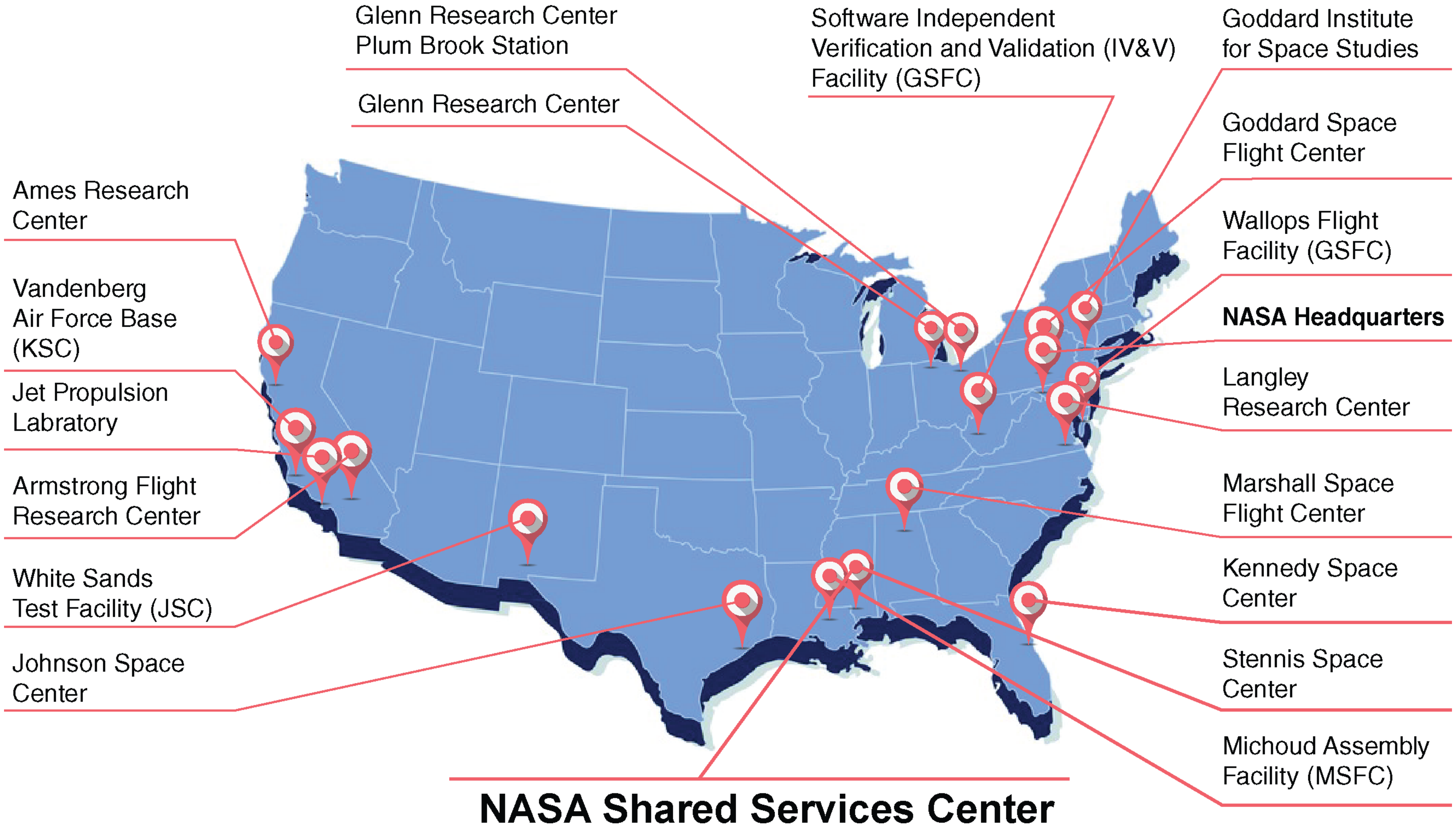
NASA Research and Transition to the FAA
Human/Systems Focus

Tom Prevot
Human Systems Integration Division
NASA Ames Research Center

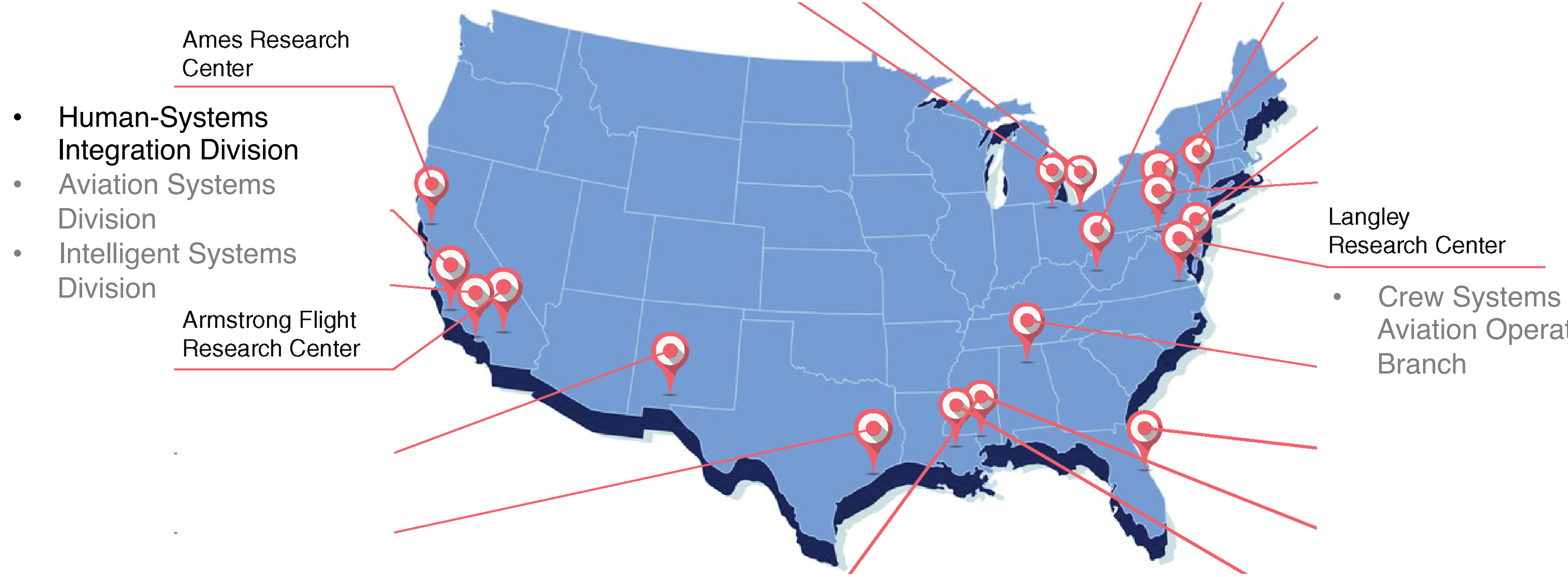
NASA Sites



Glenn Research Center
Plum Brook Station
Glenn Research Center
Software Independent
Verification and Validation (IV&V)
Facility (GSFC)
Goddard Institute
for Space Studies
Goddard Space
Flight Center
Wallops Flight
Facility (GSFC)
NASA Headquarters
Langley
Research Center
Marshall Space
Flight Center
Kennedy Space
Center
Stennis Space
Center
Michoud Assembly
Facility (MSFC)
Ames Research
Center
Vandenberg
Air Force Base
(KSC)
Jet Propulsion
Labratory
Armstrong Flight
Research Center
White Sands
Test Facility (JSC)
Johnson Space
Center
NASA Shared Services Center

NASA Sites addressing Aviation Human Factors

Human factors research at NASA is largely embedded in overarching research effort
All organizations addressing HF have a mix of engineers, computer scientists and HF specialists
Human/Systems integration primary focus rather than classic HF



NASA Aeronautics Research and FAA involvement

- NASA’s lower TRL research informs FAA and other stakeholders via publications and presentations
  - NASA Aeronautics Mission Directorate (ARMD) determines the research according to NASA’s research strategy, funds and conducts the research
  - NASA engages stakeholders and partners in research process and publishes/presents results

- NASA’s higher TRL research and technologies transitions to FAA via Research Transition Team
  - NASA develops relevant concepts and technologies to higher TRL
  - NASA/FAA Research Transition Team (RTT) is formed and technology transfer is coordinated
  - Coordinated and joint activities transition NASA research results, concepts and technologies for FAA implementation

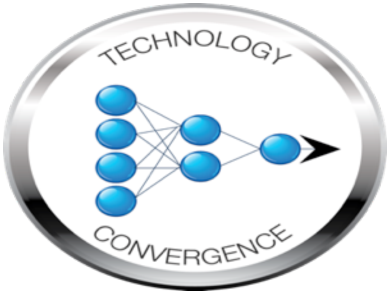
- NASA research can be directly funded by FAA
  - FAA determines that NASA has the required expertise/capabilities and funds NASA directly to conduct specific research

- Other: E.g. Commercial Aviation Safety Team (CAST) Research Safety Enhancements
  - NASA takes responsibility for Airplane State Awareness (ASA) research elements proposed by CAST

NASA HSI Research and Transition to the FAA

FROM NASA’S STRATEGIC VISION TO POTENTIAL FAA IMPLEMENTATION

NASA Aeronautics Research Six Strategic Thrusts



Safe, Efficient Growth in Global Operations
- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

Innovation in Commercial Supersonic Aircraft
- Achieve a low-boom standard

Ultra-Efficient Commercial Vehicles
- Pioneer technologies for big leaps in efficiency and environmental performance

Transition to Low-Carbon Propulsion
- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

Real-Time System-Wide Safety Assurance
- Develop an integrated prototype of a real-time safety monitoring and assurance system

Assured Autonomy for Aviation Transformation
- Develop high impact aviation autonomy applications

How are the vision's research thrusts used?

All of the programs address more than one, or all, of the research thrusts.

MISSION PROGRAMS

Airspace Operations and Safety Program

AOSP

- Safe, Efficient Growth in Global Operations
- Real-Time System-Wide Safety Assurance
- Assured Autonomy for Aviation Transformation

Advanced Air Vehicles Program

AAVP

- Ultra-Efficient Commercial Vehicles
- Innovation in Commercial Supersonic Aircraft
- Transition to Low-Carbon Propulsion
- Assured Autonomy for Aviation Transformation

Integrated Aviation Systems Program

IASP

- Flight research-oriented, integrated, system-level R&T that supports all six thrusts
- X-planes/ test environment

SEEDLING PROGRAM

Transformative Aeronautics Concepts Program

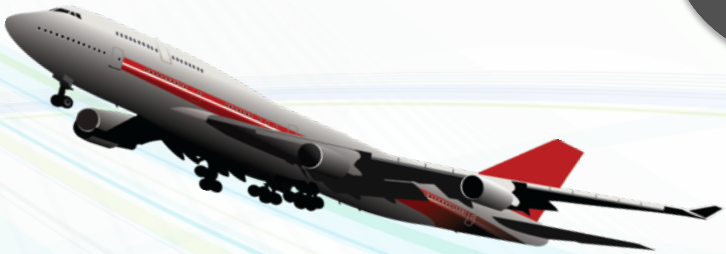
TACP

- High-risk, leap-frog ideas that support all six thrusts
- Critical cross-cutting tool & technology development

What is the Airspace Operations and Safety Program?

This program integrates the Airspace Systems Program and Aviation System-Safety work.

Mission Program



Airspace Operations and Safety Program

Develops and explores fundamental concepts, algorithms, and technologies to increase throughput and efficiency of the National Airspace System safely.

Provides knowledge, concepts, and methods to the aviation community to manage increasing complexity in the design and operation of vehicles and the air transportation system.

Continues Airspace Systems Program research, and the aircraft state awareness research and system wide safety research that was previously conducted within the Aviation Safety Program.

Projects

Airspace Technology Demonstrations

SMART NAS—Testbed for Safe Trajectory-Based Operations

Safe Autonomous System Operations

Research Transition via NASA/FAA Research Transition Teams (RTT)

- NASA Aeronautics Mission Directorate (ARMD) determines the research according to NASA's research strategy, funds and conducts the research
- NASA engages stakeholders and partners in research process and publishes/presents results

If suitable for near-term implementation and highly promising

- NASA develops relevant concepts and technologies to higher TRL
- May become Airspace Technology Demonstration (ATD) project
- NASA/FAA Research Transition Team (RTT) is formed and technology transfer is coordinated
- Coordinated and joint activities transition NASA research results, concepts and technologies for FAA implementation

NASA-FAA Research Transition Process

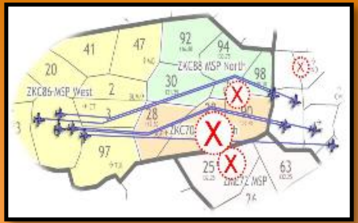
NASA Concepts →Technology Demonstrations→ FAA

NASA's work on these technologies

MULTI-SECTOR PLANNER (MSP)

- Contributes to bridging the gap between strategic flow contingency management and the tactical separation management functions

Transferred to FAA – July 2011



- *Informed Flow Based Trajectory Management Segment Bravo (2018) OI Definition*

Product Benefits

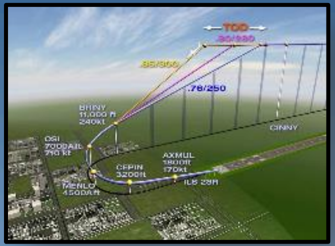
- 15% reduction in total delay
- Avg. delay reduced 24–37min/flt to 2.2–2.8 min/flt
- 1/3 of reroutes were shortened an avg of 11.2nm/flt

NASA's work on these technologies

Efficient Descent Advisor (EDA)

- Speed Advisories
- ♦ Path Stretch Advisories

Transferred to FAA - Jan. 2012



- *Operational in Albuquerque Center in 2014*
- ♦ *Potential FAA deployment 2018*

Product Benefits

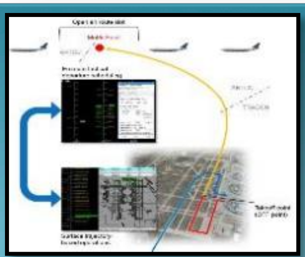
- $97M/yr savings - improved meter-fix delivery accuracy
- $31M/yr savings - reduced fuel burn in en route airspace
- ♦ $143M/yr savings - improved meter-fix delivery accuracy
- ♦ $46M/yr savings reduced fuel burn in en route airspace
- ♦ 60% reduction in metering-related clearances

NASA's work on these technologies

Precision Departure Release Capability (PDRC)

- Precision release of tactical departures for efficient en route stream merge
- Analogous to cars merging onto a busy freeway

Transferred to FAA - July 2013



- *FAA expected deployment 2018*

Product Benefits

- 50% increase in departure time conformance
- $20M/yr savings to airlines from increased en route slot merge compliance

NASA's work on these technologies

TERMINAL SEQUENCING & SPACING TOOL (TSAS)

- Advanced scheduling and sequencing of arrivals and runway
- Terminal controller advisories to maintain precision schedules implemented on FAA's STARS system

Transferred to FAA - July 2014

- *FAA Final Investment Decision (FID) December 2014*
- *FAA expected deployment 2019*

Product Benefits

- Precision scheduling (+/- 15 sec) to runway for increased throughput
- 98% PBN conformance during high density, mixed equipage operations for fuel-efficient operations
- $300-400M – Annual savings to airline

Research Transition Teams

RTT Membership

Efficient Flow Into Congested Airspace	Integrated Arrival Departure Surface Operations	Data Management
NASA, Federal Aviation Administration	NASA, Federal Aviation Administration	NASA, Federal Aviation Administration

Realtime System Wide Safety Assurance	Applied Traffic Flow Management & Wx Integration	Autonomy
NASA, Federal Aviation Administration	NASA, Federal Aviation Administration, Department of Defense United States of America, Department of Commerce United States of America	NASA, Federal Aviation Administration, Department of Defense United States of America, Department of Commerce United States of America, U.S. Department of Homeland Security

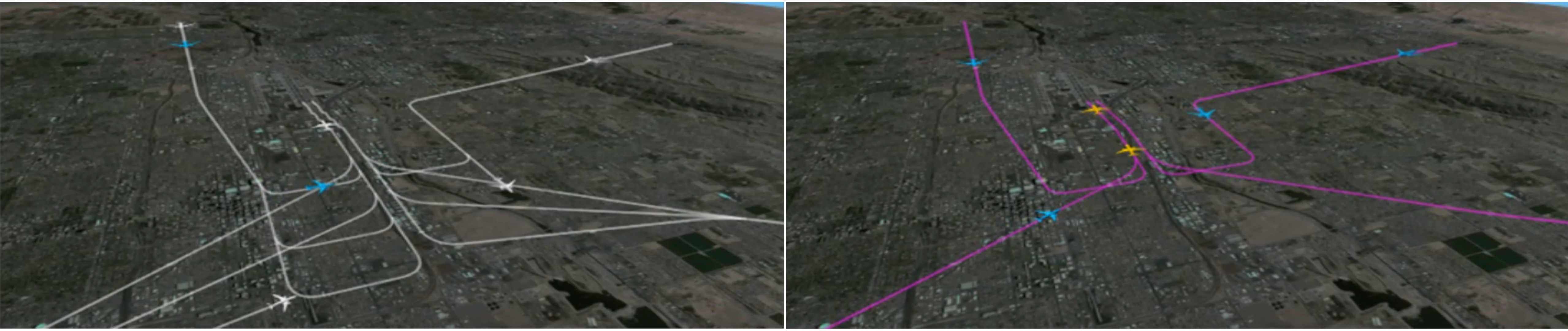
Example Research Transition Activities

- Terminal Sequencing and Spacing (TSAS)
  - Advanced scheduling and sequencing of arrivals and runway
  - Terminal controller advisories to maintain precision schedules implemented on FAA’s STARS system

- Unmanned Arial System Traffic Management (UTM)
  – Safely Enabling UAS Operations in Low-Altitude Airspace

Terminal Sequencing and Spacing (TSAS) Objectives

- Demonstrate routine use of Performance-Based Navigation (PBN) during busy traffic periods



- Accelerate transfer of NASA scheduling and spacing technologies for inclusion in late mid-term NAS

ATM Technology Demonstration #1 (ATD-1): Integrated Arrival Solution

FIM | Flight Deck Interval Management for Arrival Operations

CMS | Controller-Managed Spacing in Terminal Airspace

TBFM | Time-Based Flow Management (TBFM) with Terminal Metering

NASA Technologies
plus
ADS-B Infrastructure
Area Navigation (RNAV) Arrivals
Required Navigation Performance (RNP)
Optimized Profile Descents (OPD)

Terminal Sequencing and Spacing (TSAS): Planned FAA Capabilities

TSAS

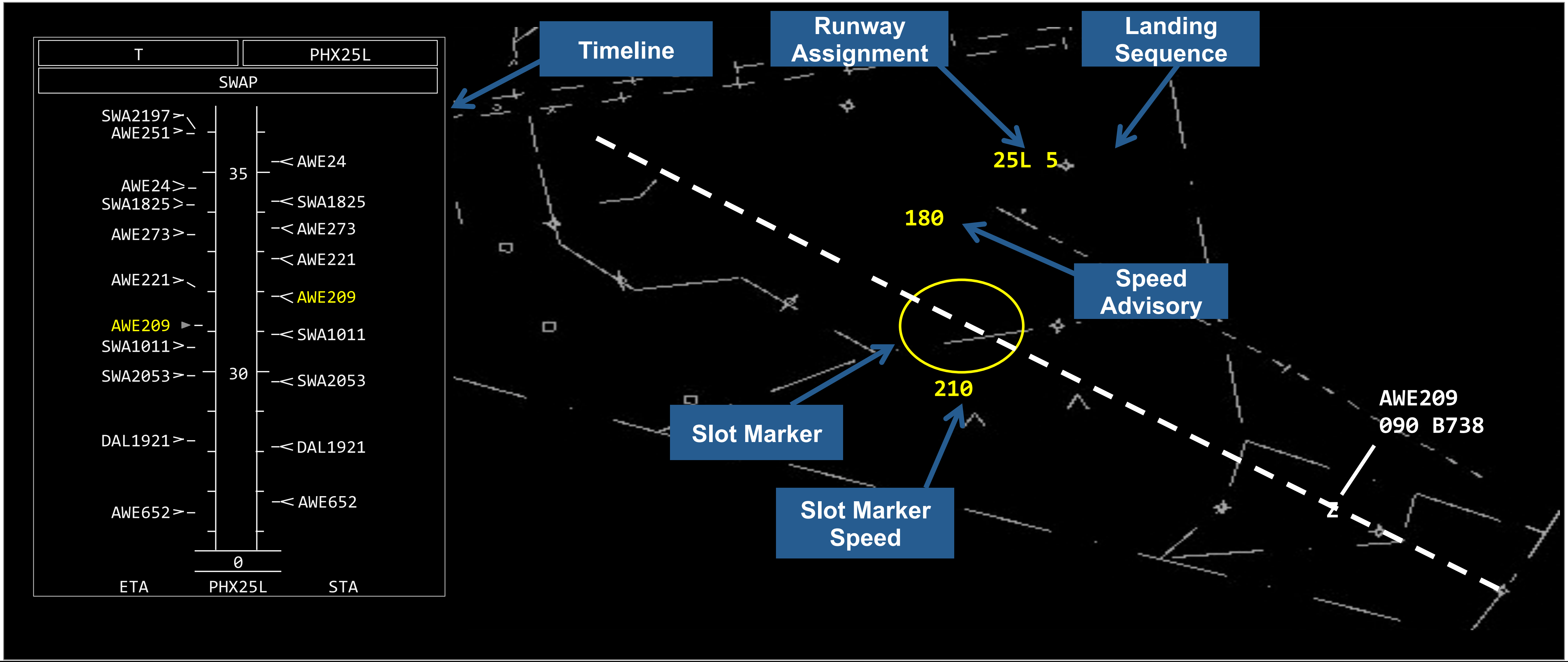
FIM Flight Deck Interval Management for Arrival Operations

CMS Controller-Managed Spacing in Terminal Airspace

TBFM Time-Based Flow Management (TBFM) with Terminal Metering

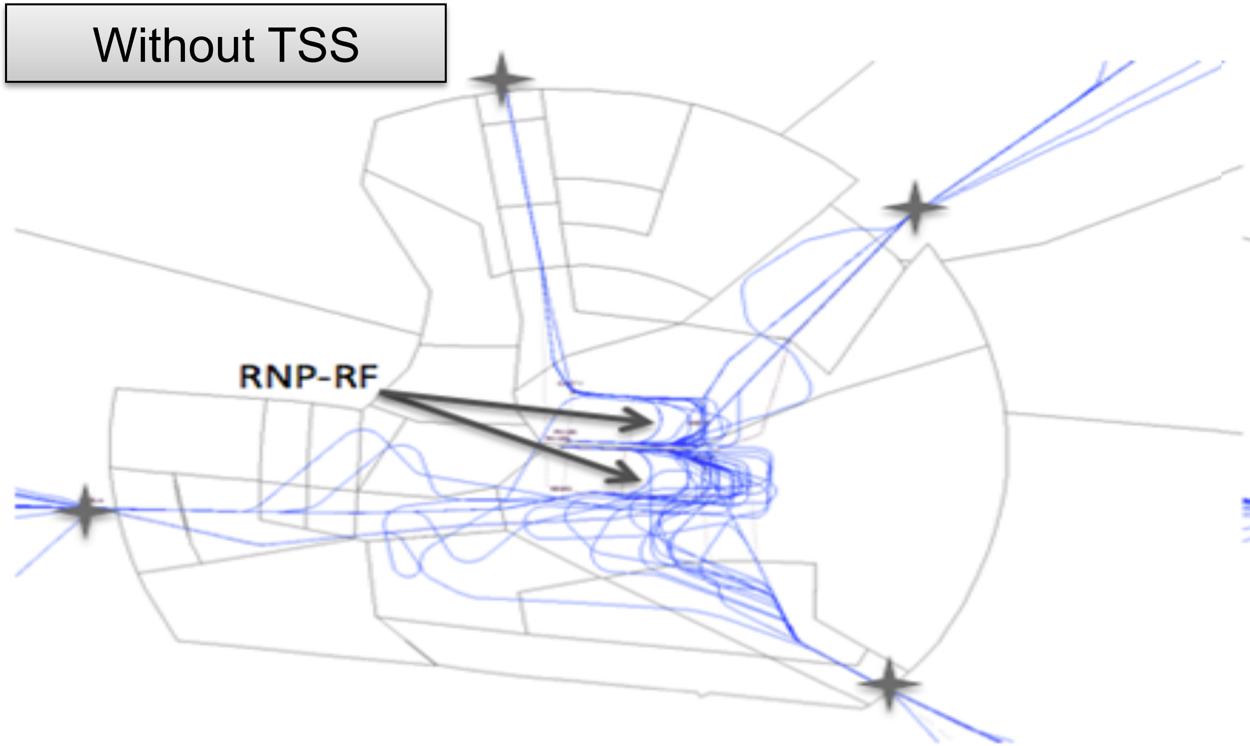
NASA Technologies
plus
ADS-B Infrastructure
Area Navigation (RNAV) Arrivals
Required Navigation Performance (RNP)
Optimized Profile Descents (OPD)

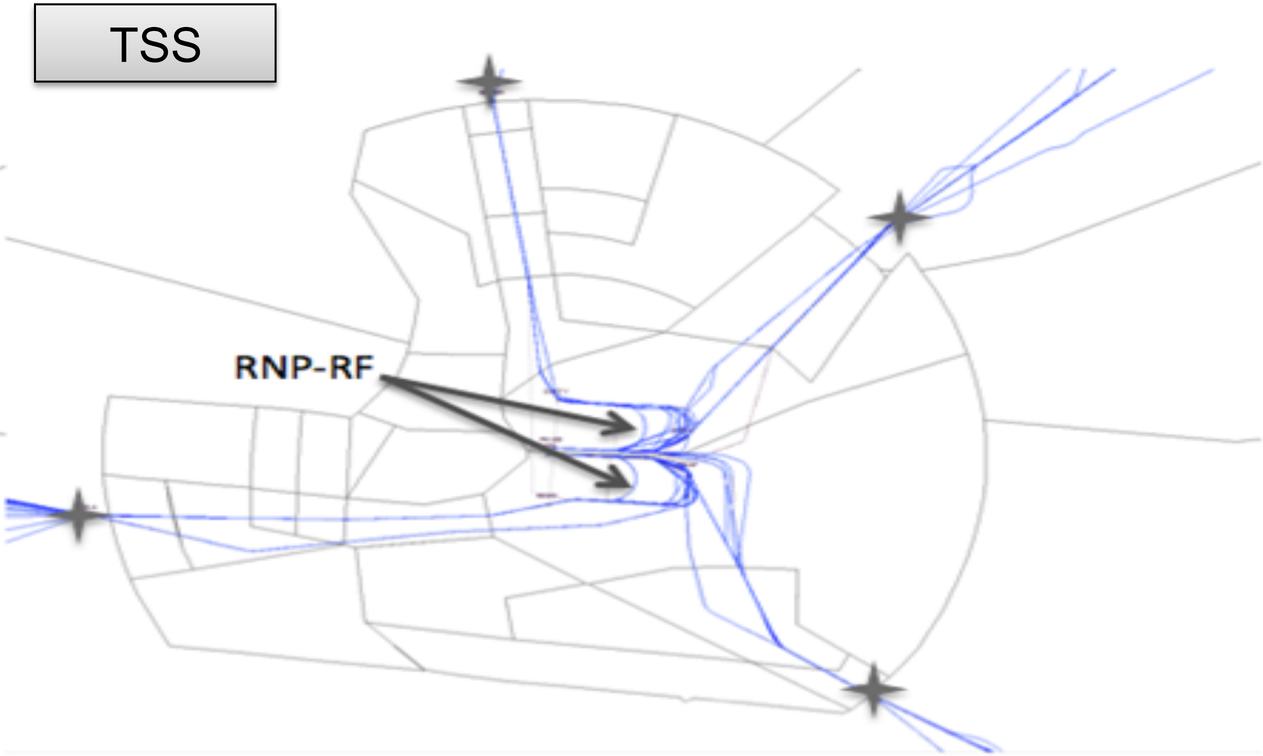
NASA TSAS Prototype Capabilities



Graphic courtesy of MITRE Corporation.

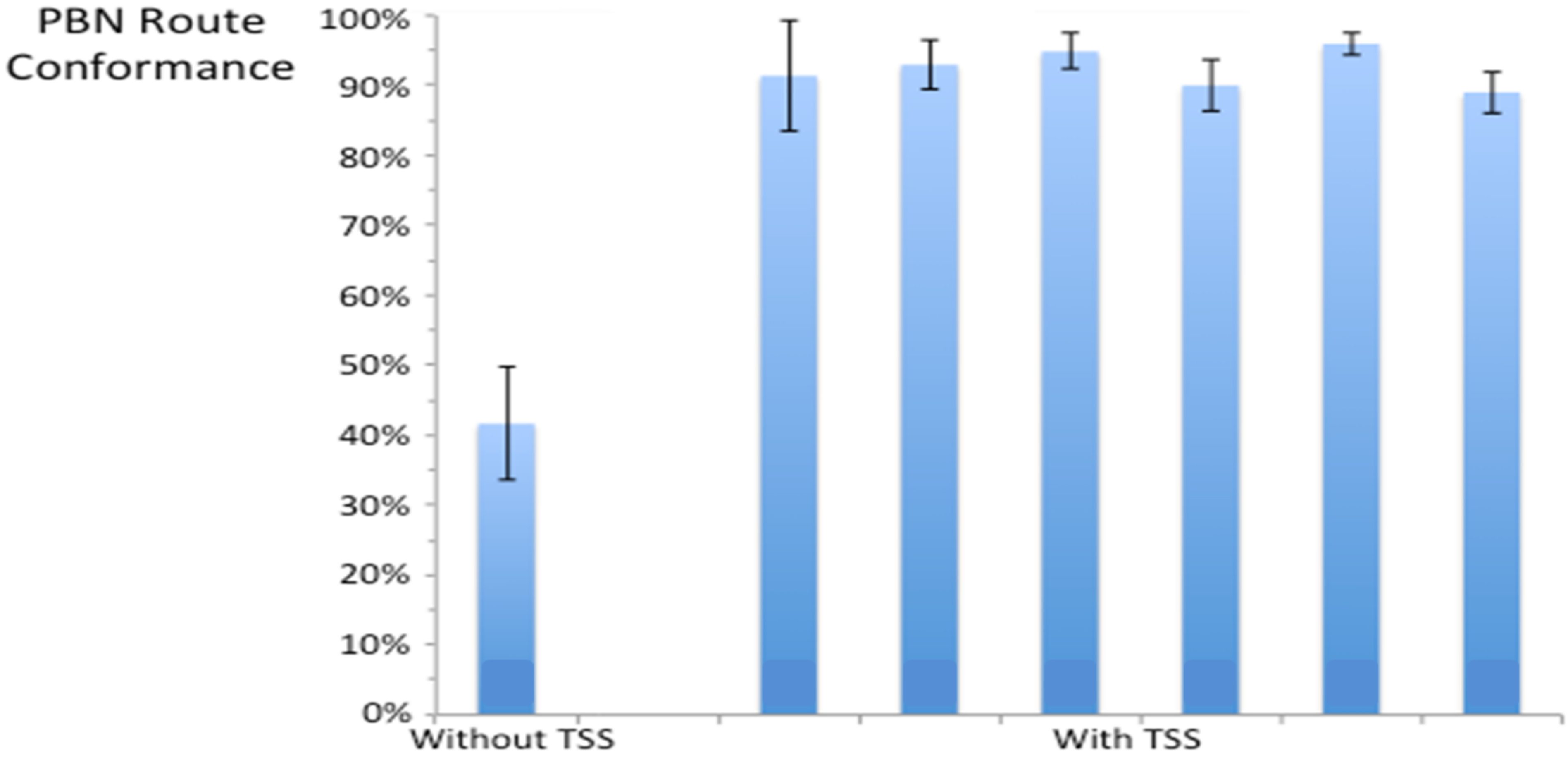
Results





During high-fidelity human-in-the-loop simulations of Terminal Sequencing and Spacing, air traffic controllers have significantly improved their use of PBN procedures during busy traffic periods without increased workload.

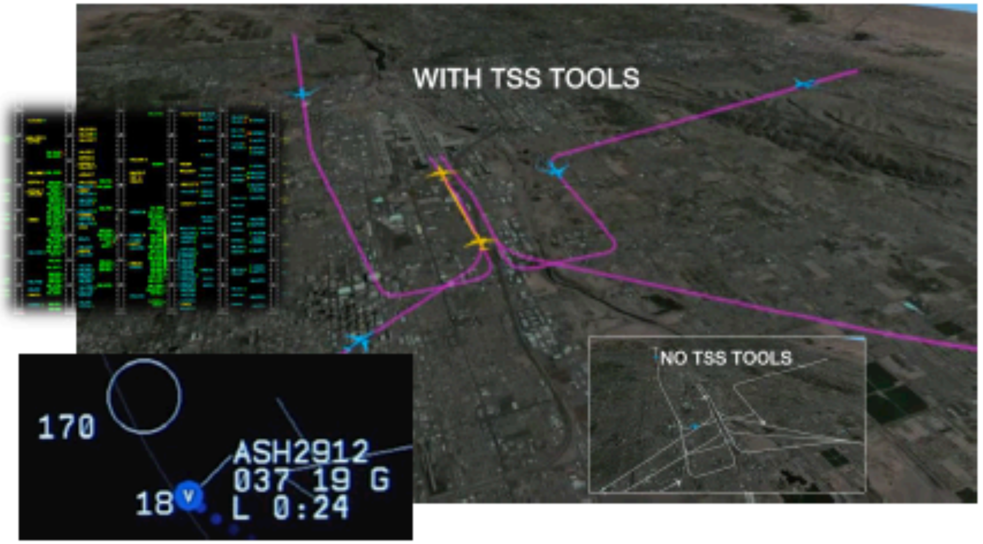
Results

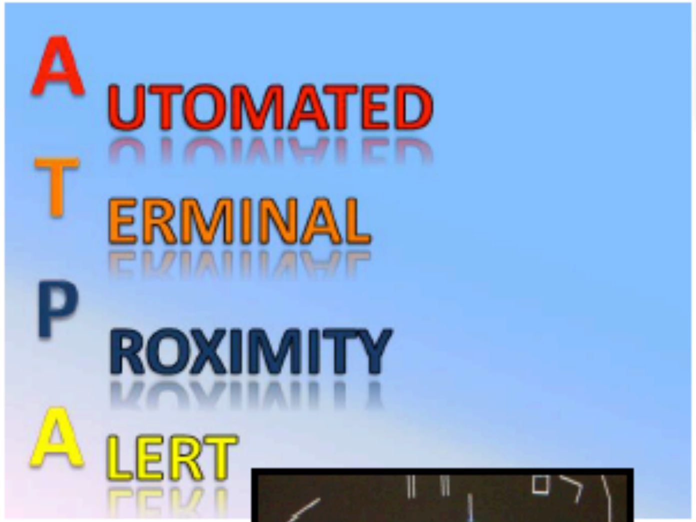

PBN Route Conformance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Without TSS
With TSS

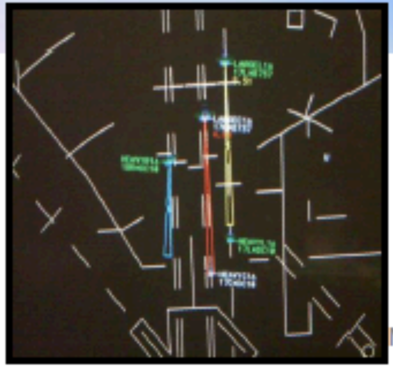
Integration with other new concepts/technologies

(Risk mitigation simulation at NASA Ames summer 2015)

TSS: Terminal Sequencing and Spacing







Wake Turbulence Separation Table for "On Approach"

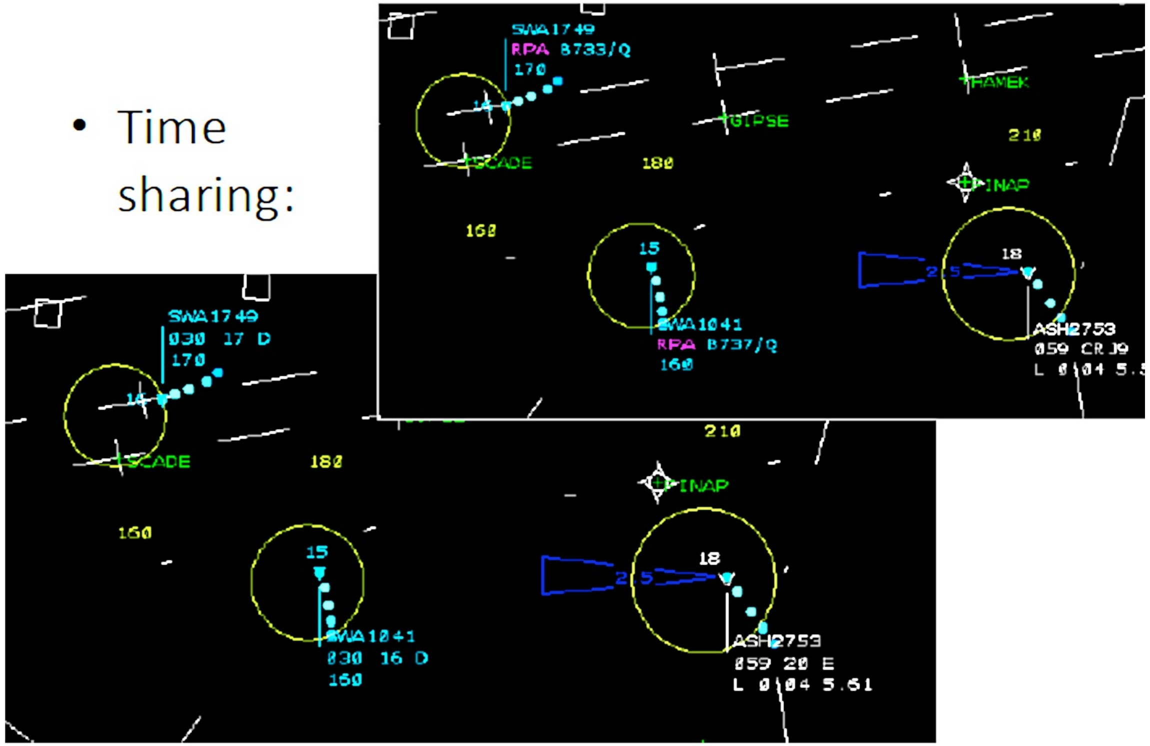
Leader	Follower A	Follower B	Follower C	Follower D	Follower E	Follower F
A		3NM	6NM	7NM		8NM
B		3NM	4NM	5NM		7NM
C				3.5 NM		6NM
D						4 NM
E						
F						

Wake Turbulence Re-categorization (RECAT)

Identifying interoperability issues

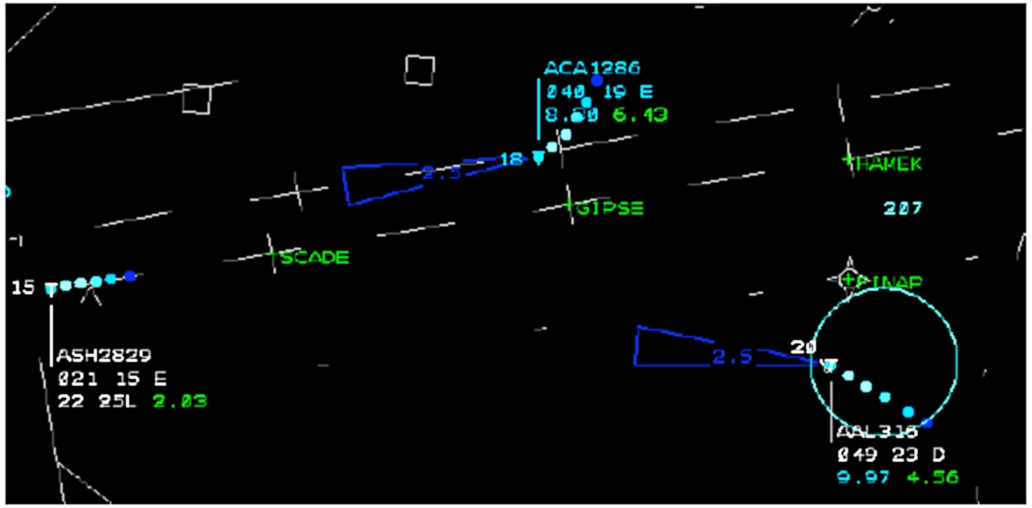
Condition 5: Concurrent

- Time sharing:



(1)

Exploratory Condition



- Dwelled to show slot maker

(staggered)

NASA Transitions TSAS to FAA

- ATD-1 transferred Terminal Sequencing and Spacing (TSAS) technologies to the FAA

- TSAS intended to enable routine use of underutilized advanced avionics and PBN procedures
  - Potential benefits to airlines operating at initial TSS sites estimated to be $300-400M/year

- FAA is planning for an initial capability in the NAS in 2019

Example Research Transition Activities

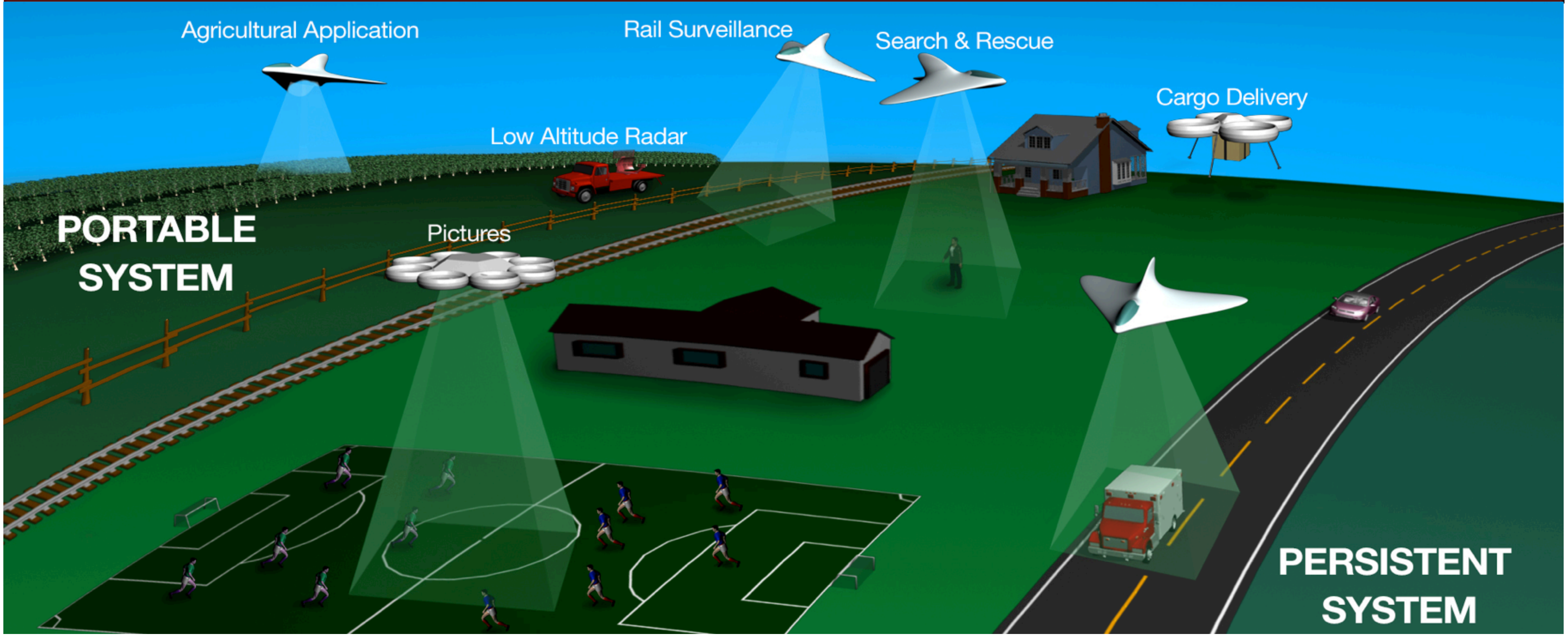
- Terminal Sequencing and Spacing (TSAS)
  - Advanced scheduling and sequencing of arrivals and runway
  - Terminal controller advisories to maintain precision schedules implemented on FAA's STARS system

- Unmanned Arial System Traffic Management (UTM)
  - Safely Enabling UAS Operations in Low-Altitude Airspace

Unmanned Aerial System Traffic Management (UTM)

Near-term Goal: Safely enable initial low-altitude UAS as early as possible

Long-term Goal: Accommodate increased demand with highest safety, efficiency, and capacity

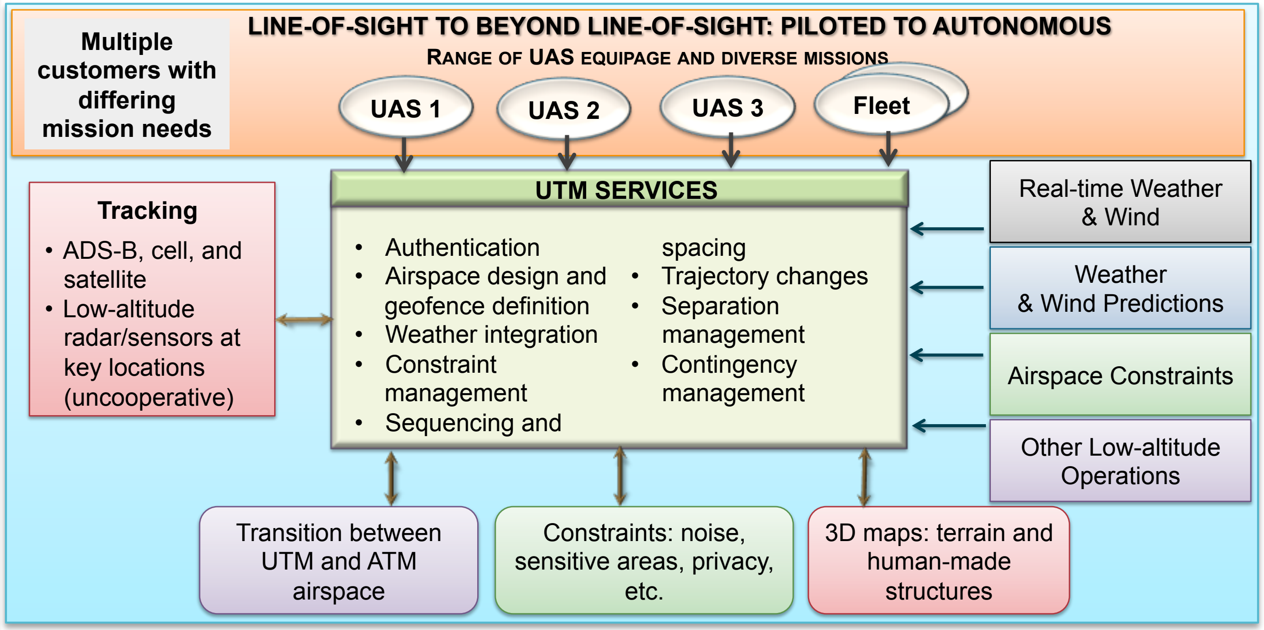


UTM Design Functionality: Cloud-based

Self-driving car does not eliminate lanes and rules for efficient and safe operations

DIGITAL, VIRTUAL, & FLEXIBLE RISK-BASED APPROACH AND SERVICE INFRASTRUCTURE

- Safe low-altitude UAS operations with
  - Airspace management and geofencing
  - Weather and severe wind integration
  - Predict and manage congestion
  - Terrain and man-made objects: database and avoidance
  - Maintain safe separation (Airspace reservation, V2V, & V2UTM)
  - Allow only authenticated operations



Each build is independent and deployable

Build 1 (August 2015)

- **Reservation of airspace volume**
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot
- Enable agriculture, firefighting, infrastructure monitoring

Build 3 (January 2018)

- Beyond visual line-of-sight
- Over moderately populated land
- Some interaction with manned aircraft
- **Tracking, V2V, V2UTM and internet connected**
- Public safety, limited package delivery

Build 2 (October 2016)

- **Beyond visual line-of-sight**
- Tracking and low density operations
- Sparsely populated areas
- Procedures and “rules-of-the road”
- Longer range applications

Build 4 (March 2019)

- Beyond visual line-of-sight
- **Urban environments, higher density**
- Autonomous V2V, internet connected
- Large-scale contingencies mitigation
- News gathering, deliveries, personal use

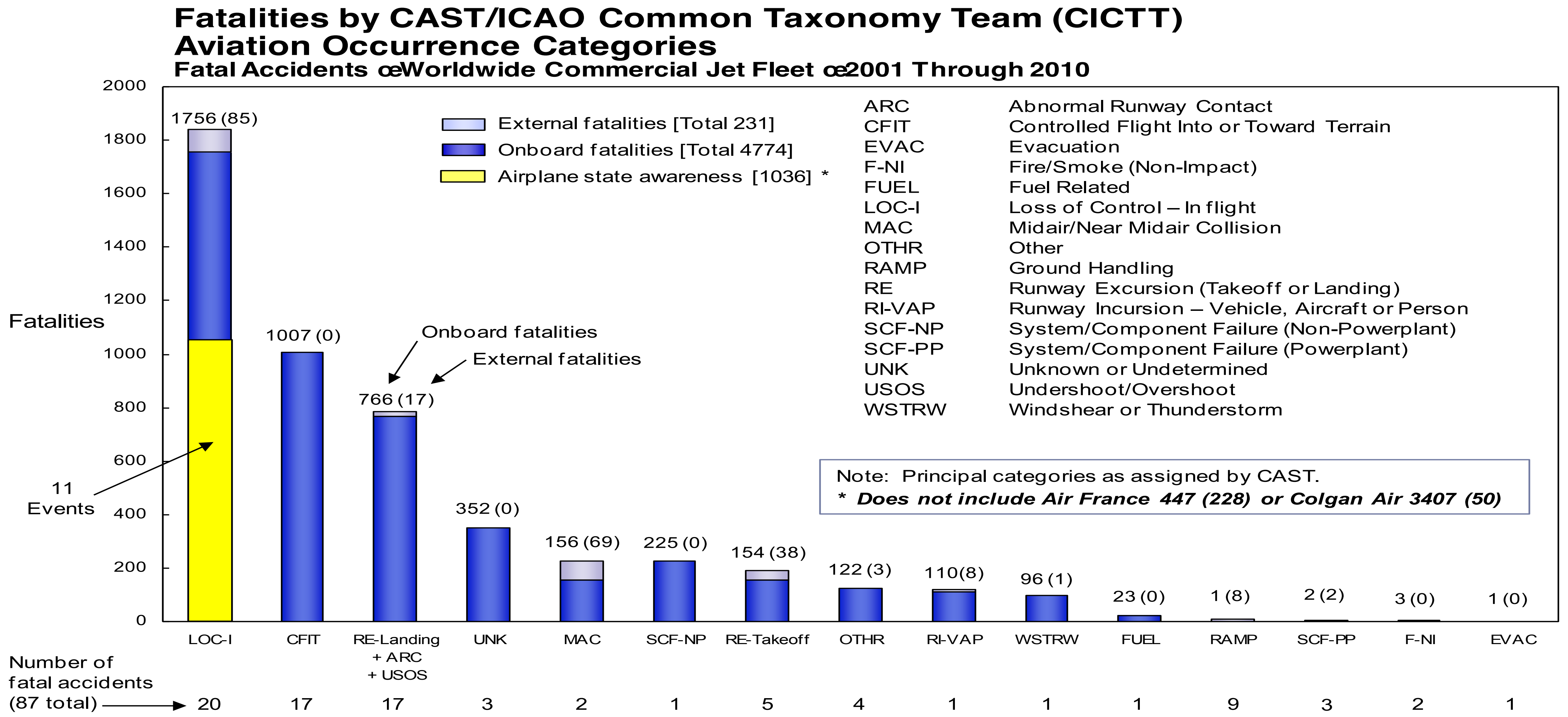
Progress

- Research Transition Team with FAA, DHS, and DoD
- **125+** industry and academia collaborators and increasing
- Initial UTM Concept of Operations: Industry, academia, and government
- Client interface is ready – **You can connect with UTM**
- **Build 1 tests** with 12 partners begin at the end of August
- **International interest**

NASA HSI Research and Transition to the FAA

COMMERCIAL AVIATION SAFETY TEAM (CAST) RESEARCH SAFETY ENHANCEMENTS

Aircraft State Awareness (ASA) Joint Safety Implementation Teams (JSIT) – Safety Enhancements



ASA JSIT – Safety Enhancements
Brief Review of ASA Study

- Joint Implementation Measurement Data Analysis Team (JIMDAT) identified loss of control in-flight (LOC-I) as area of ongoing concern, particularly:
  - Attitude (bank or pitch angle) awareness
    - ~ 15% of all fatalities in worldwide scheduled air carrier operations since 2002
    - FOQA: Rate of high-risk overbanks in the US = 4.9 per million flights
  - Low airspeed / energy state awareness
    - ~ 12% of all fatalities in worldwide scheduled air carrier operations since 2002, including last fatal accident in the US (Colgan Air 3407, Feb 2009)
    - FOQA: Rate of high-risk stall warning events in the US = 6.1 per million flights

- ASA Joint Safety Implementation Teams (JSAT) analyzed 18 events in which flight crew lost awareness of airplane attitude or energy state
  - 9 loss of attitude awareness: 8 accidents, 1 incident
  - 9 loss of energy state awareness: 5 accidents, 4 incidents
  - 161 standard problem statements (SPS's)
  - 274 intervention strategies (IS's)
  - 12 major themes

ASA JSIT – Safety Enhancements
Brief Review of ASA Study

	Lack of External Visual References	Flight Crew Impairment	Training	Airplane Maintenance	Safety Culture	Invalid Source Data	Distraction	Systems Knowledge	Crew Resource Management	Automation Confusion / Awareness	Ineffective Alerting	Inappropriate Control Actions	Total
Formosa Airlines Saab 340	×	×			×		×	×	×		×		7
Korean Air 747-200F	×			×		×	×		×		×		6
Flash Airlines 737-300	×		×		×		×		×	×	×	×	8
Adam Air 737-400	×		×	×			×	×	×	×	×	×	9
Kenya Airways 737-800	×		×				×		×	×	×	×	7
Aeroflot-Nord 737-500	×	×	×	×	×		×	×	×	×	×	×	11
Gulf Air A320	×		×				×		×		×	×	6
Icelandair 757-200 (Oslo)	×						×		×	×	×	×	6
Armavia A320	×	×			×		×		×	×	×	×	8
Icelandiar 757-200 (Baltimore)	×				×	×	×	×	×	×	×	×	9
Midwest Express 717	×				×	×	×		×		×	×	7
Colgan Air DHC-8-Q400	×	×	×		×		×	×	×	×	×	×	10
Provincial Airlines DHC-8	×		×				×			×	×	×	6
Thomsonfly 737-800	×		×	×	×		×			×	×		7
West Caribbean MD-82	×	×			×		×	×	×	×	×	×	9
XL Airways A320		×	×	×	×	×	×	×	×	×	×		10
Turkish Airlines 737-800	×			×	×	×	×		×	×	×		8
Empire Air ATR-42	×	×			×		×		×	×	×		7
Overall	17	7	9	6	12	5	18	7	16	14	18	12	

ASA JSIT – Safety Enhancements
SE Concepts from August 2012

Design

- D-1 Energy State Awareness
- D-2 Attitude Awareness
- D-3 Airplane Sensor Anomalies
- D-4 System Mode Awareness
- D-5 Flight Envelope Protection

- R-1 Energy State Awareness
- R-2 Attitude Awareness
- R-3 System Mode Awareness
- R-4 Human Error Modeling

Training

- T-1.1 Critical Flt Crew Actions
- T-1.2 Training V & V
- T-2 Revised CRM Training
- T-3.1 SBT for Stall Recovery
- T-3.2 SBT for Go-Arounds
- T-3.3 SBT for Attention Issues

- R-5 Simulator Fidelity
- R-6 Human Perf - Attention

Operations

- O-1 ATC Enhancements
- O-2.1 Maintenance Processes
- O-2.2 Non-Standard Ops
- O-3 SOP Effectiveness
- O-4.1 Flt Crew Sys Proficiency
- O-4.2 Flt Crew Roles & Resp

ASA JSIT – All Safety Enhancements

2025 Risk Reduction: 92.4%

Duration: 84 months

Cost: $177.4M

	Lack of External Visual References	Flight Crew Impairment	Training	Airplane Maintenance	Safety Culture	Invalid Source Data	Distraction	Systems Knowledge	Crew Resource Management	Automation Confusion / Awareness	Ineffective Alerting	Inappropriate Control Actions	Total
Formosa Airlines Saab 340													0
Korean Air 747-200F				x		x							2
Flash Airlines 737-300													0
Adam Air 737-400				x									1
Kenya Airways 737-800													0
Aeroflot-Nord 737-500		x		x									2
Gulf Air A320			x										1
Icelandair 757-200 (Oslo)													0
Armavia A320													0
Icelandair 757-200 (Baltimore)					x								1
Midwest Express 717					x								1
Colgan Air DHC-8-Q400													0
Provincial Airlines DHC-8													0
Thomsonfly 737-800				x									1
West Caribbean MD-82													0
XL Airways A320				x									1
Turkish Airlines 737-800				x	x								2
Empire Air ATR-42													0
Overall	0	1	1	6	3	1	0	0	0	0	0	0	

CAST SEs – NASA Tech Leads

				Lead Agency	
207	*ASA - Research – Attitude and Energy State Awareness*				Steve Young (LaRC) John Kanesighe (ARC)
		Output 1	AOA Benefits	FAA AIR	
		Output 2	Pitch Guidance for Recovery	NASA	
		Output 3	LESA Countermeasures	NASA	
		Output 4	SD Alerting	NASA	
208	*ASA – Research – Airplane Systems Awareness*				
		Output 1	Automated Systems Awareness	NASA	
		Output 2	System State Alerting	NASA	
209	**ASA – Research - Simulator Fidelity**				Gautam Shah (LaRC)
		Output 1	URT Learning Objectives	FAA AFS	
		Output 2	Stall Aero Model Reqrmnts	FAA AFS	
		Output 3	Stall Aero Model Definition	NASA	
		Output 4	Stall Sim Reqrmnts	FAA AFS	
210	**ASA - Research - Flight Crew Performance Data**				Mike Feary (ARC)
		Output 1	Human FOQA	FAA	
		Output 2	Human Perf Eval Methods in Design	NASA	
		Output 3	Attention Eval in Design	NASA	
211	**ASA - Research – Training for Attention Management**				Angela Harrivel (LaRC)
		Output 1	Attention Detection in situ	NASA	
		Output 2	Attention Training Methods	NASA	
200	**ASA – Design – Virtual Day-VMC Displays**				Kyle Ellis (LaRC)
		Output 1	MASPS for Virtual VMC Displays	NASA	
		Output 2	DO-/AC- for Virtual VMC Displays	FAA AIR	
		Output 3	Virtual VMC Displays Implementation	AIA	

Questions ?