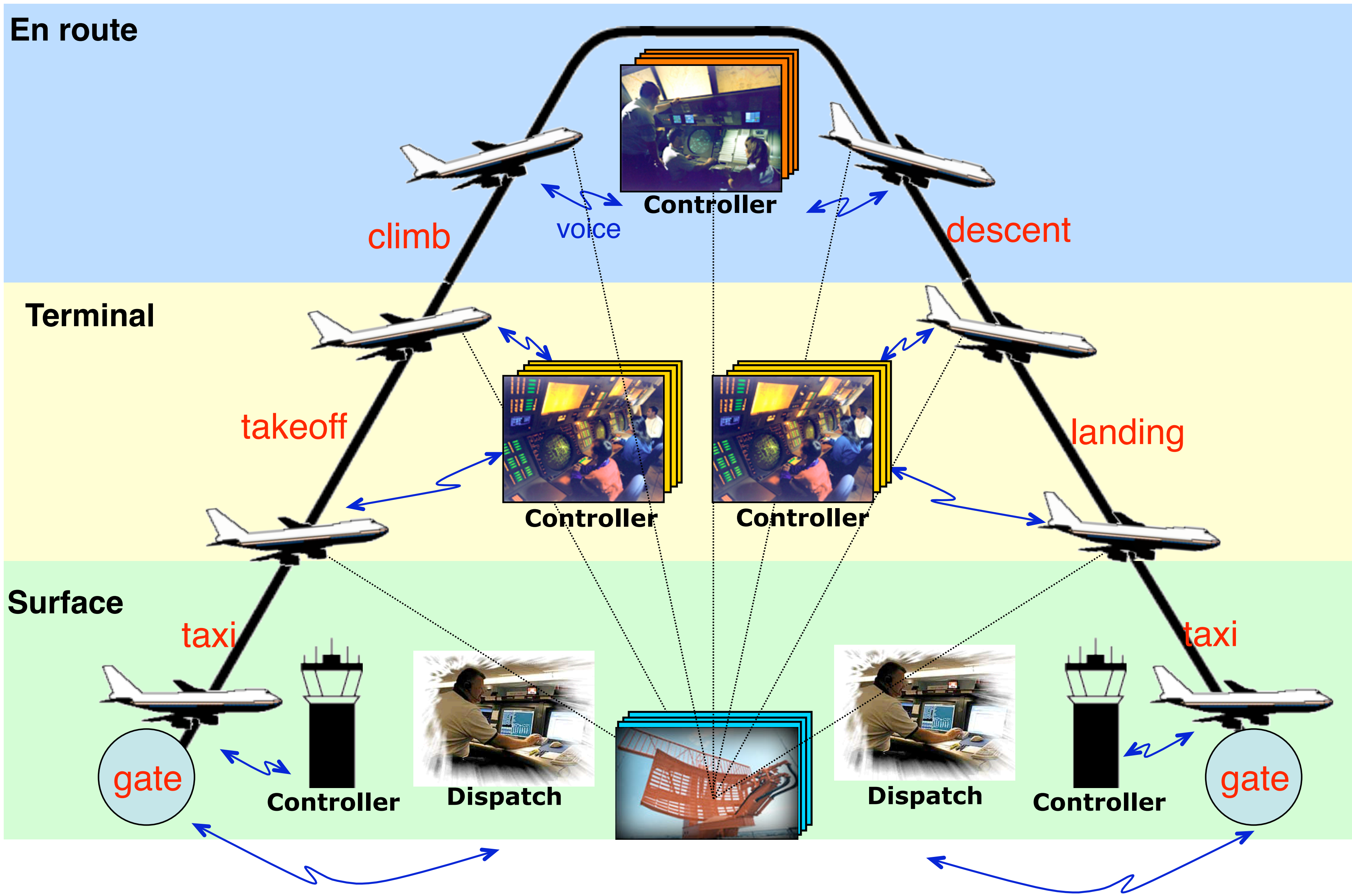


Transportation Systems Analysis Model (TSAM) Predictions

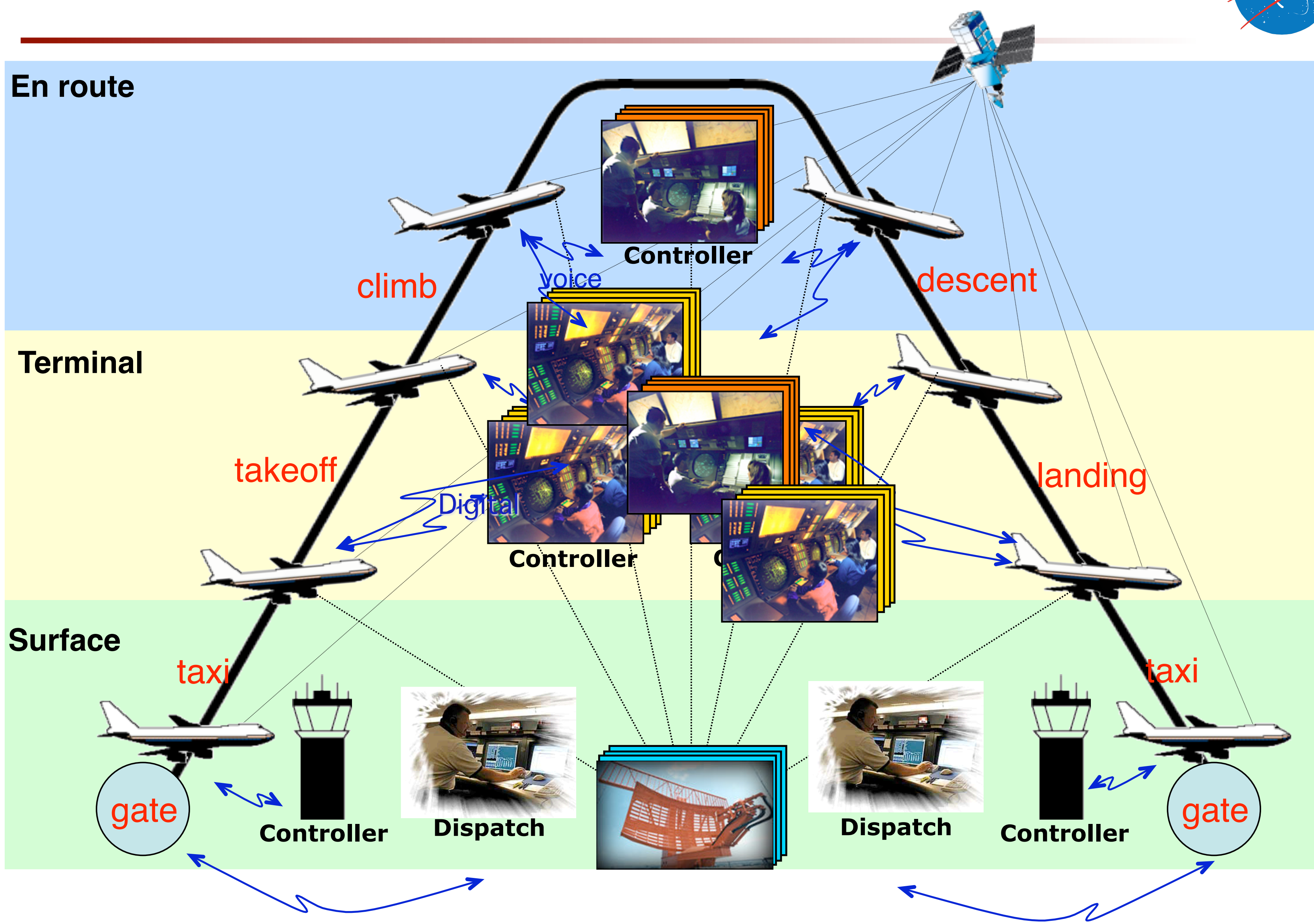
	Daily Flights		Percentage	
	2006	2025	2004	2025
Commercial	28,404	48,349	58.1%	63.9%
Domestic	25,211	41,498	51.6%	54.8%
International	3,193	6,851	6.5%	9.0%
General Aviation	18,052	23,329	36.9%	30.8%
Cargo/Freight	2,419	4,036	4.9%	5.3%
Total	48,875	75,714	100%	155%

Weather is a big delay contributor – Can't change it but we can optimize around it

Today Basic Air Transportation Operation



A Possible Future System



Contents

NextGen-Airspace Project:
Air Transportation Needs to Research

Needs

- On-time arrival/departure (schedule integrity)
- Reduce operator costs (fuel)
- Increase system productivity (aircraft/operator)
- Minimize impact on environment
- Design for scalability
- Safety
- Predictability

Challenges

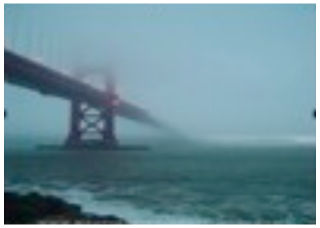
- Weather uncertainty
- Human workload limits capacity, throughput, and precision delivery
- Interactions: arrivals, departures, and surface; and metroplex
- Prediction uncertainty (trajectory, aircraft count, aircraft location)
- Mixed equipage
- Trade-off between environment and capacity/throughput

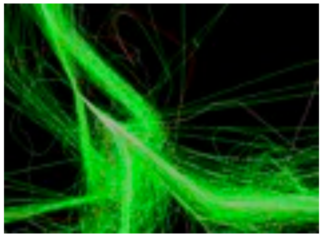
Research Threads

- Conflict detection and resolution algorithm and analysis
- Functional allocation
- Safety assessment
- Arrival Operations (integrated scheduling, sequencing, and merging and spacing)
- Integrated arrival and departure operations
- Modeling, simulation and optimization techniques to minimize total system delay
- Decision-making under uncertainty (weather integration)
- Capacity management
- Trajectory requirements
- Trajectory uncertainty prediction
- Trajectory interoperability
- Trajectory validation
- System level impact assessment
- Interactions between key research focus areas

Research Focus Area

- Separation Assurance
- Airspace Super Density Operations
- Traffic Flow Management
- Dynamic Airspace Configuration
- Trajectory Prediction, Synthesis, and Uncertainty
- System-level Design, Analysis, and Simulation Tools





Domain and operations are complex and require sustained R&D to address challenges. NASA has the skills and experience to change the Airspace System.

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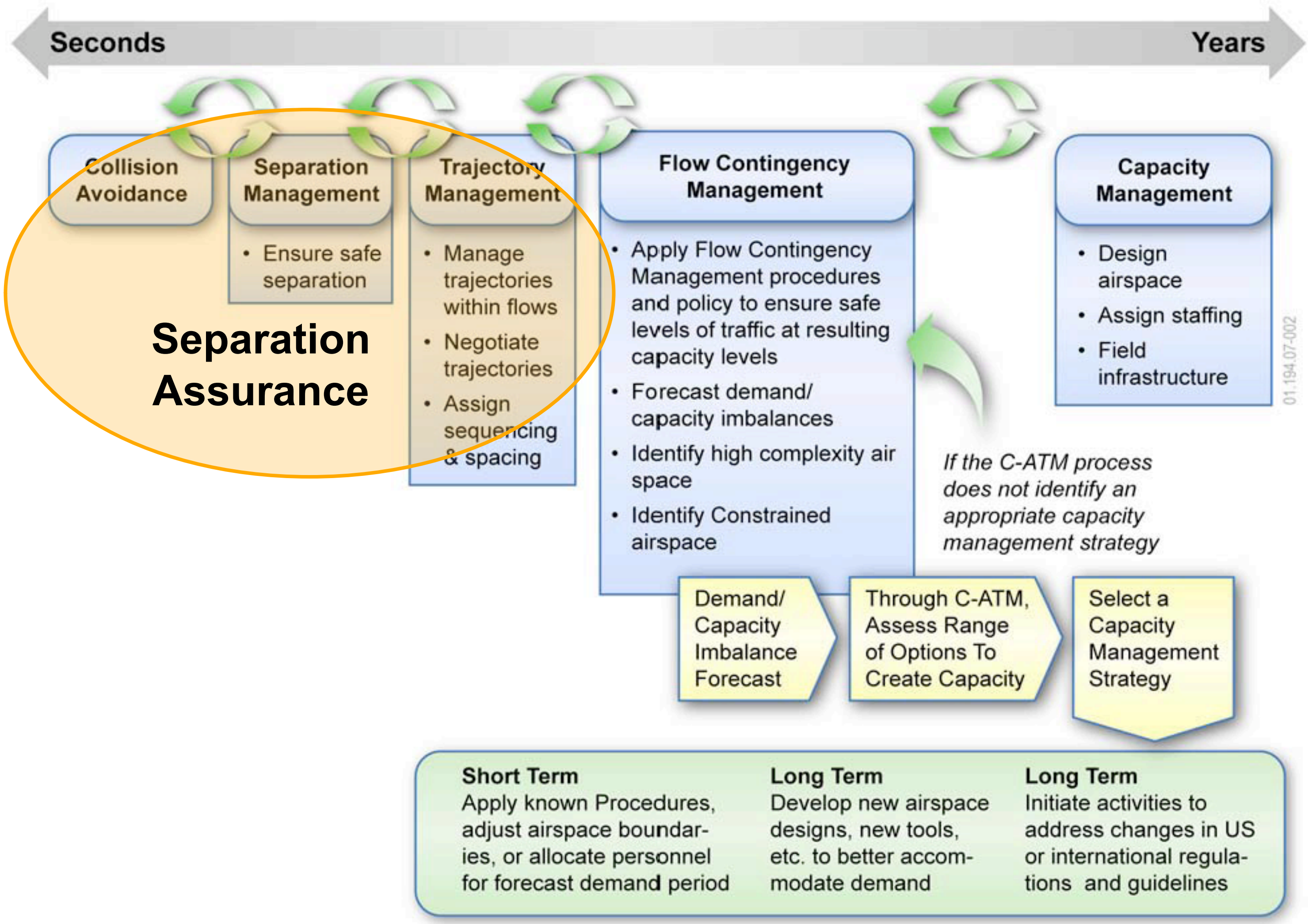
SA Elements of Automation for a Future Airspace System



"ATM Decisions-Interactive and Integrated Across Time Horizons" JPDO Concept of Operations for the Next Generation Air Transportation System, Version 2.0, June 13, 2007.

Research Focus Area
Separation Assurance

Problem

- Human controller workload limits current airspace capacity
- Mixed equipage must be safely managed

Major Research Threads

- Conflict detection and resolution algorithm development and analysis (aircraft and ground-based)
- Functional allocation
- Safety assessment

Research Being Pursued

- Automation and operating concepts for separation, metering, and weather avoidance in en route and transition airspace
- Concepts and algorithms for higher levels of separation assurance automation
- Efficient (conflict-free) arrivals into capacity constrained airspace
- Airborne and ground-based separation assurance concepts and technologies
- Separation assurance and collision avoidance algorithm compatibility

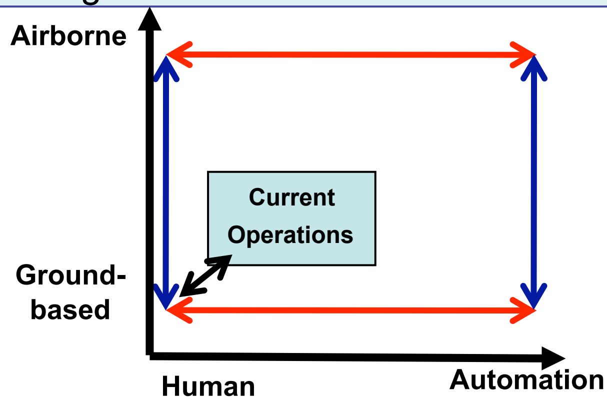
Partners: Lockheed Martin, GE, NRAs (Purdue, Stanford, UC Santa Cruz, L3, LMI, CSU Long Beach, Raytheon, Sensis)

Increased productivity, safety, and scalability

Research Thread: Functional Allocation

Problem/Need

- Identify characteristics, strengths, and weaknesses of various SA concepts
  - Humans vs. automation and aircraft vs. ground-based



Approach

- A series of human-in-the-loop simulations that examine homogeneous, mixed, nominal and off-nominal conditions

Progress

- Functional allocation examination approach planned
- First study preparations underway

Next Step

- Produce comparable results from coordinated studies
- Develop mixed operational concepts
- HITL coordinated concept evaluations (e.g., homogeneous operations, mixed operations)
- Nominal and off-nominal operations

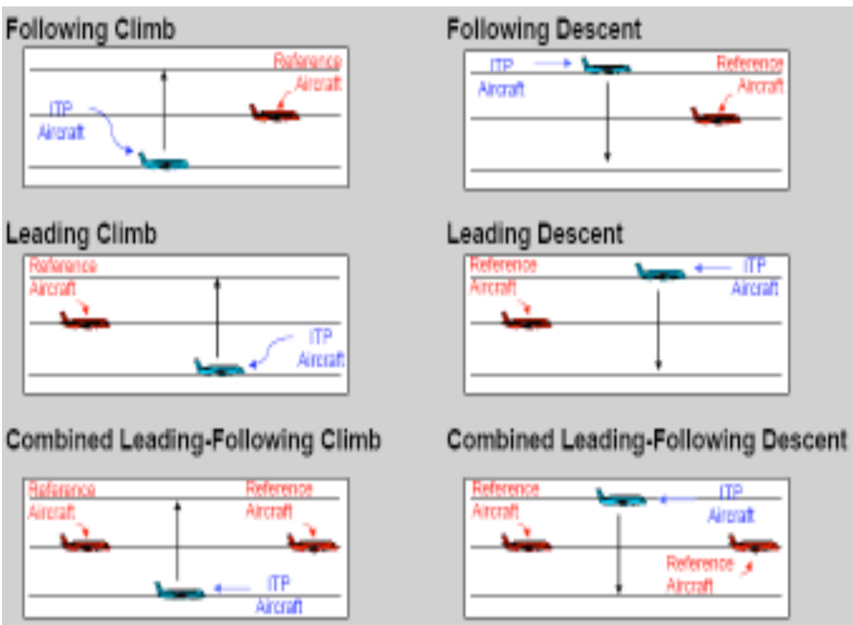
Implications on costs, roles/responsibilities, and architecture

In-trail Climb/Descent Procedures

(Development of ASAS applications in procedural airspace)

Problem/Need

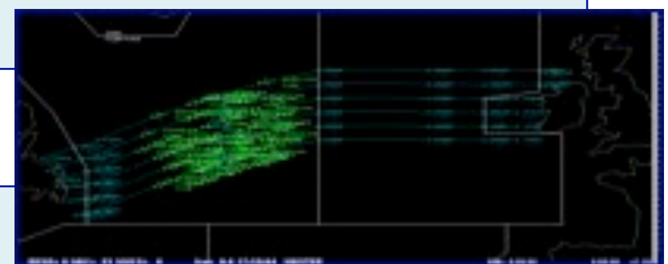
- Development of airborne separation assistance applications
- Specifically focused on in-trail climb/descent procedures in oceanic airspace



Approach

- Developed ADS-B based in-trail climb/descent procedures

Partners: FAA, Quantas and Air Services Australia



Results

- ICAO approved the procedures
- Documentation is completed
- Technology transition

Next Step

- FAA and partner airlines to do a field test in FY11

Aircraft will be able to fly at efficient altitudes and won't be stuck behind slow aircraft due to controller workload – increased productivity and efficiency

Automated Separation Assurance Simulation with Common Definitions

Problem/Need

- Functional allocation (air and ground)
- Ground-based and airborne concepts, algorithms, and analysis need to be comparable

Approach

- Develop experiment plans with common scenarios and metrics to enable comparisons

Progress

- Common definitions, scenarios, and metrics have been identified
- Technical plans are approved by project

Next Step

- Simulations in December 2009 and February 2010

Functional allocation research has implications on costs, roles/responsibilities, and architecture

Research Transition Team
En Route Descent Advisor (EDA)

Needs/Why Care?

Fuel efficient descents that meet efficient, time-based constraints set up for demand/ capacity imbalance

EDA gives speed clearances and path stretching advisories to meet the times

Focus

Technology transfer of En Route Descent Advisor

Progress/Results

Field test at Denver Center for descent trajectory prediction accuracy (15 days, 360 flights)

Participants: United and Continental B757, B737, and A319/320, and FAATC's Bombardier

Results: (median: Top of Descent accuracy = 5.5nm, meter fix accuracy = 12 sec) – As compared with current state-of-the art = 1 min

Lesson Learned: Need better top of descent predictions, meter fix accuracy is good

Next Steps

Complete hardware integration testing and overall readiness for HITL

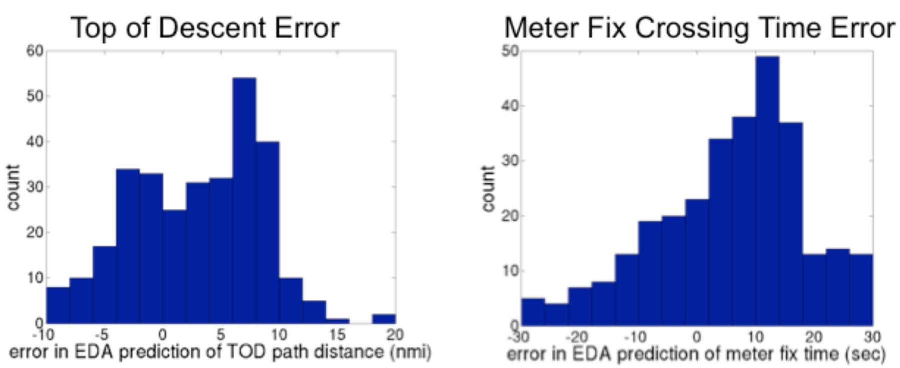
Continue scenario development and testing

Technology transition package

Partners

FAA, Sensis, Boeing, United, Continental Airlines, MITRE

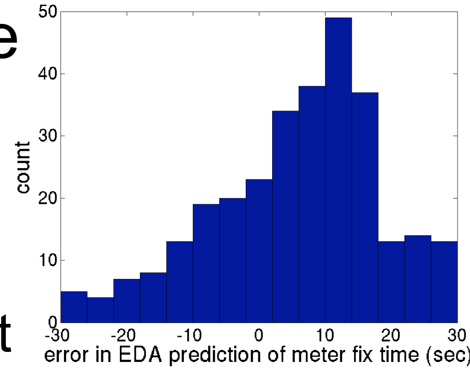
September 2009 Denver ARTCC Field Test - Preliminary Results

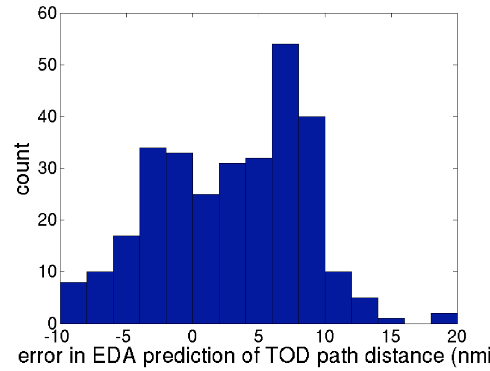


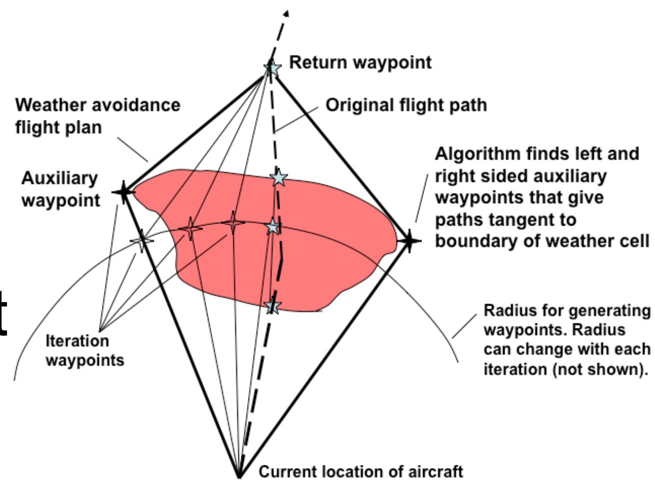
En Route Descent Advisor will increase fuel efficiency and meet-time accuracy

Significant Accomplishments

- Field test to support En Route Descent Advisor
  - Better understanding of trajectory uncertainties (median: meter fix 12 sec, Top of Descent 5.5 nm)
  - May require air/ground coordination for TOD
- Separation assurance technologies are maturing (ground based and aircraft based)
  - Traffic, time, and weather constraints

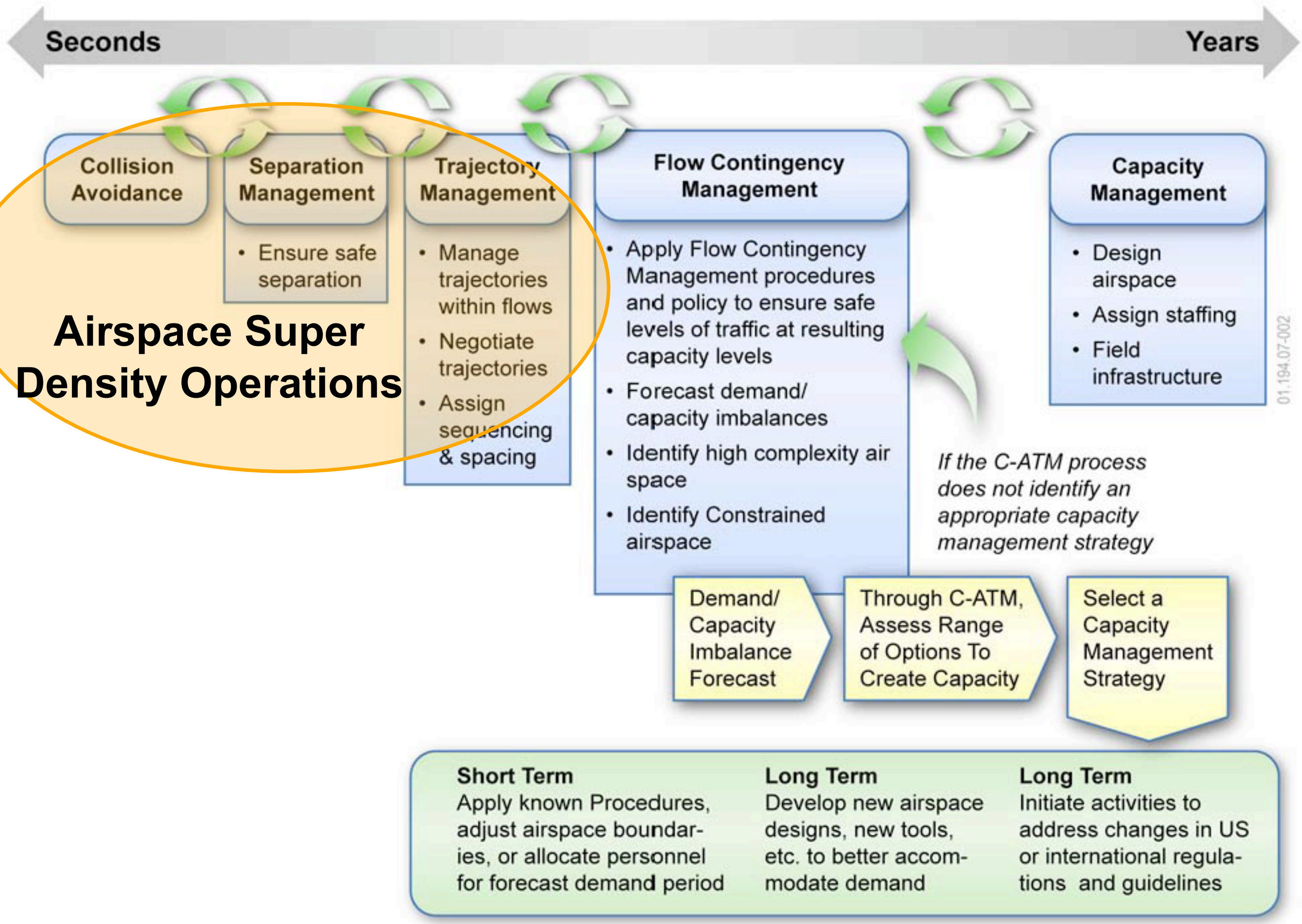






Products beginning to show impact and promise

ASDO Elements of Automation for a Future Airspace System

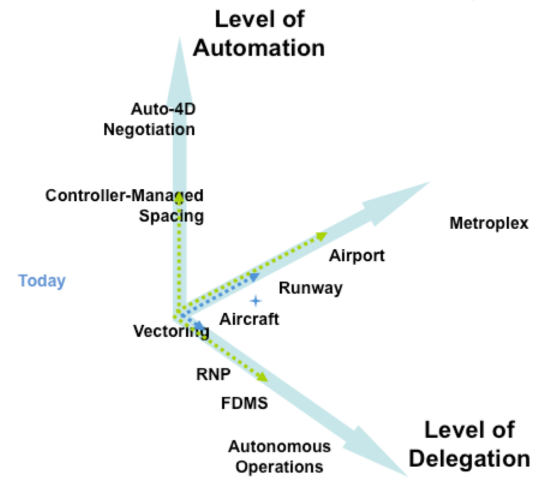


“ATM Decisions-Interactive and Integrated Across Time Horizons” JPDO Concept of Operations for the Next Generation Air Transportation System, Version 2.0, June 13, 2007.

Research Focus Area
Airspace Super Density Operations

Problem

- Human control of spacing, merging, and separation assurance limits the capacity of the terminal airspace
- Mixed equipage must be safely managed
- Interactions between arrivals and departures



Major Research Threads

- Arrival Operations (integrated scheduling, sequencing, and merging and spacing)
- Integrated arrival and departure operations
- Metroplex operations optimization

Research Being Pursued

- Algorithms that simultaneously solve/optimize the sequencing, merging, de-confliction and spacing
- Regional resource utilization or metroplex operations
- Closely spaced parallel runways

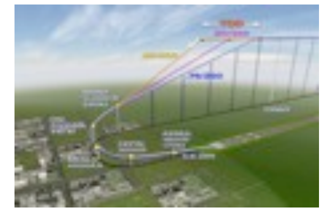
Partners: FAA, UPS, MITRE, ACSS, NRAs (MIT, Purdue, Metron, SJSU, Mosaic ATM)

On-time arrival/departure, reduce costs, impact on environment, safety and scalability

Super-Density Operations Vision

Optimized for single aircraft

- Continuous Descent Arrivals (CDAs) for individual aircraft
  - Efficient arrivals from top of descent to meter fix or runway threshold with other (interfering) traffic



Optimized for multiple aircraft

- CDAs with merging multiple aircraft flows to one airport
  - Using ANSP 4D trajectory management to schedule complex, conflict-free flows to the runway
  - Using Flight Deck merging and spacing capability to enable efficient multiple CDAs/TAs to runway threshold
  - Closely spaced parallel approaches where possible
- Integrated arrival, departure, and surface operations that maximize efficiency and throughput

Optimized for multiple airports

- Integrated arrival, departure, and surface operations including runway balancing for metroplex operations (multiple airports) with efficient airspace allocation

Increased automation needed to cover multiple airport and interactions

Research Thread: Arrival Operations

Problem/Need
- Develop new concepts, procedures and algorithms to maximize arrival rates to a single airport, as well as reduce fuel burn, emissions, and noise

Partners: FAA, UPS, MITRE, and NRAs (MIT, Metron, Purdue, SJSU, Mosaic ATM)

Approach
- Develop concepts, algorithms, and examine feasibility and benefits for variety of capabilities

Progress
- Developed multiple concepts across the entire ASDO domain
- Evaluated several concepts independently
  - Scheduler development
  - Flight Deck Merging and Spacing
  - Controller Managed Spacing Scenarios
  - Very Closely Spaced Parallel Runways Operations
  - Tactical Conflict Prediction and Resolution Algorithms

Next Steps
- Scheduling tool must consider integrated perspective

On-time arrival, reduce fuel burn, and increase productivity

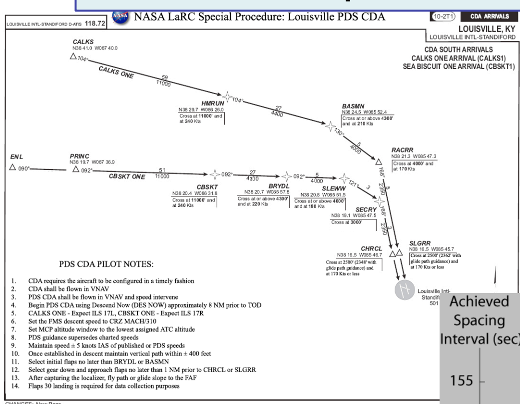
Algorithms and Procedures for Merging and Spacing Operations to Single Runway

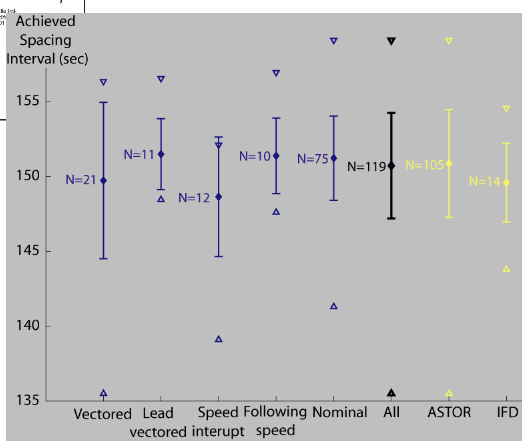
Problem/Need

- Increase throughput and execute efficient profile
- Develop and verify acceptance of procedure
- Examine performance

Approach

- Conduct human-in-the-loop simulation to determine performance and acceptability
- Off-nominal (vectors, speed, spacing)





Partners:

FAA, UPS, ACSS

Results

- Precise spacing (±5 sec)
- Acceptable and stable

Increase throughput and execute as efficient profiles as possible

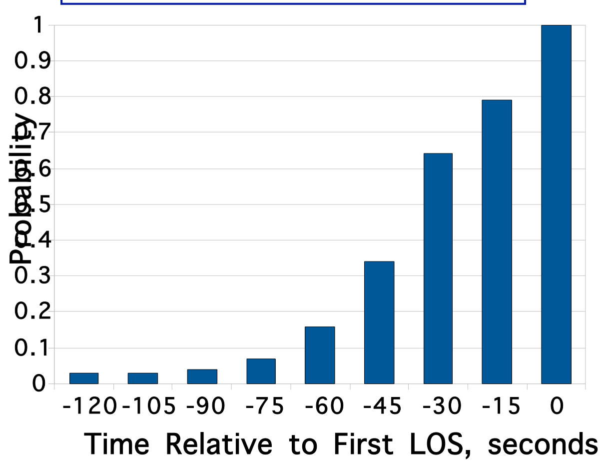
TRACON Operational Error Analysis

Problem/Need

- Increase safety in TRACON airspace
- Human workload limits

Summary of Operational Error Taxonomy

- 59 involved arriving aircraft
- 44 involved aircraft on final approach (compression)
- 15 involved metroplex traffic
- 4 involved arrival/departure interaction at same airport
- 3 were procedural in nature



Partner:
FAA

Approach

- 73 DFW TRACON operational errors investigated to understand the specific nature of each incident, and categorized to develop a taxonomy of situations, causes and resolutions

Progress/Results

- TRACON Operational error data analysis – detected all conflicts
- Median lead time = 38 sec.

Next Step

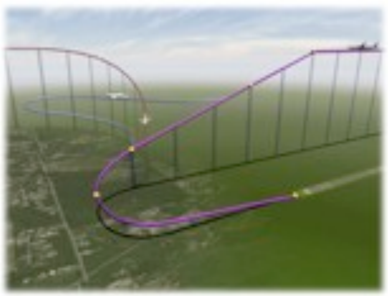
- Wider data set, intent information, sensitivity, false alert and stochastic

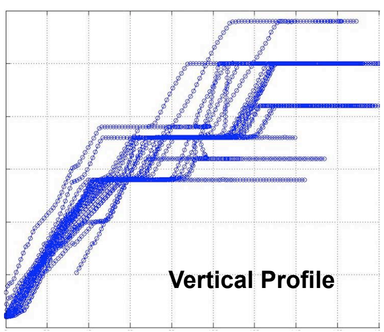
Increase productivity and safety in TRACON airspace

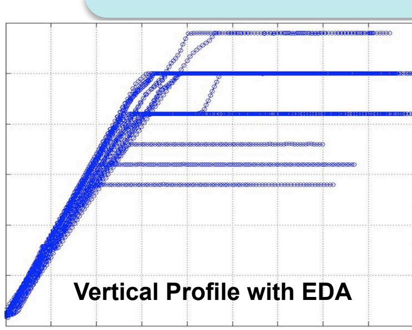
Research Transition Team
Efficient Flow into Congested Airspace
Overview

Needs/Why Care?

Fuel efficient descents that meet efficient, time-based demand/capacity balance







Focus

Demand/capacity imbalances analysis based on historical data

Advanced scheduling

Implementation of EDA concept for fuel efficient descents in medium/heavy traffic

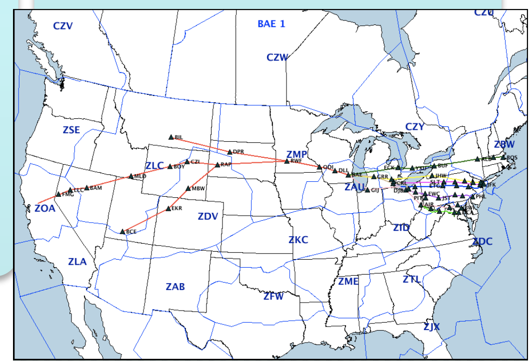
Interval Management

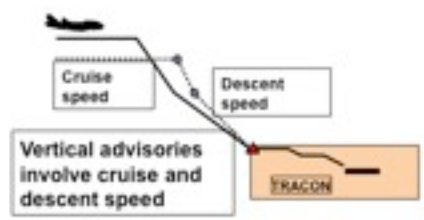
Progress

RTT was reformulated to broaden the scope

RTT plan to cover these four elements

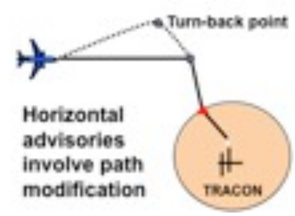
En Route Descent Advisor field test





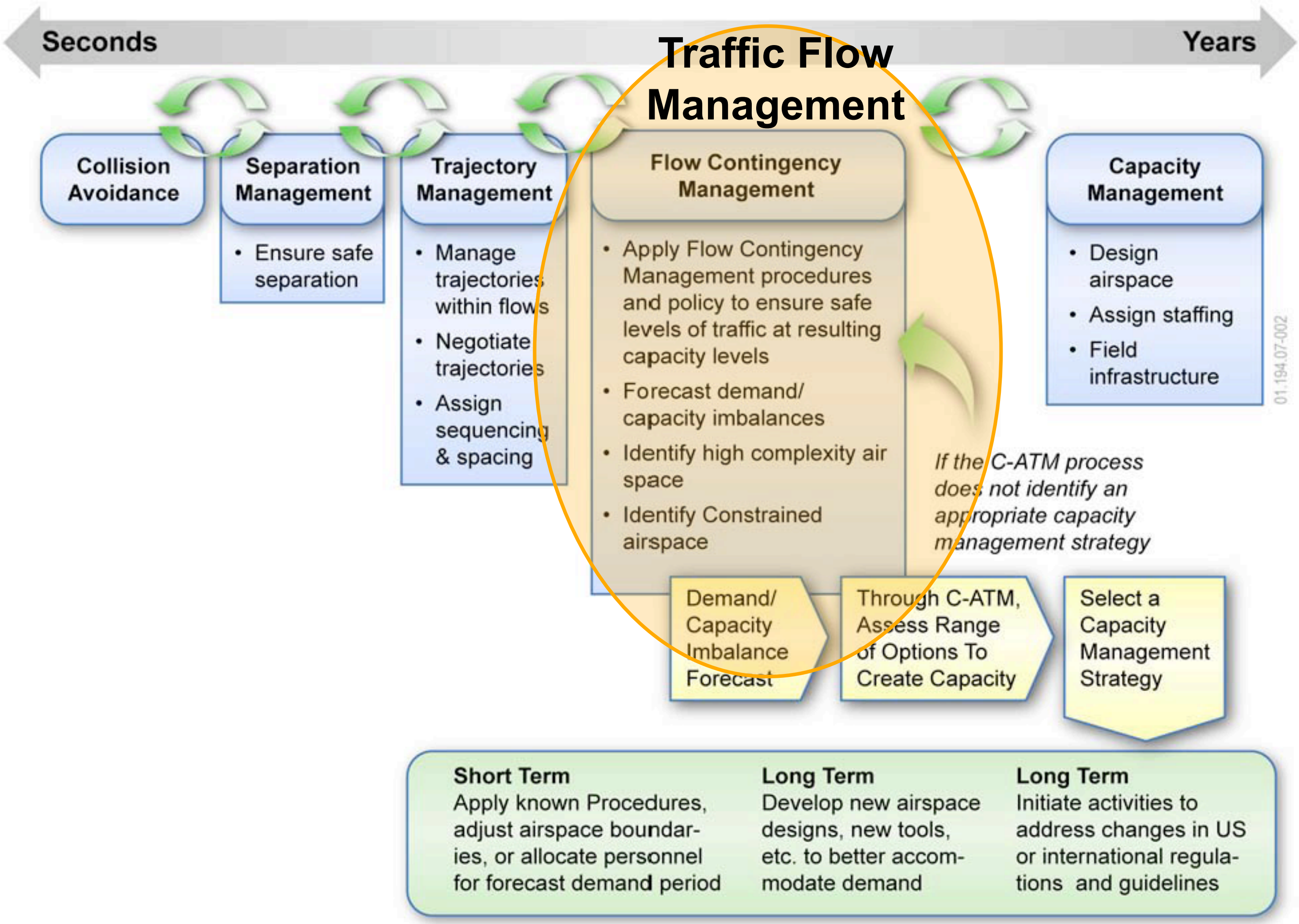
Next Steps

Work with the FAA for TFM, Flight Deck Merging and Spacing/ Interval Management, and Advanced Scheduling for specific products.



Flow management, scheduling, and merging and spacing needed to increase arrival efficiency in congested airspace

TFM Elements of Automation for a Future Airspace System



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Research Focus Area
Traffic Flow Management

Problem

- Planning involves multiple time scales (local, regional, and national)
- Multiple decision with different goals (pilots, dispatchers, ATSP flow managers)
- Decision making under uncertainty (e.g., weather)

Research Threads

- Modeling, simulation and optimization techniques to minimize total system delay (deterministic and stochastic)
- Decision-making under uncertainty (weather integration)
- Collaborative traffic flow management

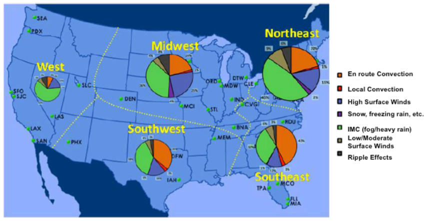
Research Being Pursued

- Optimization methods for advanced flow management
- Probabilistic and stochastic methods to address system uncertainties
- Weather Translation
- Collaborative Traffic Flow Management

Partners: FAA, MIT-LL, NOAA, NRAs (MIT, GMU, UC Berkeley, GaTech, UofM, Mosaic, OSI, Metron, Washington State)

Demand/capacity imbalance needs to be addressed with demand management options as efficiently as possible

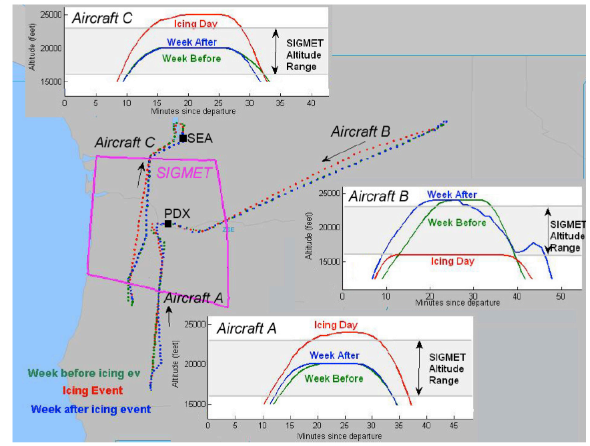
TFM Research Threads Progress: Decision Making Under Uncertainty



	Non-Convection			Convection			
	Ceiling and Visibility	In Flight Icing	Turbulence	CWAM (0-2hrs)	CoSPA (0-6 hrs)	LAMP-CCFP (0-24 hrs)	Ensemble Forecasts (0-9hrs)
Translation	Work in Progress	Work in Progress	Work in Progress	Work in Progress	Near Term Research	Work in Progress	Work in Progress
Deterministic Routing	X	Far Term Research	Work in Progress	Work in Progress	Near Term Research	Near Term Research	Far Term Research
Stochastic Routing	X	Far Term Research	Far Term Research	Near Term Research	Near Term Research	Near Term Research	Far Term Research
Stochastic Ground Holding	Work in Progress	Far Term Research	Far Term Research	Near Term Research	Near Term Research	Near Term Research	Far Term Research
Integrated Decision Making	X	Far Term Research	Far Term Research	Work in Progress	Near Term Research	Near Term Research	Far Term Research

Work in Progress | Near Term Research | Far Term Research

Partners: MIT-LL, NOAA, NRA (Mosaic ATM, Metron)



Explored the translation of non-convective weather constraints (turbulence, in-flight icing, ceiling and visibility) into air traffic management impacts

- **Reliable weather forecasts products under development for the 2+ hr time horizon**
- **Significant computational challenges remain for solving NAS-wide TFM problems with a 6+ hr planning horizon under uncertainty**

CWAM - Convective Weather Avoidance Model CoSPA - Consolidated Storm Prediction for Aviation
LAMP – Localized Aviation MOS (Model Output Statistics) Program CCFP – Collaborative Convective Forecast Product

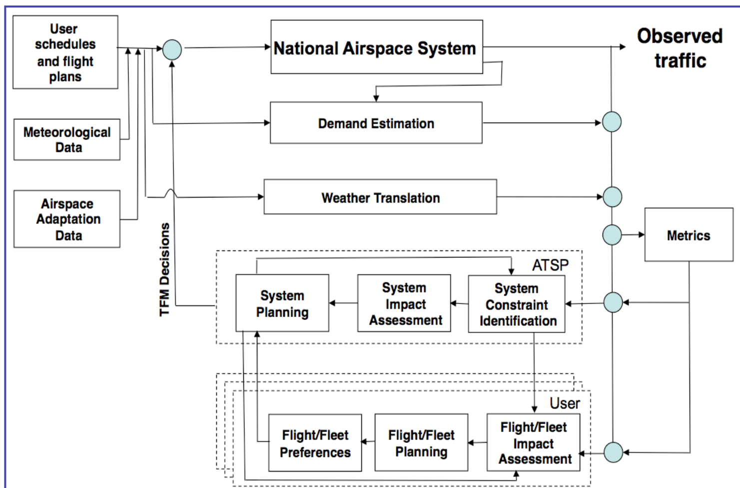
Early Integrated TFM Concept Definition and Development

Problem/Need
- Understand integrated impact of current TFM operations controls (e.g., ground holding, airborne holding, rerouting)
- Develop and test an integrated TFM architecture

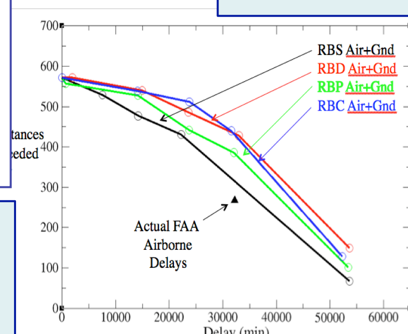
Approach
- Completed several experiments testing different strategies and applying specific TFM controls

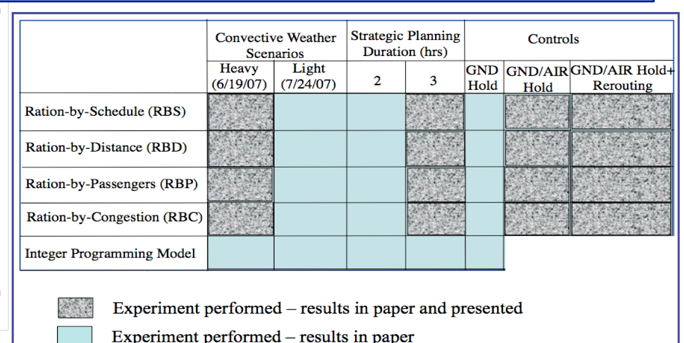
Results
- Scheduling algorithms effective at alleviating sector congestion
- Tactical rerouting dominant for avoiding en route weather

Next Step
- Compare with actual operations



Partners: MIT-LL, NOAA, NRA (Mosaic ATM, Metron, UC Berkeley, University of Michigan)





	Convective Weather Scenarios: Heavy (6/19/07)	Convective Weather Scenarios: Light (7/24/07)	Strategic Planning Duration (hrs): 2	Strategic Planning Duration (hrs): 3	Controls: GND Hold	Controls: GND/AIR Hold	Controls: GND/AIR Hold+ Rerouting
Ration-by-Schedule (RBS)							
Ration-by-Distance (RBD)							
Ration-by-Passengers (RBP)							
Ration-by-Congestion (RBC)							
Integer Programming Model							

Experiment performed – results in paper and presented

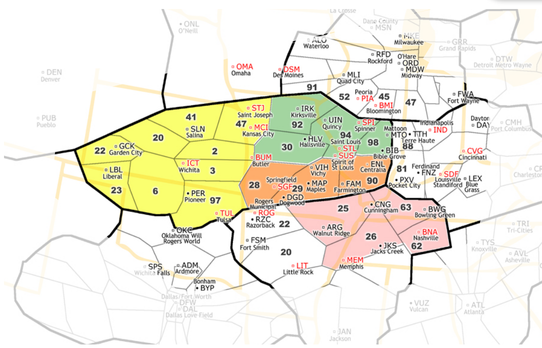
Experiment performed – results in paper

Need to develop flow management strategies to reduce delays

Research Transition Team
Flow-Based Trajectory Management (FBTM)
[Multi Sector Planner]

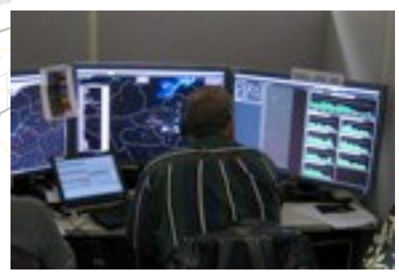
Needs/Why Care?

- Who manages trajectory?
- Between traffic flow and tactical controller



Focus

- Investigate roles, procedures, functions, operations, and tools
- Flow based Trajectory Management



Progress/Results

- Initial concept of operations
- Human-in-the-loop simulations
- Subjective data indicates acceptability objective data is being analyzed

Lessons Learned

- Mixed equipage environment
- Determine benefits
- Investigating collaboration between MSP and an "airspace manager"

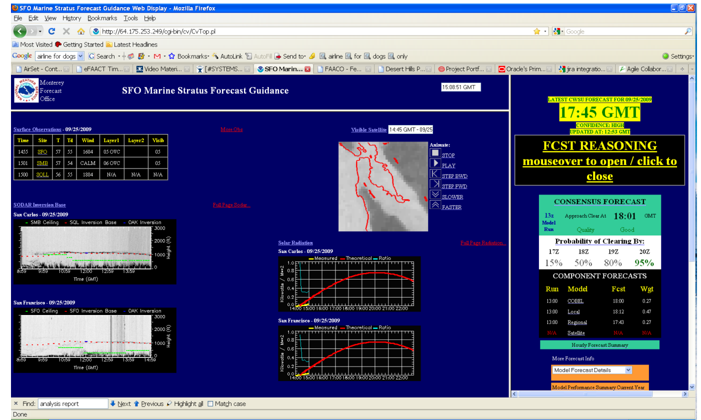
Next Steps

- Determine feasibility and benefits of one or more candidate MSP updates
- Complete analysis and report
- Plan and conduct appropriate follow-on simulations to study mixed equipage and benefits

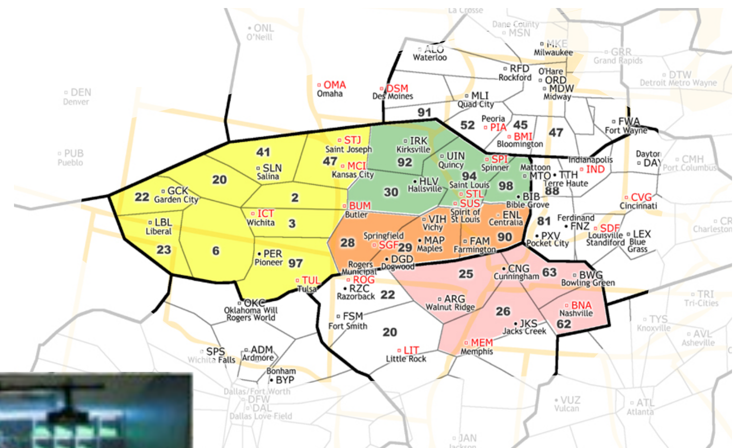
Capabilities, roles, and responsibilities for trajectory management need to be addressed

Significant Accomplishments

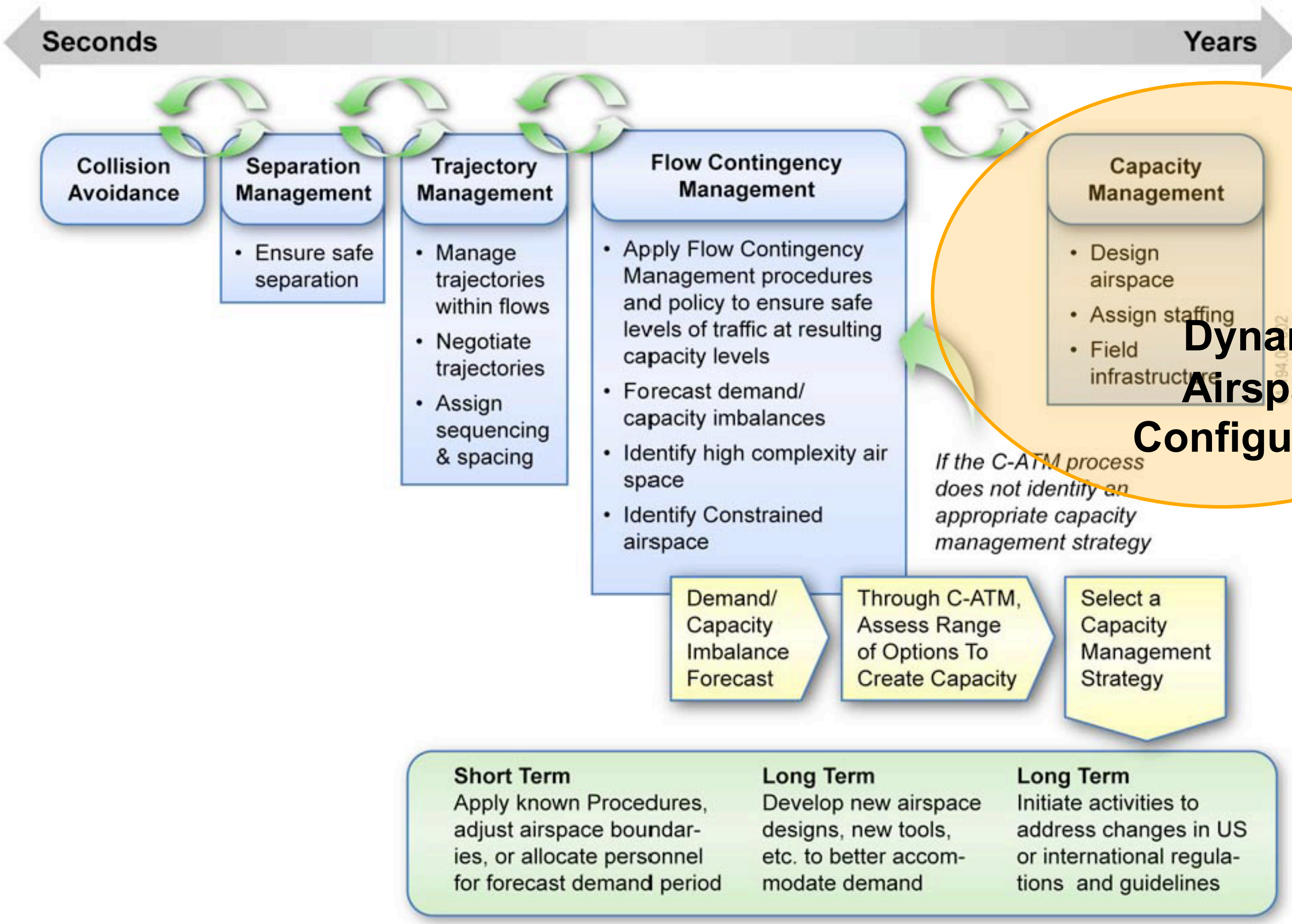
- FAA is investigating the use of San Francisco Stratus algorithms (NRA research)
  - Potential savings: $2.9M/ year



- Multi-sector planner investigations are helping FAA
  - Roles and responsibilities
  - Functions



DAC Elements of Automation for a Future Airspace System



"ATM Decisions-Interactive and Integrated Across Time Horizons" JPDO Concept of Operations for the Next Generation Air Transportation System, Version 2.0, June 13, 2007.

Research Focus Area
Dynamic Airspace Configuration

Problem

- Limited degrees of freedom for airspace changes (e.g., combine two adjoining sectors) and controller interchangeability
- Substantial time to modify airspace (years) and train controllers (months)

Research Thread

- Capacity management

Research Being Pursued

- Structure of the airspace (e.g., corridors-in-the-sky)
- Algorithms for airspace configurations - benefits and feasibility considerations
- Generic airspace

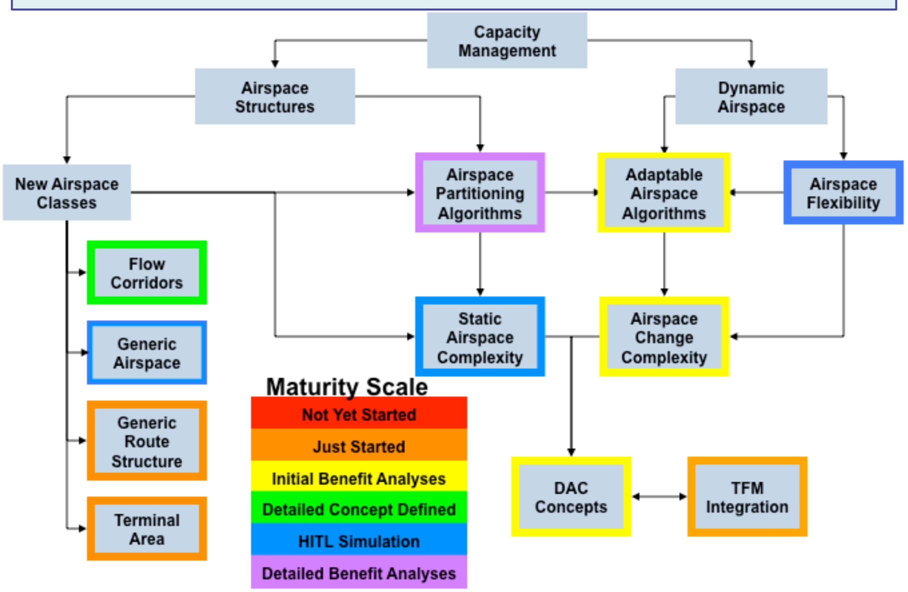
Partners: FAA, MITRE, NRAs (Metron, Mosaic ATM, and CSSI)

Demand/capacity imbalance needs to be addressed by resource management (airspace capacity and controller resources)

Research Thread:
Airspace Capacity Management

Problem/Need

- Determine airspace structures, their feasibility and benefits
- Develop algorithms for airspace changes and examine feasibility and benefits
- Define generic airspace concepts and assess their feasibility and benefits



Approach

- Concepts, algorithms, analysis, and simulations

Progress

- Develop concepts and algorithms for corridors-in-sky
- Develop algorithms for airspace boundary adjustments
- Early human-in-the-loop simulations to study boundary adjustments
- Generic airspace concepts

Next Step

- Feasibility and benefits of corridor
- Detailed feasibility and benefits of adaptable airspace
- Feasibility, benefits, and applicability of generic airspace

Manage Demand/Capacity imbalance by capacity adjustments rather than demand management

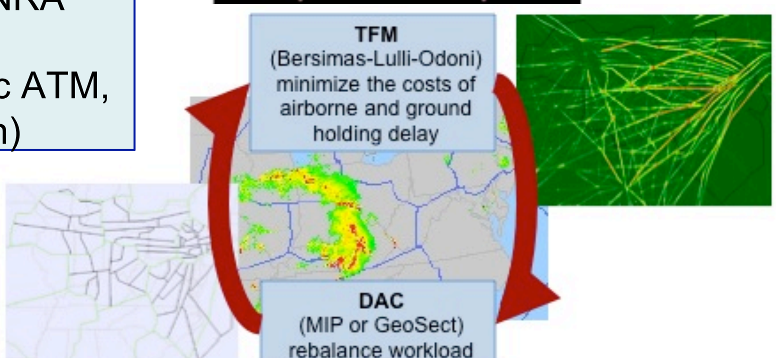
Airspace Redesign Benefits Analysis

Problem/Need

- Benefits of airspace redesigns are less understood
- Airspace allocations and TFM interactions need to be studied

	Recovered Throughput	Reduced Delay	Complexity Balancing	Demand/ Capacity Balancing	Number of Sectors
Current Day			16.8	0.22	470
Flight Clustering	55%	59%	13.4	0.16	1031
Voronoi Genetic	50%	63%	14.0	0.17	565
Mixed Integer Programming	31%	33%	12.5	0.18	593

Partners:
FAA, NRA (CSSI, Mosaic ATM, Metron)



Approach

- Number of airspace partitioning approached were combined using common scenarios
- Use simplified complexity metrics
- Examine airspace changes and flow restrictions

Results

- Airspace redesigns reduce delay
- Opens up airspace
- Iterations not converging

Next Steps

- Detailed benefits analysis
- Frequency of changes and limit number of sectors
- DAC-TFM interactions

Airspace and flow management need to be coordinated

Research Transition Team
Dynamic Airspace Configuration (DAC)
Flow Corridors

Needs/Why Care?

- Demand-capacity Imbalance
- Mixed equipage

Focus

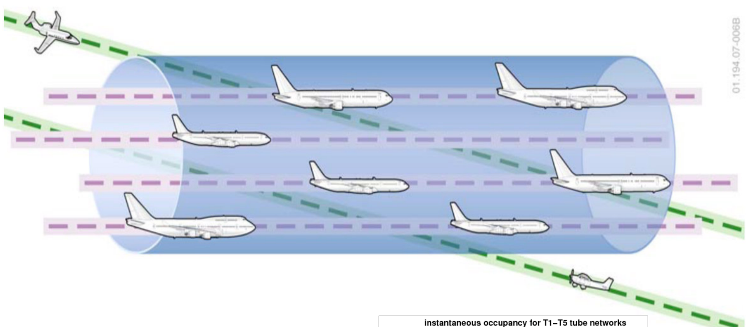
- What are the needed airspace structures?

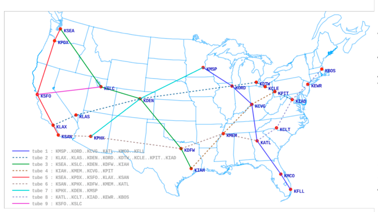
Progress

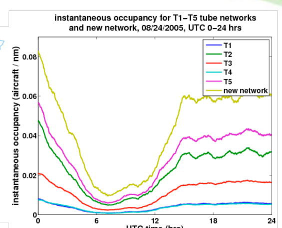
- Developed algorithms and strategies
- Determined the best criteria for a network
- Developed methods for dynamically assessing a flow corridor

Next Steps

- Analyze flow corridor utilization (mixed equipage)
- Examine feasibility of using flow corridors for mixed equipage
- Two years to complete

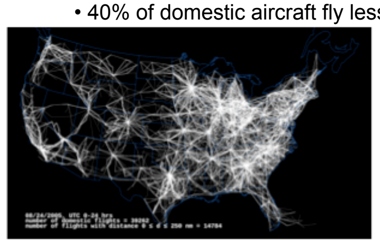




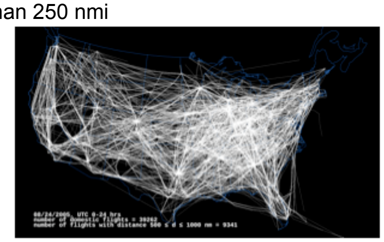


Features of the best airport based corridor network
- Relatively short total length.
- Large separation of nodes (separated by greater than 100 nautical miles).
- Follows domestic air traffic flows relatively well.

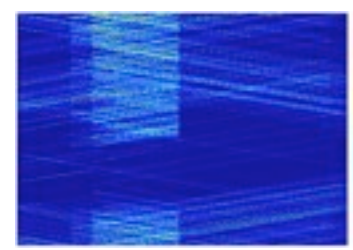
Inherent problem with corridor networks designed to increase user pool
- Short-hop flights not amenable to utilize any corridor network
- 40% of domestic aircraft fly less than 250 nmi



Air traffic traveling less than 250 nmi
Not amenable to tube utilization

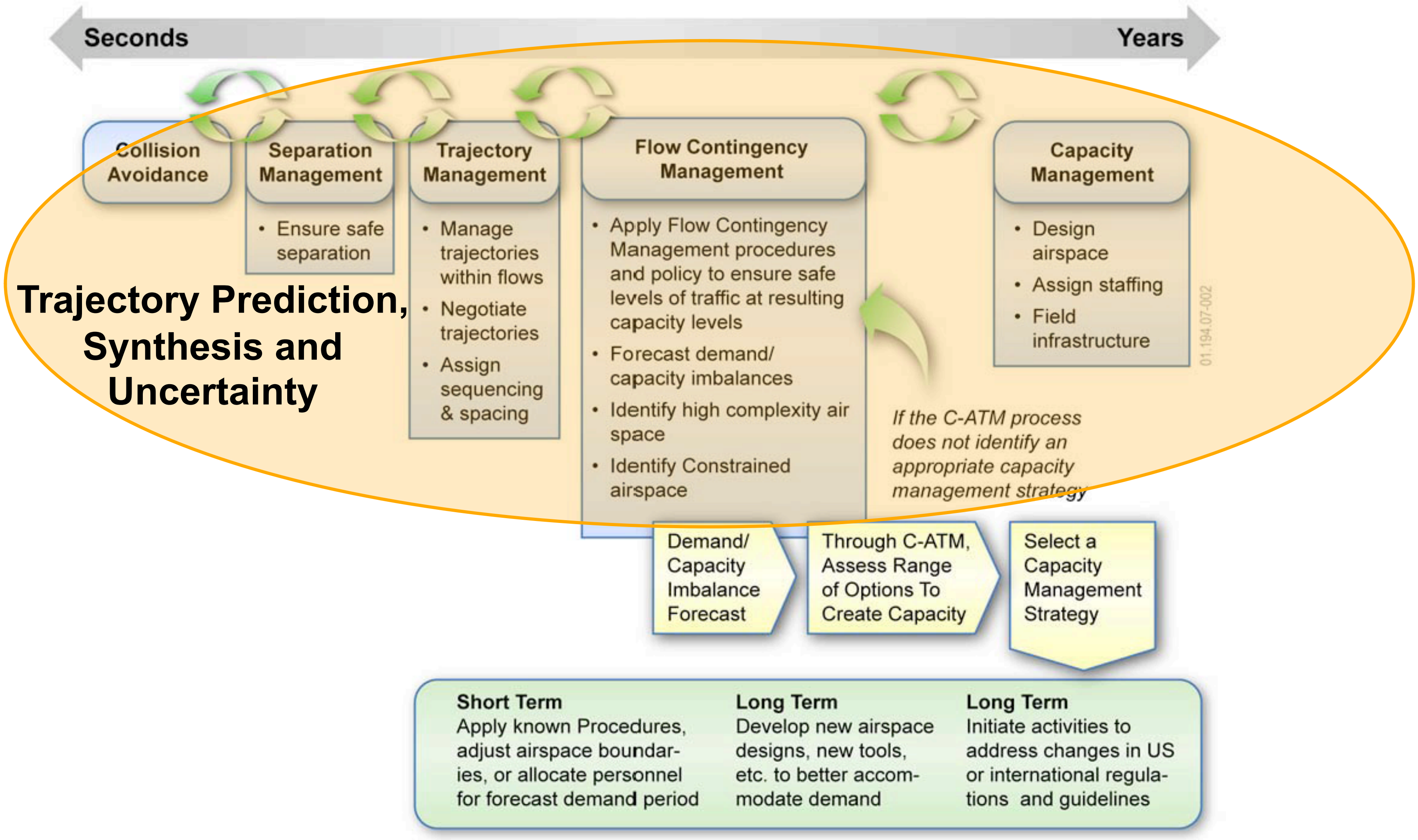


Air traffic traveling 500 to 1000 nmi
Best candidate corridor network users



Corridors may be useful for dedicated and segregated operations to increase efficiency – Still don't know if they are beneficial and necessary?

TPSU Elements of Automation for a Future Airspace System



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Research Focus Area: Trajectory Prediction, Synthesis and Uncertainty

Problem

- Lack of understanding of trajectory uncertainty characteristics
- Lack of functional specific requirement and standards
- Lack of interoperability of trajectory prediction techniques

Research Threads

- Trajectory requirements
- Trajectory uncertainty prediction
- Trajectory interoperability
- Trajectory validation

Research Being Pursued

- Trajectory predictions accuracy as a function of time, model parameters, meteorological effects and aircraft intent modeling
- Trajectory modeling requirement, analysis, and validation

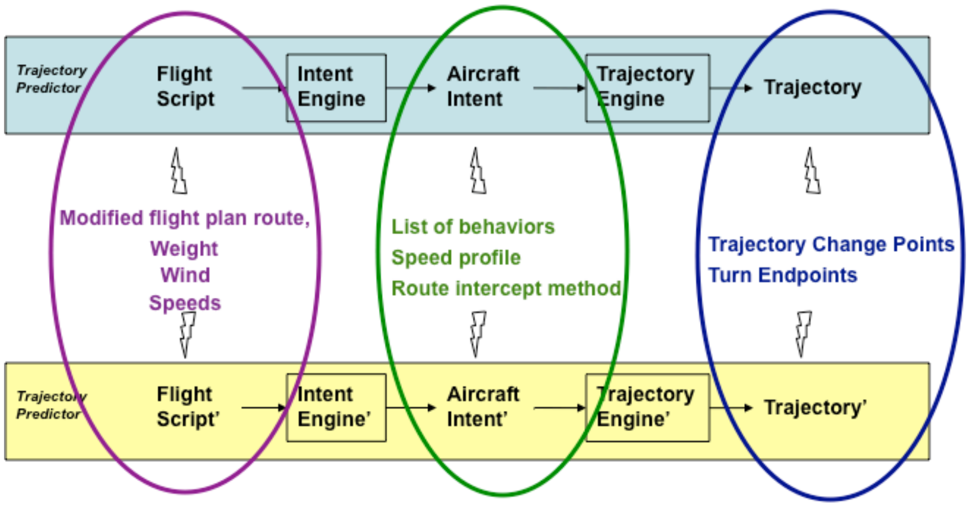
Partners: Lockheed Martin and NRAs (L3, U of Minnesota)

Users need accurate predictions and safety critical automation needs interoperable trajectories

Research Thread: Interoperability

Problem/Need

- Lack of interoperability of trajectory prediction techniques
  - Trajectory based operations
  - Precise trajectories for reducing uncertainty (e.g., Separation assurance vs. TFM)



Partners: NRA (L3)

Trajectories need to be interoperable to ensure maximum precision and compatibility

Approach

- Improve trajectory prediction of disparate system through the exchange of trajectory information
- Examine real-time data exchange needs for different applications

Progress (10%)

- Identified candidate trajectory predictors for data exchange
  - 4D-FMS and CTAS
- Standalone trajectory generators developed

Next Steps

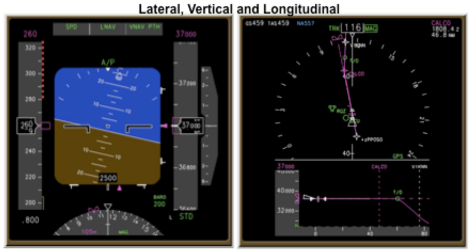
- Identify critical information for exchange
- Implement common data exchange language and real-time exchange
- Involve industry (e.g., FMS)

Complex Combination of Constraints

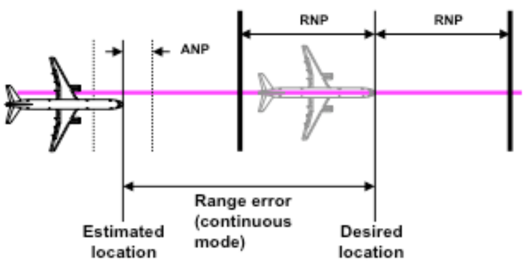
Problem/Need
- Develop capability to handle multiple constraints in altitude, speed and time (needed for better predictability)

Approach
- Ground-based Center-TRACON Automation System
- Aircraft based Flight Management System

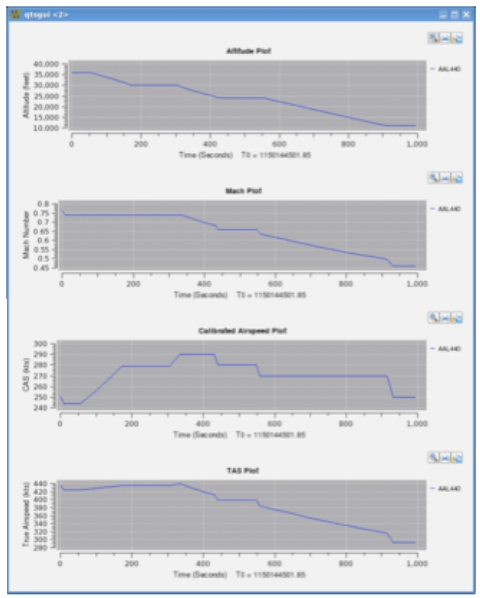
4D-FMS – RNP Pilot Interface
Lateral, Vertical and Longitudinal



Primary Flight   Navigation



- Longitudinal RNP = Temporal RNP * Ground Speed
- Temporal ANP = Longitudinal ANP / Ground Speed



Results
- Initial capabilities for 4DFMS and CTAS are developed

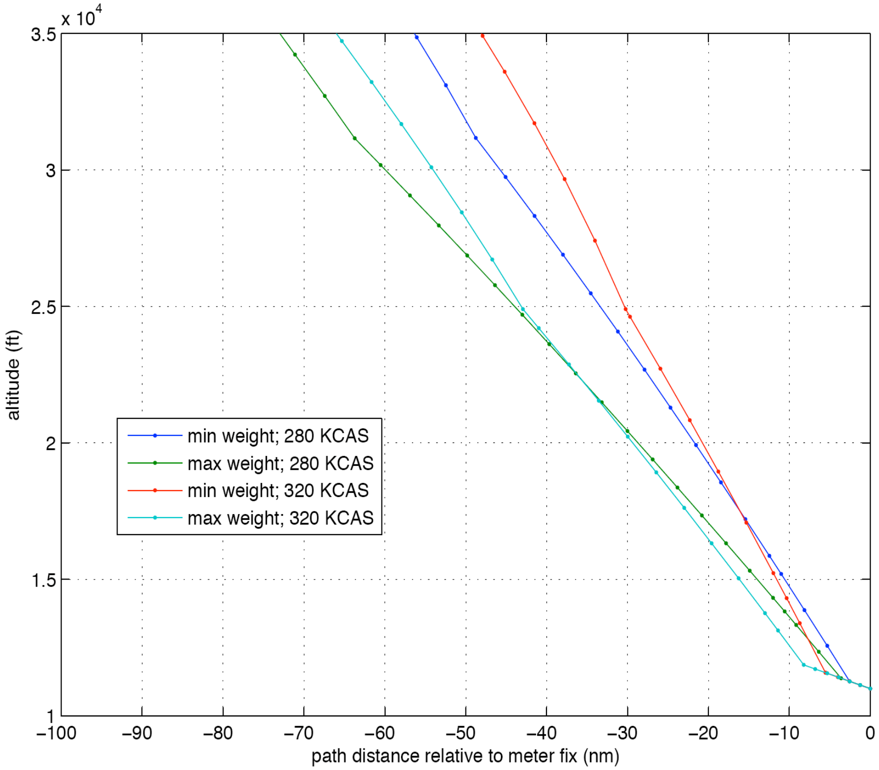
Next Step
- Conduct research to determine needs and implications on interoperability
- Validation is necessary

Partners: GE

Ability to meet complex combination of constraints to support 4D trajectory-based operations

Trajectory Uncertainty Modeling for EDA

Problem/Need
- Examine trajectory uncertainty with look-ahead time



Approach
- Develop model of the trajectory prediction error due to weight, wind and performance as a function of look-ahead time

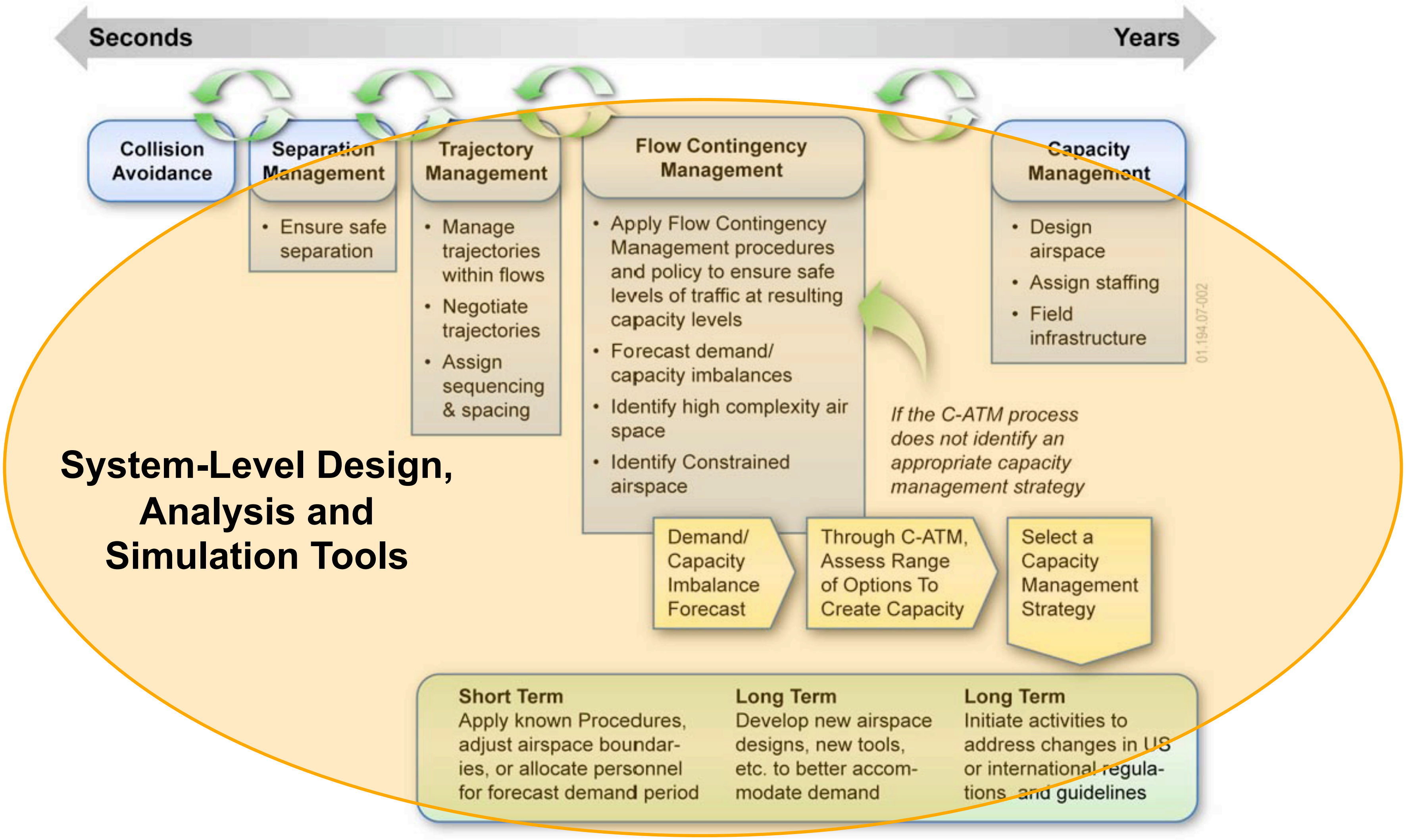
Progress/Results
- Developed initial method to model uncertainty
- Developed application for En Route Descent Advisor

Next Steps
- General model for trajectory uncertainty prediction
- Validation

Partners: NRA (L3) and Lockheed Martin

Need to clearly understand trajectory uncertainties and technology requirements

SLDAST Elements of Automation for a Future Airspace System



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Research Focus Area System-Level Design, Analysis and Simulation Tools

Problem

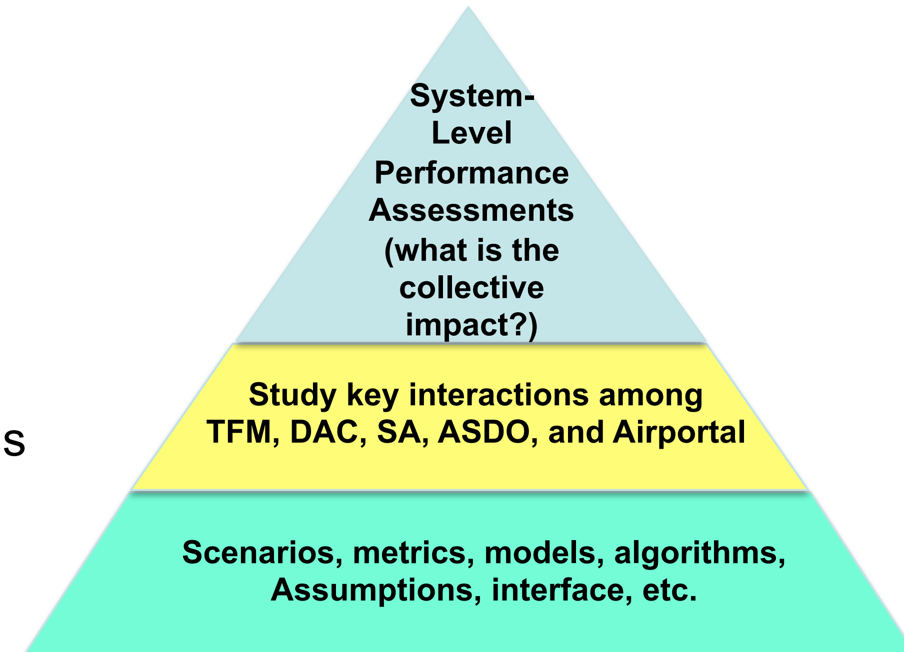
- Complex and interacting concepts and technologies
- Collective impact of concepts and technologies is not easily understood

Expected Impact or End Result

- System level impact assessment
- Interactions between key research focus areas

Research Being Pursued

- Metrics, scenarios, assumptions, and models
- Interaction studies
- System-level performance assessment



Partners: Volpe, NRAs (SJSU, GMU, U. of Virginia, OSI, and Sensis)

Collective impact of concepts and technologies need to be clear

Human Factors Assessment I

Problem/Need
- Identify (initial) human-performance-related considerations

Approach
- Detailed cognitive walkthrough
- Expert opinions through NRA

Supported by NRA team (SJSU)

Progress (Examples)
- Trust and reliance when automation is safety-critical
- Non-overlapping task distributions (mixed equipage)
- Degraded conditions

Next Steps
- Use the lessons learned during further maturity process

Partners: NRA **(**SJSU), and Volpe

Ultimately, humans will be part of the system. What is their role?

Concluding Thoughts

Attributes	Description
Objectives/Needs	• On-time performance • Reduce operator costs (fuel) • Increase system productivity • Minimize impact on environment • Design for scalability, safety, predictability
Current state of the art	• Capacity and throughput is limited due to human centric nature (not scalable) • Weather causes large delays • Uncertainty • Interactions limit capacity
Approach	Advance concepts, procedures, and technologies for both ground and aircraft
Lessons learned	• Uncertainty (weather, wind, traffic, etc.) • Solutions will involve roles/responsibilities, automation, procedures, and air/ ground integration • Off-nominal situations and mixed equipage need to be carefully examined • Interactions among traffic • RTTs need to stay focused
Impact	• FAA: Increase productivity • Users: Reduce costs and increase on-time performance • Manufacturers: Sell more aircraft and accessories • Public: Fly as needed and minimum delays
NASA's role	Complex domain, unique and relevant skills, experience (ground-based and aircraft), JPDO identified NASA as lead on many research items