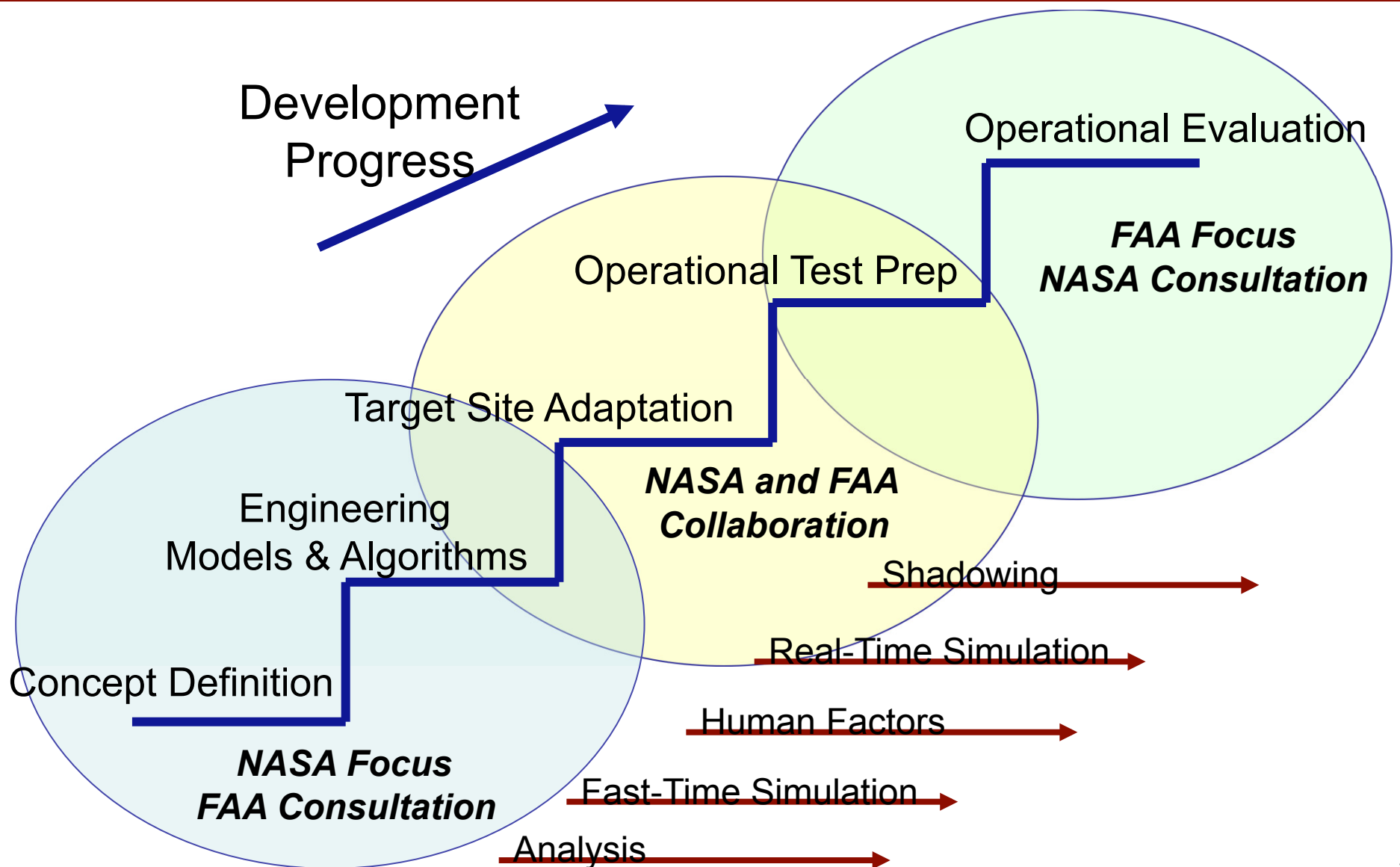# NASA Systems Analysis, Integration and Evaluation Research

Barry T. Sullivan
Airspace Systems Program
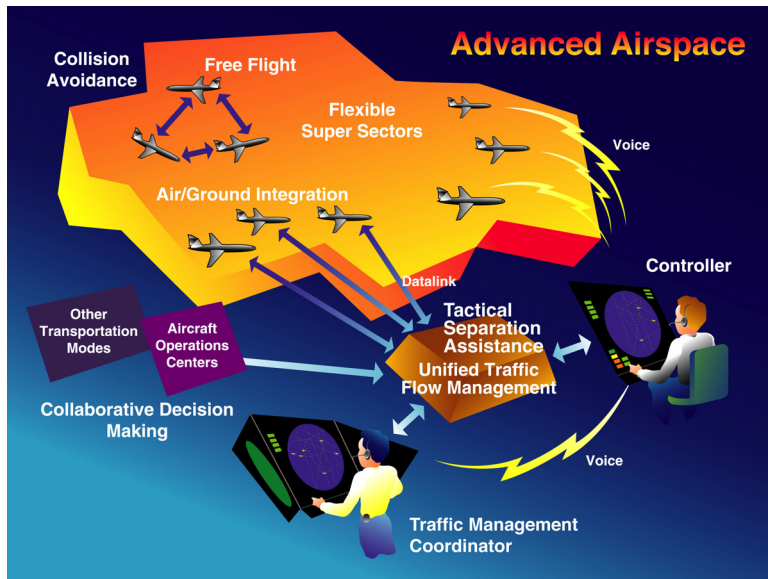Briefing for NRC Panel of Experts
May 14-15, 2009

Purpose

- The Airspace Systems Program (ASP) is planning new system experimentation activities to address community recommendations

- Overall goal is to integrate advanced operational concepts, technologies and procedures to safely increase both system capacity and airspace system efficiencies

R&D Progression

Development Progress

Operational Evaluation

**FAA Focus
NASA Consultation**

Operational Test Prep

Target Site Adaptation

**NASA and FAA
Collaboration**

Engineering
Models & Algorithms

Concept Definition

**NASA Focus
FAA Consultation**

Shadowing

Real-Time Simulation

Human Factors

Fast-Time Simulation

Analysis

Refocused ASP Portfolio

Advanced Airspace

Collision Avoidance · Free Flight · Flexible Super Sectors · Voice · Air/Ground Integration · Controller · Datalink · Tactical Separation Assistance · Unified Traffic Flow Management · Other Transportation Modes · Aircraft Operations Centers · Collaborative Decision Making · Voice · Traffic Management Coordinator

NextGen - Concept & Technology Development	NextGen - Systems Analysis, Integration & Evaluation

- Dynamic Airspace Configuration
- Traffic Flow Management
- Separation Assurance
- Super Density Operations
- Safe & Efficient Surface Operations

- Systems Analysis (e.g., collective impact)
- Interoperability (e.g., trajectories)
- Integration, Test & Evaluation of System Concepts
  - Research Transition Teams (RTT)

Purpose of the Remaining Brief

- To define the NextGen Systems Analysis, Integration, and Evaluation (SAIE) Project
- To provide an overview of the work being formulated to support this effort

SAIE Vision, Mission & Scope

- Vision
  - Transition from the laboratory to the field, concepts, technologies and procedures that are beneficial to NextGen.

- Mission
  - Identify collective impacts of integrated concepts
  - Accelerate the maturity of key concepts, technologies and procedures that provide operational benefit, and integrate and test these capabilities in relevant environments to enable increased capacity, efficiency and throughput.

- Scope
  - Conduct system analysis, integration, testing and evaluation of key research concepts integrating surface, terminal, transitional airspace and en route capabilities in collaboration with research stakeholders.

Benefits

- Integration of advanced operational concepts, technologies and procedures will safely enable significant increases in:

    - efficiency, capacity and throughput

- Balance demand/capacity constraints

- Additional benefits include reductions in:

    - flight time and flight path

    - fuel consumption and operating costs

    - emissions (CO_2 and NOx)

    - noise

Bridges the gap between foundational and systems integration activities to transition NASA research to implementers
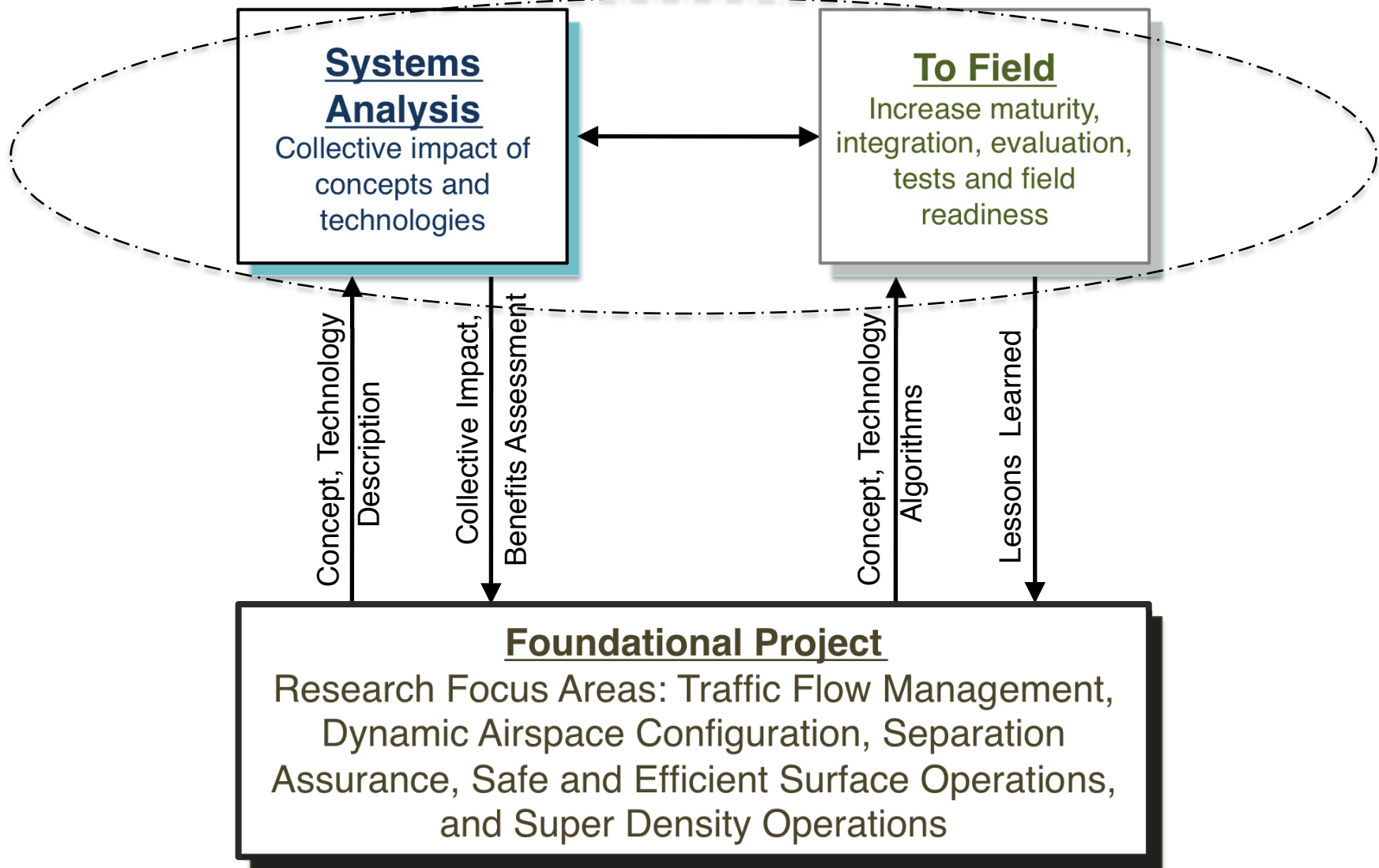
Technical Objectives

- Mature technologies for increasing capacity, efficiency and throughput

- Assess collective impact of these technologies using fast-time modeling and simulation, and feed back results into the baseline program to enhance and validate research concepts

- Examine the feasibility and impact of integrated concepts and technologies using human-in-the-loop simulations in relevant environments

- Assess alternate fleet implications on National Airspace System (NAS) operations
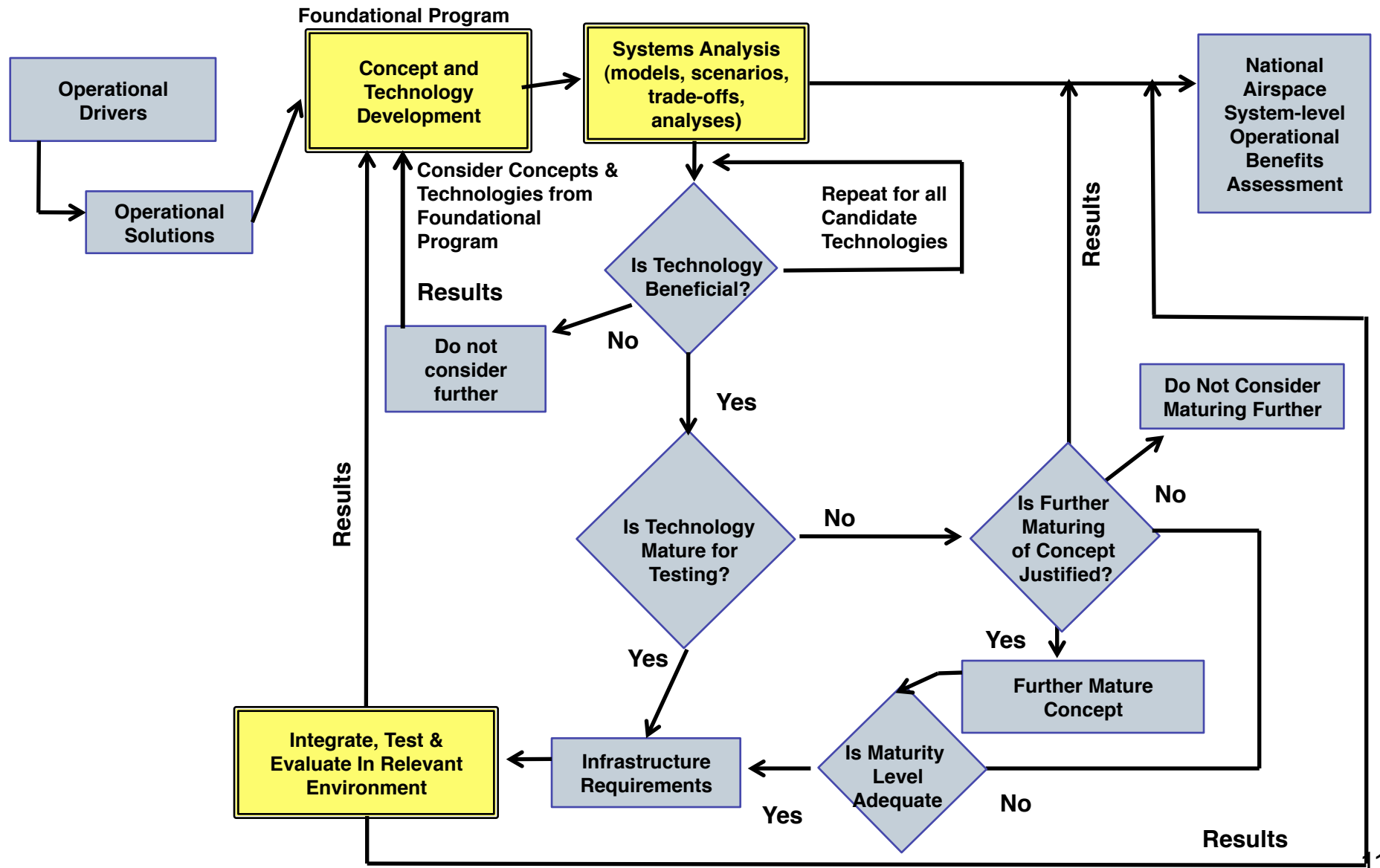
Technical Approach

- The SAIE Plan will build upon on-going work within the current Airspace Systems Program research portfolio and will leverage the existing RTTs

- Research focus areas will emphasize all flight domains with a primary goal of maturing concepts, technologies and procedures for increasing capacity, efficiency and throughput

- Work conducted within this activity can be categorized in 3 main areas:
  - Systems Analysis
  - Interoperability
  - Integration, Testing and Evaluation of candidate concepts

- Candidate research concepts will be assessed as to their maturity and their operational benefit through systems testing as follows:
  - Full-mission system evaluations using human-in-the-loop simulations
  - Integrated air-ground flight test of concepts down-selected from full-mission simulations

- Collaborate with industry and government partners to transition technologies that enable increases in capacity and efficiency, while maintaining or improving safety and environmental conditions.

Systems Analysis, Integration, and Evaluation

Systems Analysis
Collective impact of concepts and technologies

To Field
Increase maturity, integration, evaluation, tests and field readiness

Concept, Technology Description

Collective Impact, Benefits Assessment

Concept, Technology, Algorithms

Lessons Learned

Foundational Project
Research Focus Areas: Traffic Flow Management, Dynamic Airspace Configuration, Separation Assurance, Safe and Efficient Surface Operations, and Super Density Operations

Notional Process for Integrated Testing

Foundational Program

Operational Drivers

Operational Solutions

Concept and Technology Development

Systems Analysis (models, scenarios, trade-offs, analyses)

National Airspace System-level Operational Benefits Assessment

Consider Concepts & Technologies from Foundational Program

Results

Repeat for all Candidate Technologies

Results

Is Technology Beneficial?

Do not consider further

No

Yes

Do Not Consider Maturing Further

Is Technology Mature for Testing?

No

Is Further Maturing of Concept Justified?

No

Yes

Yes

Further Mature Concept

Results

Integrate, Test & Evaluate In Relevant Environment

Infrastructure Requirements

Is Maturity Level Adequate

Yes

No

Results

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Systems Analysis

- Systems Analysis will build upon existing foundational program to determine and document those concepts having the highest potential of improving capacity and operational efficiencies

- Systems Analysis will include the following activities:
  - Verifying focus on aviation system operations
  - Defining operational metrics and targets
  - Survey existing tools and models and determine enhancements required to support this activity
  - Enhance existing tools and models to conduct system-wide assessments including insertion of new aircraft types and different fleet mixes
  - Perform concept assessments and NAS-level operational impact analysis and optimization of integrated concepts and technologies
  - Feedback to foundational project regarding interdependencies and collective benefits

Interoperability & Integration of System Concepts

- Efficient Arrival Management
- Integrated arrival scheduling and flight deck merging and spacing
- Air-ground interoperable trajectory
- Automated separation assurance (detection and resolution)
- Probabilistic weather and flow management integration
- Adaptable airspace algorithms
- Integrated arrivals/departures/surface operations for high throughput and environmental considerations

Candidate Research Concepts Maturity Levels

	Function	Additional Work to be Done
Arrivals		
Optimized Profile Descents (OPD)	Arrival procedures with vertical profiles optimized to facilitate a continuous descent from the top of descent to touchdown. OPD flight procedures use the capabilities of the aircraft Flight Management System to fly a continuous, descending path without l	Procedure design; simulations to validate that routing and profile constraints are compatible with flight execution through the FMS; embed EDA solutions within a datalink-compatible TA clearance.
Tailored Arrivals (TA)	Defines the mechanisms and procedures for the communication & execution of flexible RNAV/RNP routes to the runway via datalink.	Procedure design; sims to validate that routing and profile constraints are compatible with flight execution through the FMS; embed EDA solutions within a datalink-compatible TA clearance. Previous work had focused in oceanic environment, where needed wo
Traffic Management Advisor (TMA) Scheduler	Tactical time-based metering; Plans strategic sequence and schedule to TRACON meter fixes.	Integrate tools for aircraft spacing at the arrival meter fixes for uninterrupted OPD to the runway and expeditious taxi to gate; pass ETAs to SMS; receive SMS surface constraints.
En Route Descent Advisor (EDA)	Generates trajectory-based descent solutions in transition airspace to meet TMA schedule.	Ensure conflict-free OPD; Functions and computer-human-interface for clearance delivery over datalink, using standard (CPDLC) message sets for FMS interoperability; Embedding of EDA solutions within a comprehensive TA trajectory clearance; Accommodation
Required Time of Arrival (RTA)	FMS uses RTA to achieve Continuous Descent Arrivals (CDAs).	Extend to system-benefits (vs. individual aircraft); simulations to explore potential for providing another RTA at a waypoint near the TRACON boundary and/or the runway threshold.
Energy Navigation (eNAV)	Real-time FMS vertical navigation and auto throttle commands.	Develop and test a stand-alone version of eNAV for test aircraft.
Airborne Precision Spacing (APS)	Fine-tuned spacing.	Complex multi-runway airport operations; dynamic routing; APS-equipped with not-equipped.
Arrival scheduler	Ensure efficient operations for super density situations by creating a robust arrival schedule.	Develop and evaluate meter-fix and runway threshold schedule based on traffic demand, aircraft equipage, runway configuration, arrival rates, and weather.

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Candidate Research Concepts Maturity Levels

	Function	Additional Work to be Done
Surface Operations		
Surface Management System (SMS)	Strategic departure and arrival management	Enhance with coordinated arrival and departure schedules; Optimized taxi routes; quality of conformance to planned schedules and routes: resolutions to potential conflicts; incorporate weather as a constraint; Integrate environmental planner: Integrate w
Departures		
Combined Arrivals/Departure Runway Scheduling (CADRS)	Arrivals/Departures runway assignment and scheduling across given runway configurations	Integrate with SMS; integrate with TMA for accurate arrivals schedule; Integrate tool for identifying appropriate departure times for Approval Requests (APREQS) to departing aircraft based on overhead stream constraints
Departure Release Calculator (DRC)	Ensure departures are seamlessly integrated into the en route overhead traffic flow	Integrate with departure scheduling tools
En Route		
Direct-To (D2)	Provide direct routings to aircaraft - saves time and fuel	Integrated solution to request direct routings from aircraft
Multi-Sector Planner (MSP)	Provide trajectory clearances to aircraft and serve as an intermediate role between tactical radar controller and strategic traffic flow management	Identify information and display needs, automation functions, and roles and responsibilities
Traffic Flow Management (TFM)	Flight routing and scheduling.	Combine with wind optimal routes.

Candidate System Technologies

- Arrival management with En Route Descent Advisor (EDA) - simulations, field tests planned
- Ground-based scheduling integrated with flight deck merging and spacing
- San Francisco marine stratus and ground delay program

Efficient Flow Into Congested Airspace (EFICA) RTT Focus

- EDA is a key underlying capability to the EFICA RTT focus which is aimed at enabling Optimized Profile Descents

- EFICA focus also includes:
  - Traffic flow management
  - Ground-based scheduler
  - Flight deck merging and spacing

- Four new products (under formulation)
  - Implications of weather on traffic management strategies
  - Storyboarding terminal airspace operations for NextGen
  - Develop concept of operations for arrival management
  - Develop integrated ground-based scheduling technology and flight deck merging and spacing

En Route Descent Advisor (EDA)

NASA's En Route Descent Advisor (EDA) is a controller decision-support tool that enables 3DPAM

Human-in-the-loop Simulation

- Software development and hardware integration
- First 3DPAM simulation: April 27, 2009
- Shakedown of EDA Build 4.0.
- Controller participants: facility managers and recently-retired controllers from Denver Center

Two field tests at Denver Center

- First field test (September 2009): data collection for assessing real-world descent trajectory uncertainty
- Develop uncertainty models for incorporation in future simulations. Goal is to provide more defendable simulation results for basing final FAA investment decisions
- Test will include commercial (United and Continental) flights into Denver, along with an FAA test aircraft (Global 5000 business jet)
- Second field test (December 2010): EDA prototype in front of sector controllers for real-time, operational decision support
- FAA final investment decision: 2012, Tentative Deployment: 2015
- Post ERAM Build 3

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Refine Algorithms for Merging and Spacing Operations to a Single Runway

- Examined the flight deck merging and spacing technologies to increase throughput at the runway threshold
  - A human-in-the-loop simulation was conducted using 26 pilots and 3 controllers
  - Flight crew followed on-board speed guidance to maintain controller assigned spacing using Airborne Spacing for Terminal Arrival Routes system

Speed Guidance

Actual Time Interval Between Aircraft at Arrival Waypoints
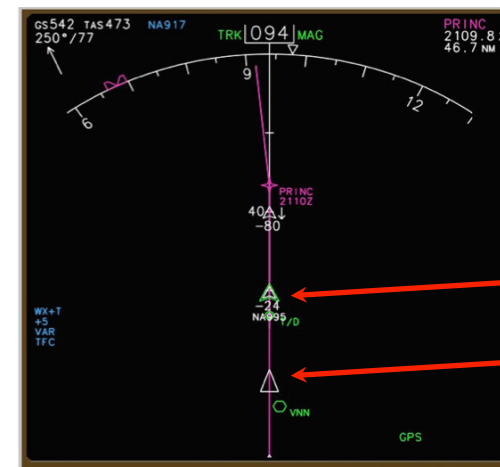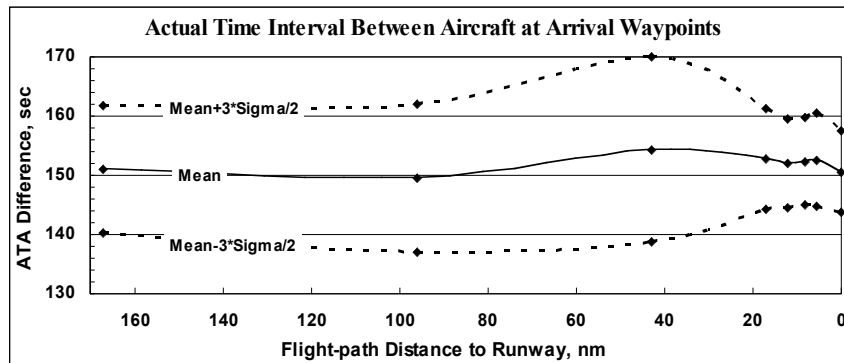
Lead Aircraft

Ownship

Higher runway threshold accuracy was maintained (0.8 sec error) indicating that higher throughput can be maintained

M/S 3.6.02 (4QFY09)

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San Francisco Stratus and Flow Scheduling

- Develop decision support to <u>reduce delays</u> for San Francisco arrivals based on <u>better stratus forecast and flow management algorithms</u>

- Enabling research pursued in FY2009
  - Model developed to recommend key parameters for establishing Ground Delay Programs at SFO
  - Model uses probabilistic weather data from the National Weather Services' SFO Status Forecast System
  - Model leverages the FAA's operational ground delay program modeling system, and requires no modifications to the operational system
- Analysis and integration done in FY2010
  - Field evaluation of a model at the FAA Air Traffic System Command Center to enhance Ground Delay Program decision making with probabilistic stratus clearance time forecasts at San Francisco International airport
- Collaboration with FAA and NRA partner

- Potential benefits
  - Model recommends Ground Delay Program end times that are on average 58 minutes earlier than operational times

Estimated savings to airlines: $2.8 million/year

Integration of Advanced Vehicles and Concepts into NextGen

- Two $6M, 18-Month NASA Studies which seek to understand tradeoffs involved for both vehicles and the ATM system, including safety considerations, system performance, environmental constraints
  - "Advanced Vehicle Concepts and Implications for NextGen," Sensis Corporation (PI: Fred Weiland) Cruise Efficient STOL, Rotorcraft, Supersonic Transports, Very Light Jets and Un-crewed Aerial Vehicles

  - "Integration of Advanced Concepts and Vehicles into NextGen Study," Raytheon Company (PI: Ed Stevens) Supersonic Business Jets, Very Large Transports, Very Light Jets and Un-crewed Aerial Vehicles.

- Two major outcomes required by the solicitation
  - An analyses and study over the trade-space of capacity performance, safety and environmental impact for advance vehicle classes in NextGen.
  - An initial analyses framework to used to conduct the study including all modeling and software tools developed and utilized.

Integration, Testing and Evaluation

- Evaluate the impact of the concepts and technologies in relevant environments

    – Define requirements and capabilities to support full-mission system level simulations and integrated air-ground field testing

    – Examine the feasibility of the integrated concepts and technologies using human-in-the-loop simulations

    – Enhance existing simulation capabilities (e.g., North Texas Facility - NTX) to enable integrated testing, linking simulation facilities and components, data feeds, aircraft and air navigation service provider elements

    – Assess collective impact of these technologies and feed back results into the foundational program to enhance and validate research concepts

    – Collaborate with industry and government partners to transition technologies that enable increases in capacity and efficiency, while maintaining or improving safety and environmental conditions

Example Experiments using NextGen Testbeds

DFW is 3rd busiest US tower (movements) per FAA 2007

W ATCT
AA Ramp Tower
E ATCT
DFW ATCT & TRACON

DFW

AA

AA AOC
ZEW & NTX

NTX
North Texas Research Station
NASA / FAA

NextGen requires tests of multiple, integrated concept capabilities such as:

- Linking surface, arrival and departure flows
- Interaction of flow management with separation assurance

DAL is 50th busiest US tower (movements) per FAA 2007

North Texas Facility (NTX) embeds NASA research assets in a complex, relevant metroplex operational environment

- Concept definition activities support experiments
- System analyses enable consideration of future aircraft fleets and operations

W A AOC
DAL ATCT

SOUTHWEST
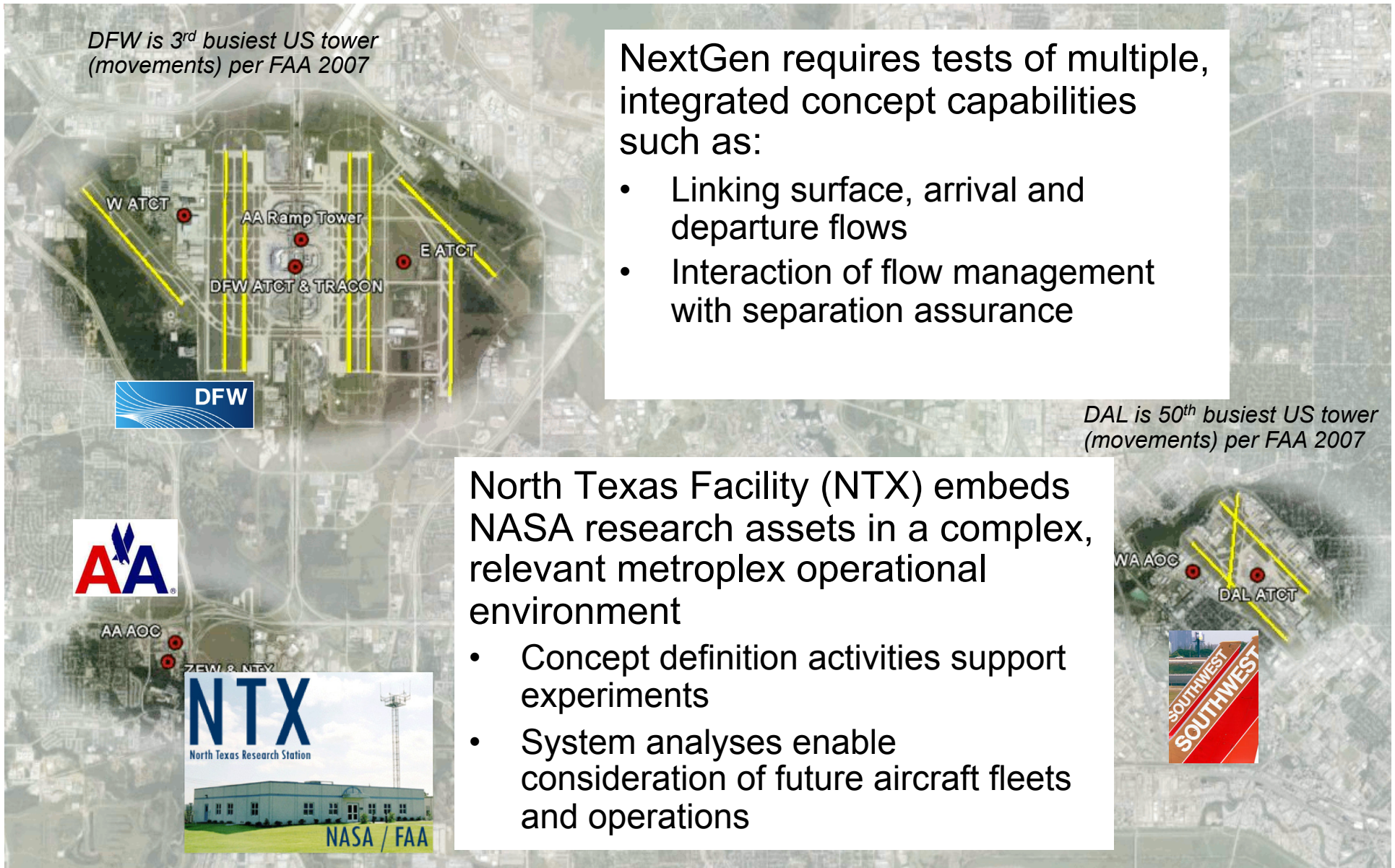
Alignment with Other Programs

- The SAIE builds upon existing work within the baseline ASP, which already is in direct alignment with the JPDO's vision for NextGen

- SAIE will highly leverage the existing Research Transition Teams

  – Efficient Flow into Congested Airspace

  – Multi-Sector Planning

  – Integrated Arrival/Departure/Surface Operations

  – Dynamic Airspace Configuration

- SAIE will leverage existing industry work being performed in the following NRAs:

  – "Integration of Advanced Concepts and Vehicles into NextGen Study" (ASP Systems Study)

  – "Advanced Concept Studies for Subsonic and Supersonic Commercial Transports Entering Service in the 2030-2035 Period" (FAP "N+3" System Study NRA)

- SAIE is being planned in coordination with both the Fundamental Aeronautics (FAP) and Aviation Safety Programs

Summary

- The Airspace Systems Program is developing a plan for Systems Analysis, Integration, and Evaluation, to mature and transition technologies from the laboratory to the field

- Plan is focused on building upon existing research elements and maturing those concepts that are expected to provide operational benefits and then testing in relevant environments

- SAIE plan is being coordinated with inputs from the Fundamental Aeronautics and Aviation Safety Programs

- SAIE plan will leverage existing RTTs and will collaborate with industry and other government partners to transition technologies that enable increases in capacity and efficiency.

ASP Contributions to NextGen
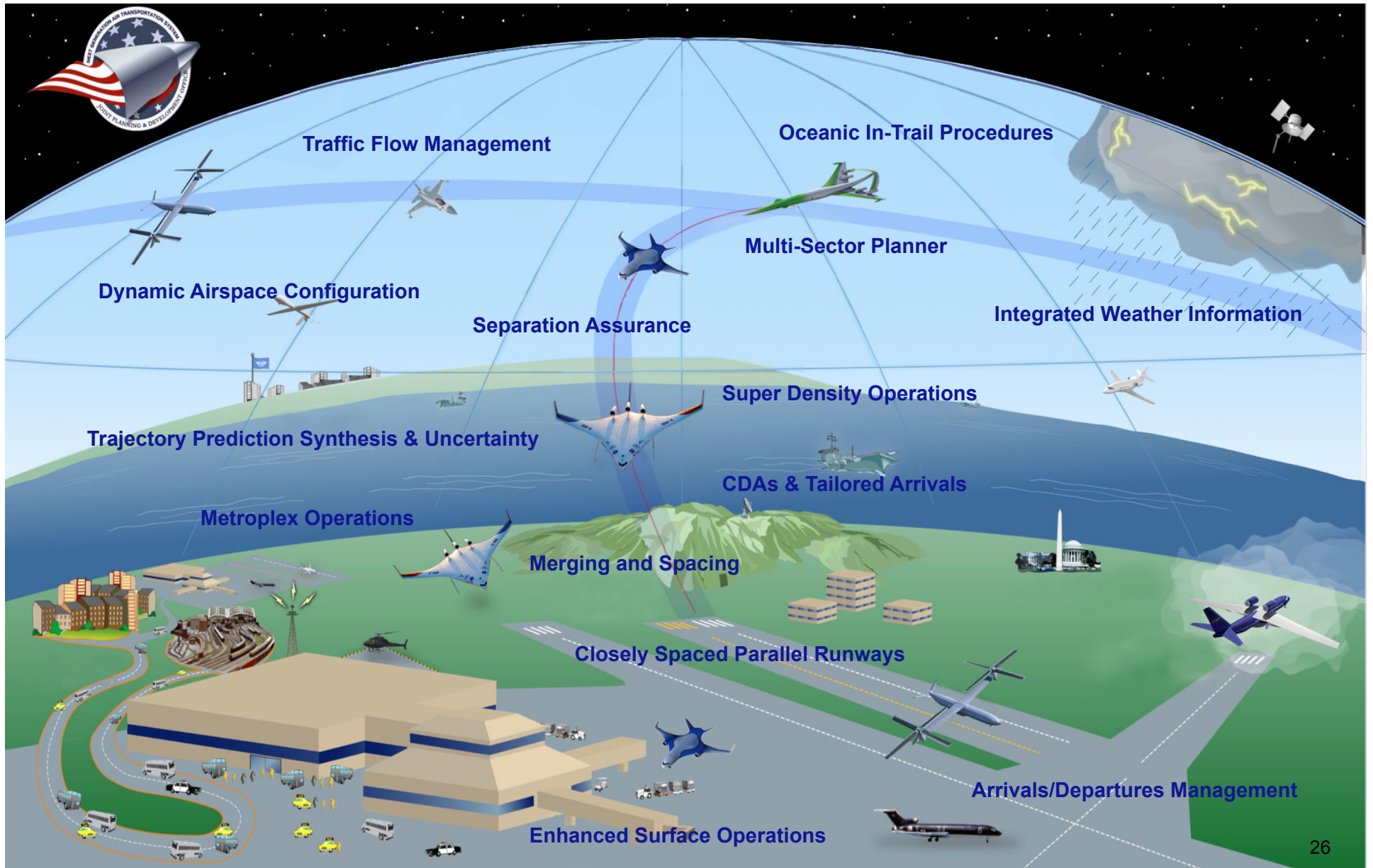
Back-Up Slides

NASA/FAA Roles/Responsibilities

NASA Roles/Responsibilities	TRL	FAA Roles/Responsibilities
No NASA Responsibillity	9	Hardware acquisition, training, installation, and initial operations
No NASA Responsibiility	8	Site adaptations, control and monitor functions added, system acceptance testing.
Technical expertise support to FAA in addressing how to modify prototype to address site specific operations and integration with other facility tools which operate in same environment.	7	Upgrading prototype for facility-specific operations and integration with other tools operating in the facility.
Testing "pre-development DST" for functionality, acceptability, and performance in field environment. Update life-cycle cost/benefits, safety and human factors assessments. Finalize TRL 6 SSS, SSDD, SDDs, STDs, and STRs. Write SUM and SIOM.	6	Continues DID documentation development, creates development plans for site-specific upgrades, integration with other tools, and general site adaptation. Selects deployment sites and schedules. Provides controllers, live data feeds and access to facilities for testing.
Adapting "research DST" to actual hardware to create "pre-development DST" and testing in lab environment Updating SSS, SSDD, SDDs, STDs, & STRs. Support FAA discussions on evolvability/ capability/ limitations/ integration.	5	Initiates conversion of NASA documentation to FAA data item descriptions (including formal requirements), assesses site applicability based on capabilities and limitations of prototype, evaluates integration issues associated with other tools in same environment, and evaluates ops con in terms of likely deployment environment. Provides controllers, live data feeds and access to facilities for testing.
HITL testing of "research DST" in high fidelity environment (lab and/or field), life-cycle cost/benefits, updated safety and human factors assessments. Update OCD, SSS, and SSDD. Begin SDD, STD, and STR's.	4	Designate key FAA point of contact. FAA participates in testing as agreed in RMP. Provides controllers, live data feeds, and access to facilities for testing.
Testing "conceptual DST" for basic algorithm, procedures, and CHI evaluation in office lab environment Update SSS and begin SSDD. Brief FAA deployment org (AOZ).	3	Receive briefing on tool. Provides controllers, live data feeds, and access to facilities for testing.
Developing research plans to address NASA responsibilities, site surveys, single-year benefits assessment, initial safety assessment, and initial human factors assessment. Begin SSS. Develop NASA part of RMP.	2	Develop FAA part of RMP. Maintain FAA awareness through IA/IPT.
Developing operational concept description (OCD).	1	No FAA responsibility; however awareness through IA/IPT.

**System Management**   ■ - Technical Direction and Ownership   ■ - Technical Support

Multi-Sector Planner (MSP) RTT

- Goal is to bridge gap between the strategic planning of traffic management and the tactical operations of the en route sector team

- The MSP:
  - Creates efficient trajectory-based solutions by fine tuning traffic management initiatives to increase efficiency, reduce delays, and ensure that sectors under their management do not exceed complexity thresholds
  - Supports redistributed roles, responsibilities, and flexible workforce management options
  - Adapts to work where the demand is expected (not assigned to a static position)
  - Minimizes impact of reroutes, manages complexity and maximizes capacity

MSP RTT

- MSP feasibility HITL in 2006 to explore two variant concepts – Area Flow MSP chosen to explore in a follow-up study

- FAA has initial draft of Midterm Operational Concept for MSP (April 2009)

- MSP experiment plan is being finalized; experiment review to be conducted soon

- Simulation will be conducted in June-July 2009

- Goals: roles and responsibilities, communication and coordination, information and decision support tool needs
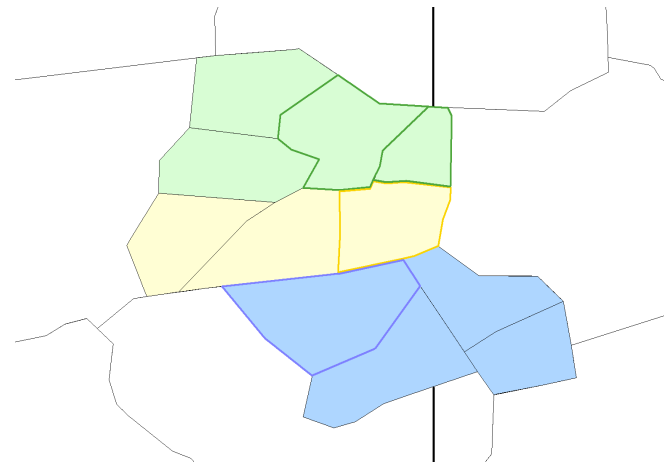
MSP adjust traffic flow to meet sector capacity