National Aeronautics and Space Administration

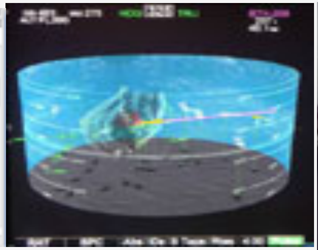
Human Factors in Aeronautics at NASA

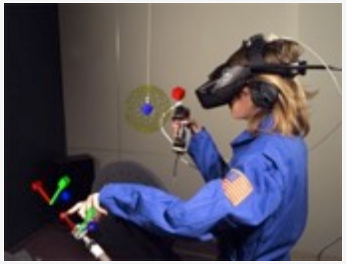
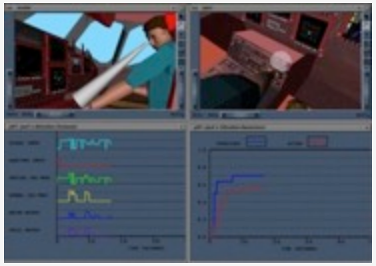
Richard Mogford, Ph.D.
NASA Ames Research Center
Moffett Field, CA

Ames Human Factors

- Human Systems Integration Division
  - About 120 people in the division
  - 50 civil servants, about 70 contractors
  - Most with graduate degrees in psychology, engineering, computer science, or other technical disciplines
- Working primarily in three areas:
  - Aeronautics
  - Exploration (space)
  - External collaborations (e.g., Federal Aviation Administration, DoD, Commercial Aviation Safety Team, and international groups)
- Aviation Systems Division
  - Develops and prototypes new concepts for air traffic control and airlines
  - Has a human factors staff

Ames Technical Areas

- Human-machine Interaction
  - Planning and scheduling systems
  - Problem analysis and correction action systems
- Human Performance
  - Visual and auditory interface research
  - Performance modeling (e.g., pilot control strategies to vehicle dynamics)
  - Crew cockpit design and evaluation
  - Perceptual, cognitive, and physiological analyses
- Integration and Training
  - Flight deck display design and evaluation
  - Air traffic management integration
  - Training, procedures, and team coordination
  - Safety analysis and reporting systems

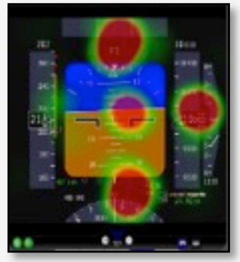


Langley Human Factors

- Largely contained within the Crew Systems and Aviation Operations Branch within Langley's Research Directorate
  - 45 civil servants
  - Most with graduate degrees in psychology, engineering, computer science, or other technical disciplines
  - Working primarily Aeronautics programs
  - External collaborations include: the FAA, DoD (including DARPA, AFRL, ARL, ONR), Airlines, Industry, Academia
  - Other working groups/participation/leadership: RTCA, CAST, AIAA, etc.
- Additional 5-8 human factors civil servants within the Systems Analysis and Concepts Directorate and the Engineering Directorate, working mostly NASA Exploration Programs

Aeronautics Human Factors at NASA






Langley Human Factors Technical Areas

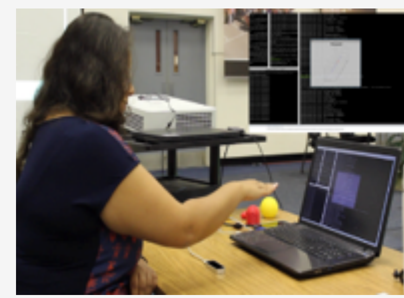
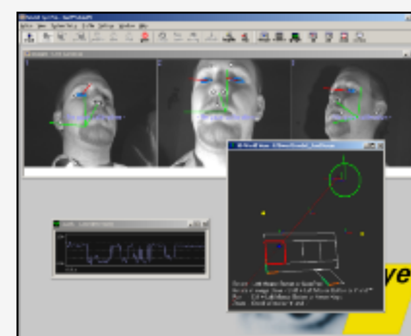
Human Performance Characteristics and Capabilities
- Interaction across modalities
- Spatial orientation
- Oculometry and vision perception
- Cognitive processes
- Situational awareness – detection, assessment, and risk mitigation strategies

Cockpit and display design and development
- Input devices and controls
- Visual and auditory displays
- Multi-modal, virtual, and augmented reality displays

Human Computer Interface
- Natural language Interface and gesture control
- Brain-computer interfaces

Multi-agent Teaming
- Human-automation integration - function allocation, trust in automation, adaptive automation
- Crew Resource Management
- Human-machine teaming and collaborative decision making
- Human-system verification and validation and performance metrics

Training
- Computer based training development for human machine interfaces
- Crew state feedback for training

Examples of NASA Aeronautics Projects

- *Aircrew Checklists*
- *Dispatch Operations*
- *Playbook*
- *Dynamic Weather Routes*
- *Traffic Aware Strategic Aircrew Requests*
- *Airplane State Awareness and Prediction Technologies*

Note: Most human factors work is embedded in aeronautics tasks. There is only limited basic research.

Barbara Burian, PhD – NASA Ames

Checklists and Procedures in Aviation and Medicine: Paper, Electronic, Context-Sensitive and Dynamic

NASA/TM—2016–219109

Integrated Checklists for Un-alerted Smoke, Fire, and Fumes: Adherence to Guidance from the Industry

Barbara K. Burian
NASA Ames Research Center

April 2016

NASA/TM—2014–218382

Factors Affecting the Use of Emergency and Abnormal Checklists: Implications for Current and NextGen Operations

Barbara K. Burian
NASA Ames Research Center

Aerospace Medical Association
87th Annual Scientific Meeting

Checklist Development: Optimizing for the Medical Environment

Barbara Burian, Ph.D., FRAeS
Human Systems Integration Division
NASA Ames Research Center

Human Systems Integration Division

Autonomous, Dynamic, Flight, Automation, and Information Management (FAIM) System

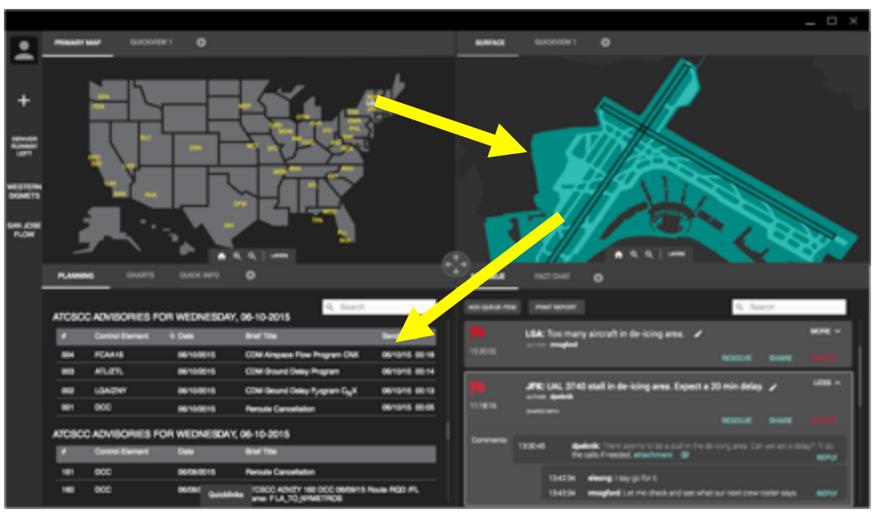
- Conditions, limitations, aircraft status, and operational demands (i.e., constraints) are used to facilitate access and guide autonomous, dynamic presentation and sequencing of information from multiple sources including:
  - normal and non-normal checklist actions
  - instrument procedures
  - enhanced nav displays
  - FMS/autoflight/datacomm information/actions
  - aircraft system status and alerting systems
  - weather conditions
  - current ATM procedures, etc.

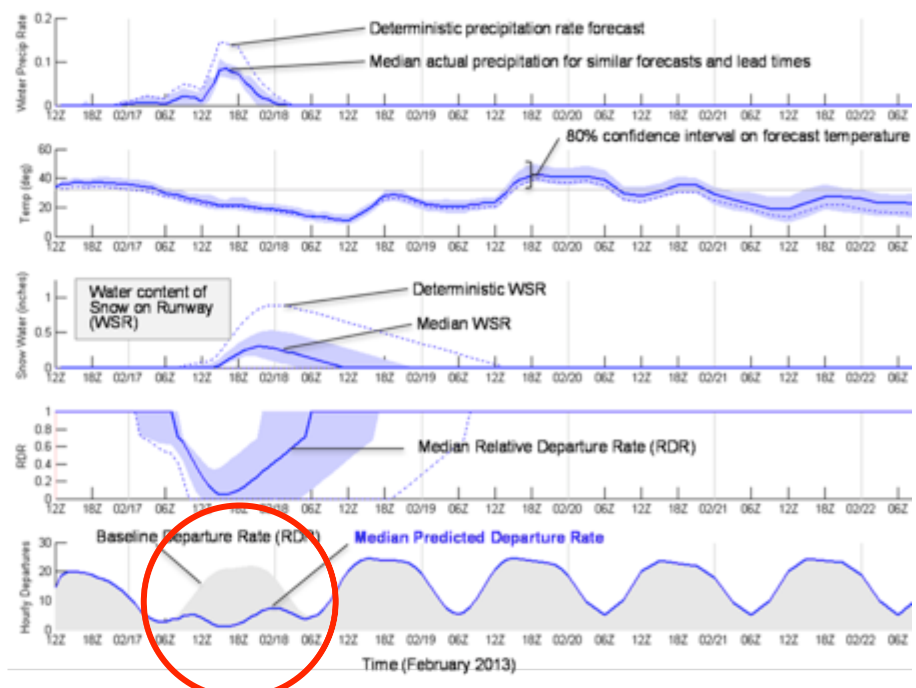
- Autonomously helps pilots/remote operators prioritize tasks, minimize overall workload, increase situation awareness, reduce/eliminate errors and better manage overall normal and non-normal flight operations, through:
  - Three completely novel cockpit displays and multi-modal interfaces: visual, aural, haptic/tactilc
  - Information that is "pushed" by FAIM (automatically displayed); but FAIM also supports information "pull" through enhanced search/link capabilities to facilitate access to additional information as desired, when/if needed (e.g., FCOM, systems, and training manuals, etc.)
- **Supports crewed, RCO, RPA/UAS operations; leads to a fully functioning autonomous vehicle**

> ***"Dynamic** "– to change in real-time based on constraints and conditions in response to data gathered through sensors, digital sources, pilot/user input, or a* priori *selection*

Airline Dispatch Operations

- Developing the "Flight Awareness Collaboration Tool" (FACT)
- Concentrates information about winter weather events on one display
- Includes predictive tools
- Supports collaboration between AOC, air traffic control, airport authority, and de-icing operators
- User interface designed completed and web-based prototype under development
- User group at Detroit airport

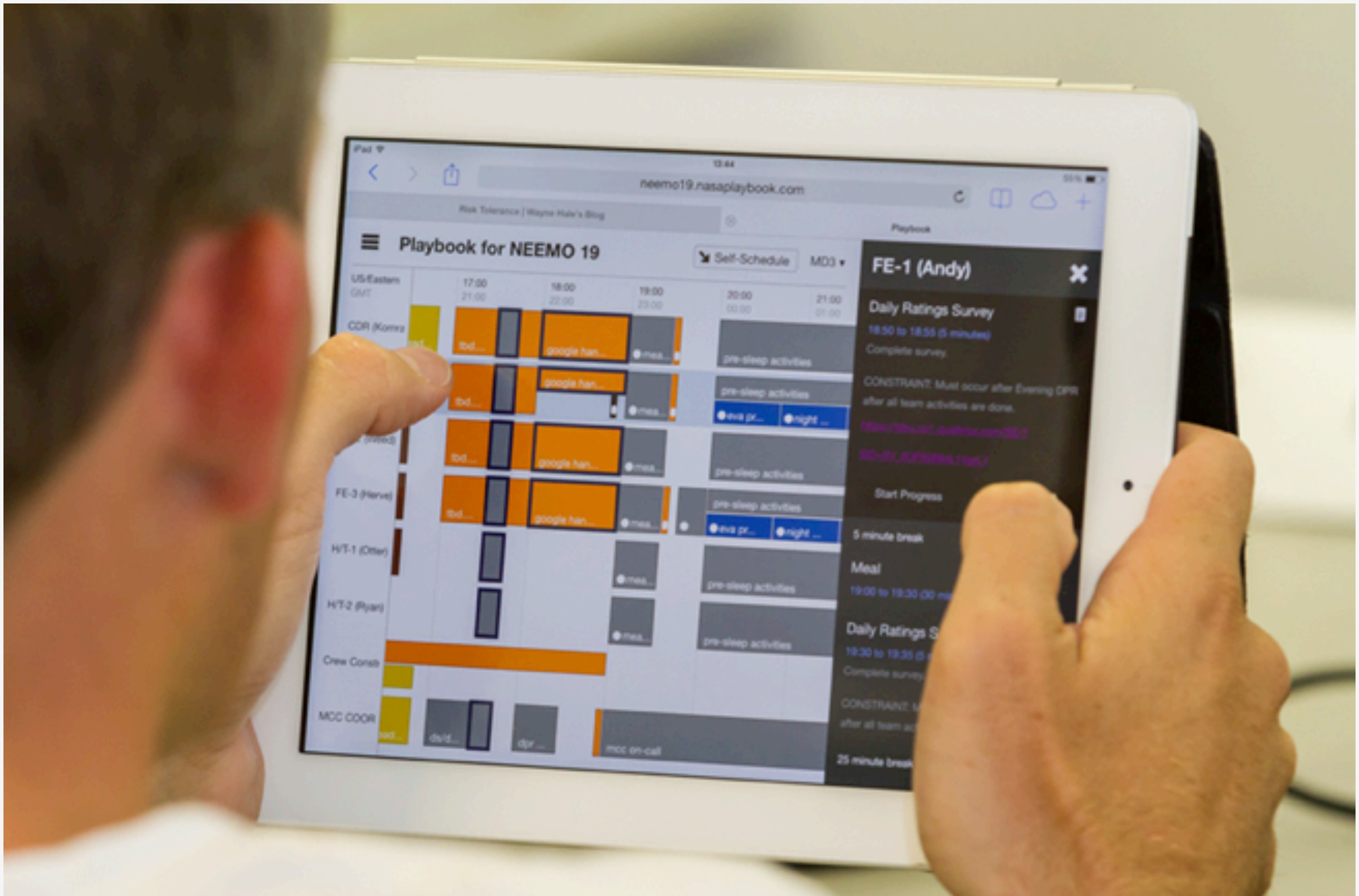




NASA/Industry Collaboration

- Held an Airline Operations Workshop at NASA Ames in August 2016
  - About 200 attendees
  - Focused on NASA, FAA, and private sector innovations to support the airlines (AOC and flight deck)
  - Identified gaps where research is needed
  - Formed partnerships with airline industry
  - Focused on the airlines and airline software vendors
- Research themes
  - AOC simulation
  - Display/system integration
  - Managing large information database from multiple sources

Playbook: next generation easy-to-use mobile web-based plan & execution tool



Playbook's Capabilities

- Collaborative self-scheduling with constraint checking and violation visualizations of timeline
- Activity execution status with procedure linking
- Integrated multimedia communications chat functionality (text, photo, video, or files)
- Adding new activities, scheduling task list activities, and rescheduling flexible activities
- Communication availability bands
- Field-tested in more than a dozen different spaceflight analogs for crew and robotic operations, including delayed communication simulation between ground & crew teams.

POC: Steve Hillenius (steven.r.hillenius@nasa.gov)
Playbook Lead, SPIFe Lead, NASA Ames Research Center

Dynamic Weather Routes: Two Years of Operational Testing at American Airlines

Dave McNally, Kapil Sheth, and Chester Gong

NASA Ames Research Center

Moffett Field, California

Mike Sterenchuk

American Airlines, Integrated Operations Control

Fort Worth, Texas

Scott Sahlman, Susan Hinton, Chuhan Lee

University of California, Santa Cruz

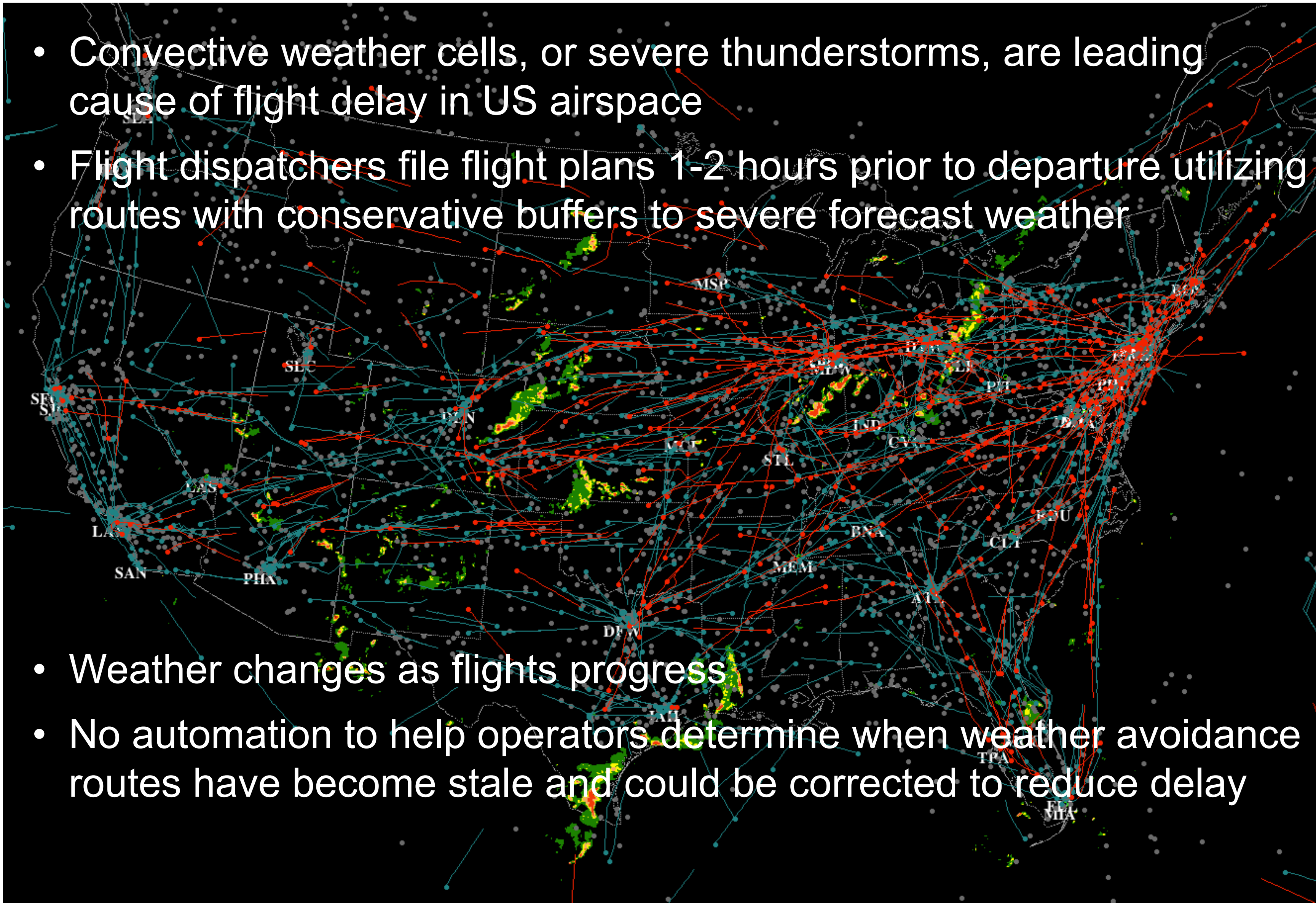
Moffett Field, California

Fu-Tai Shih

SGT, Inc.

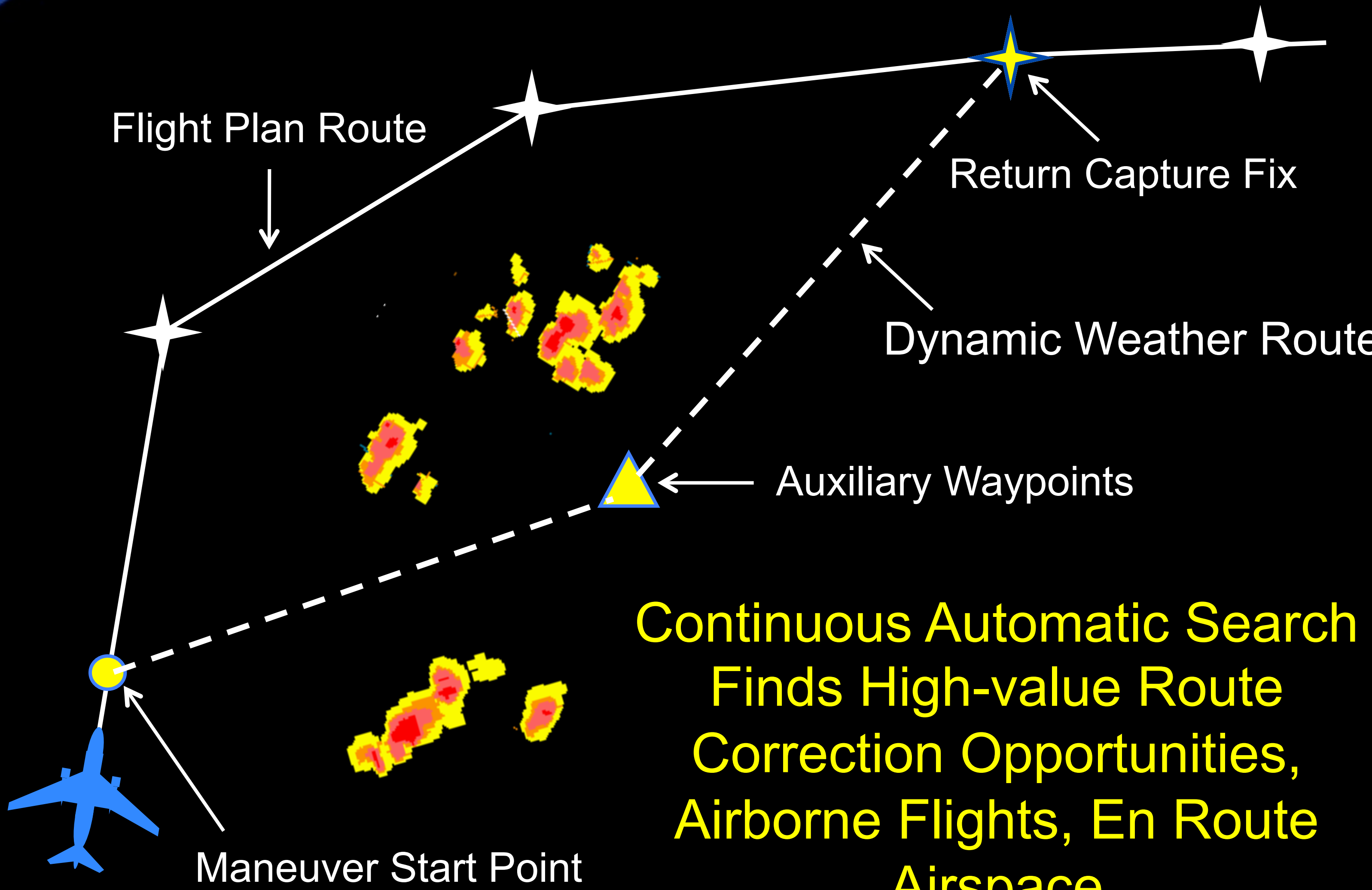
Moffett Field, California

What's the Problem?



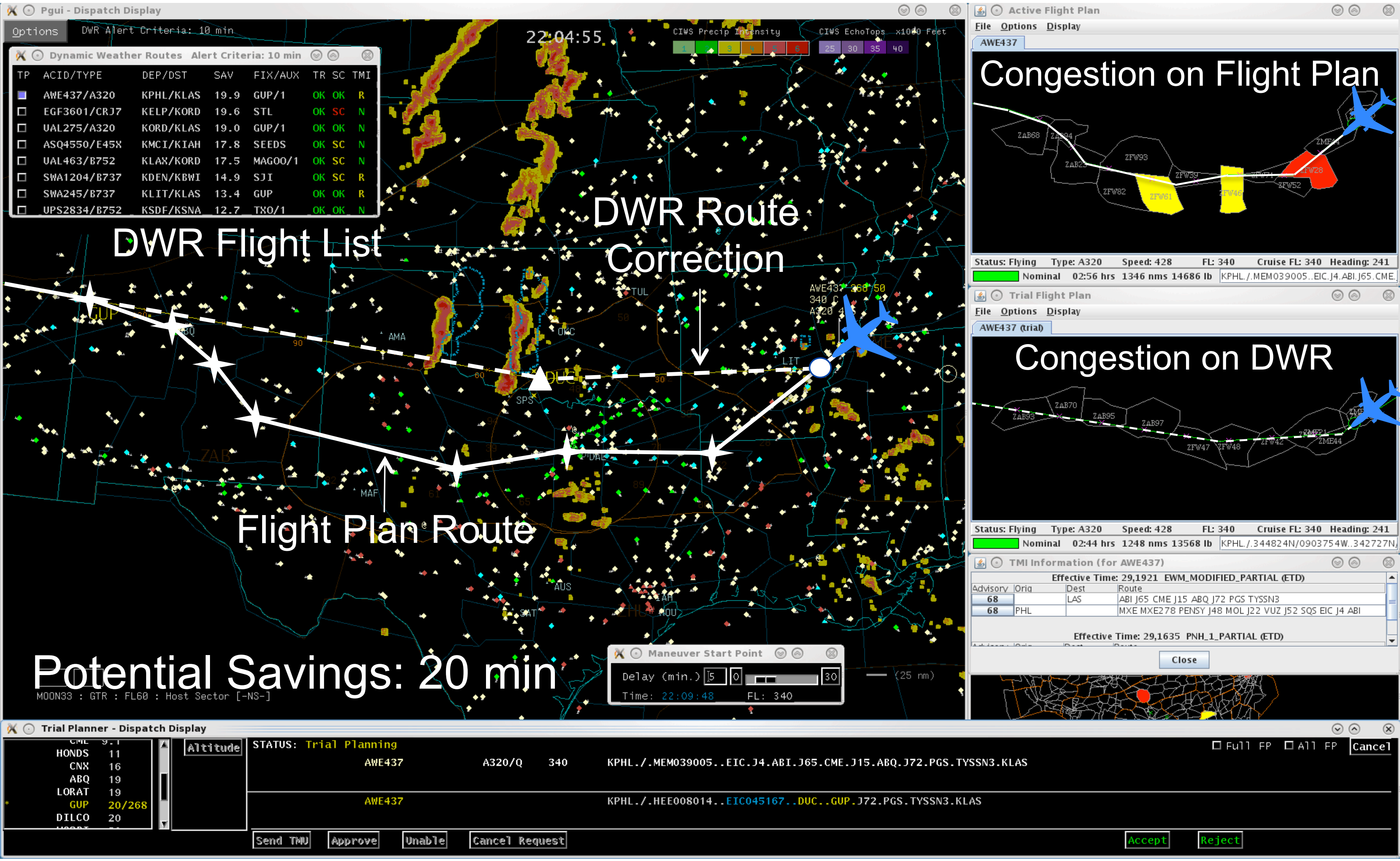
- Convective weather cells, or severe thunderstorms, are leading cause of flight delay in US airspace
- Flight dispatchers file flight plans 1-2 hours prior to departure utilizing routes with conservative buffers to severe forecast weather
- Weather changes as flights progress
- No automation to help operators determine when weather avoidance routes have become stale and could be corrected to reduce delay

Dynamic Weather Routes (DWR)



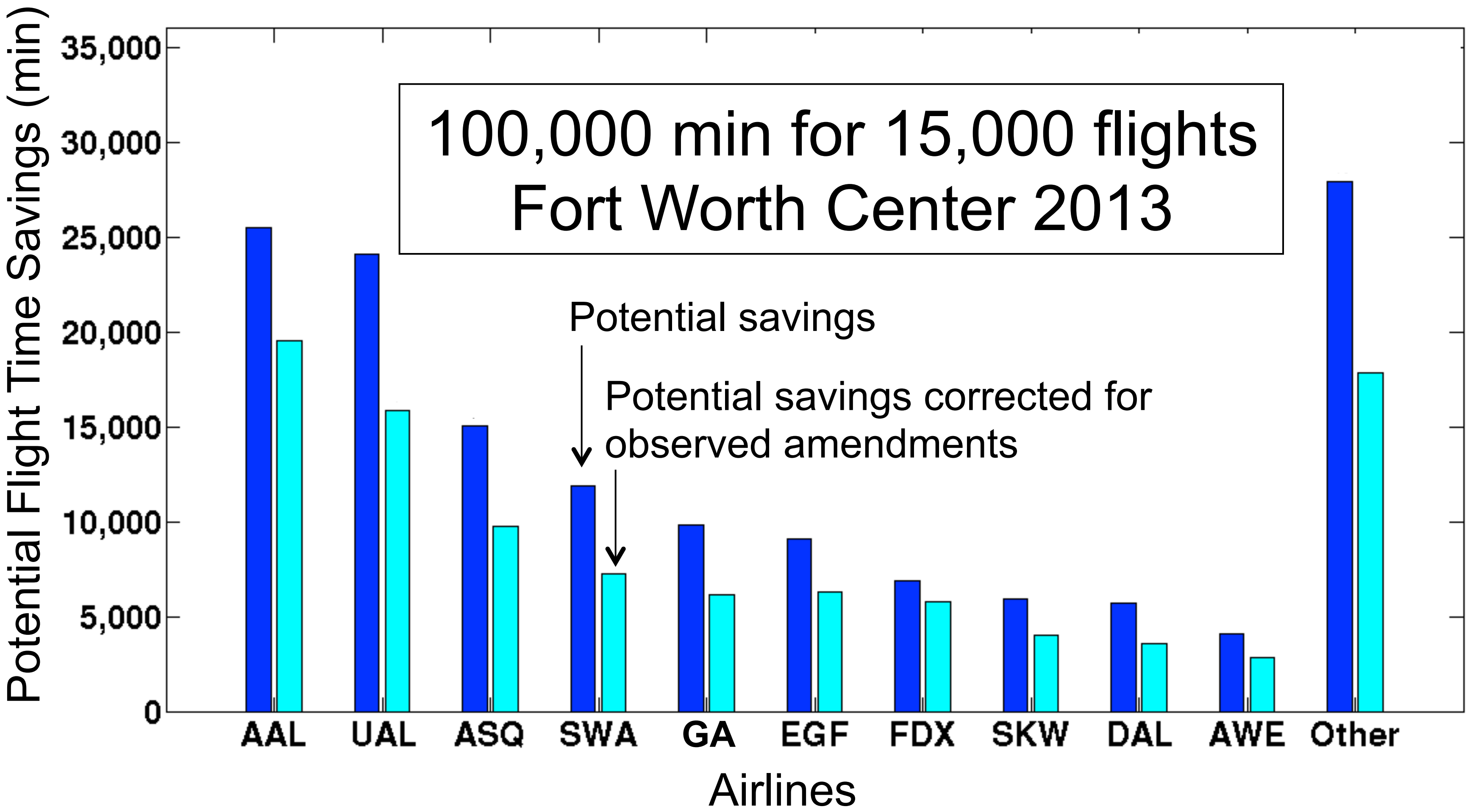
Continuous Automatic Search Finds High-value Route Correction Opportunities, Airborne Flights, En Route Airspace

DWR User Interface



Potential Benefits Analysis

All Airlines, All Flights, Fort Worth Center 2013

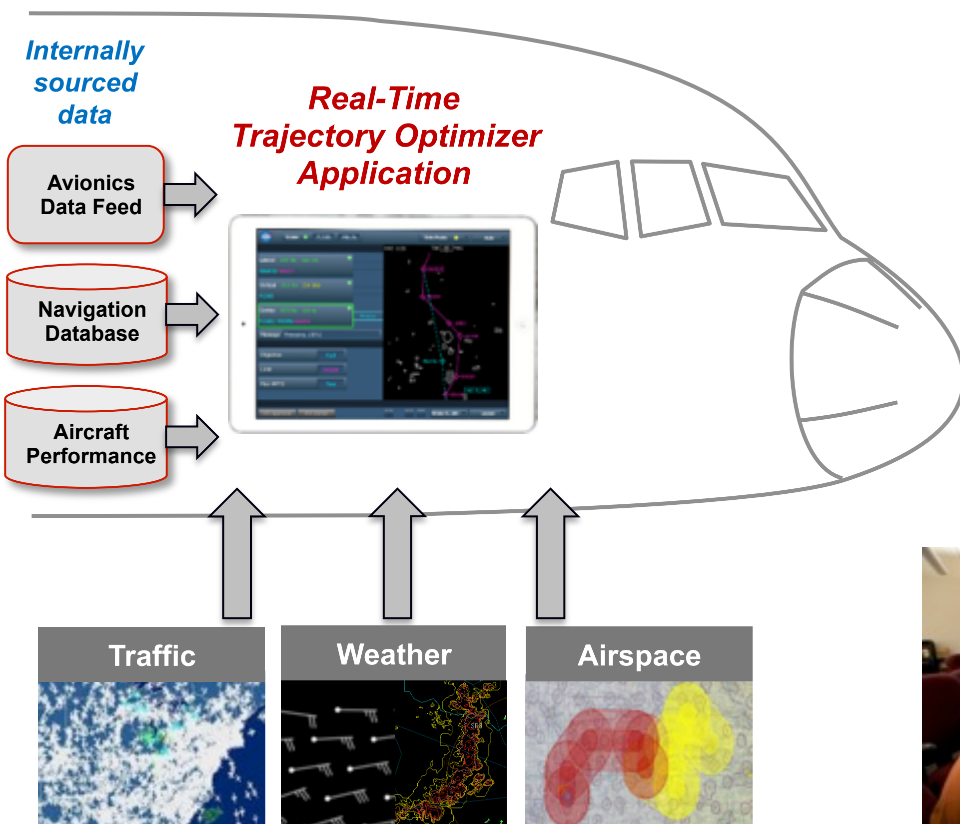


Traffic Aware Strategic Aircrew Requests (TASAR) NASA Flight Deck Application for En Route Flight Optimization

David Wing, TASAR Principal Investigator
NASA Langley Research Center
david.wing@nasa.gov

TASAR Design

Enhanced User Request Process leveraging Cockpit Automation and Networked Connectivity to real-time operational data to optimize an aircraft's trajectory en route

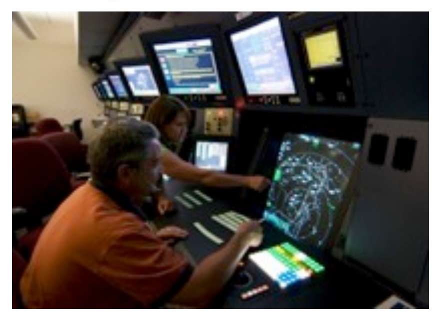


Externally sourced data

Increased flight efficiency

Enhanced ATC request/ approval process

Enhanced dispatch/aircrew coordination



ATC = air traffic control

NASA Traffic Aware Planner (TAP)

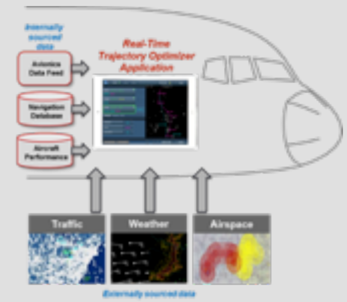
Flight-Efficiency EFB Application (“Type B”)

<u>Connected to avionics via standard interfaces</u>

Ownship flight data, ADS-B traffic data

<u>Connected to external data sources via internet</u>

Latest winds, weather, airspace status, etc.



Computes real-time route optimizations

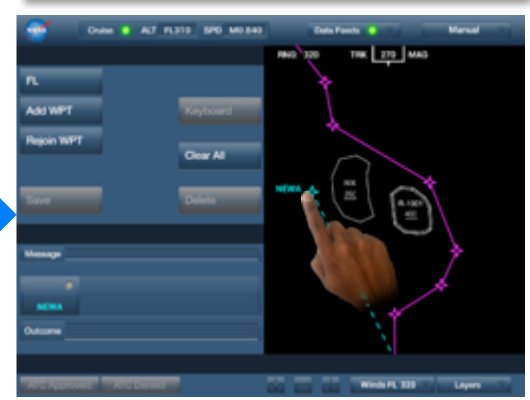
- Integrates route optimization with conflict avoidance (traffic, weather, restricted airspace)
  - *Powerful pattern-based genetic algorithm*
  - *Processes 400-800 candidates every minute*
- Produces 3 solution types: <u>lateral</u>, <u>vertical</u>, <u>combo</u>
- Computes time & fuel outcomes of each solution
- Displays solutions and outcomes to the pilots for selection and ATC request

Auto Mode

Analyzes pilot-entered route/alt changes

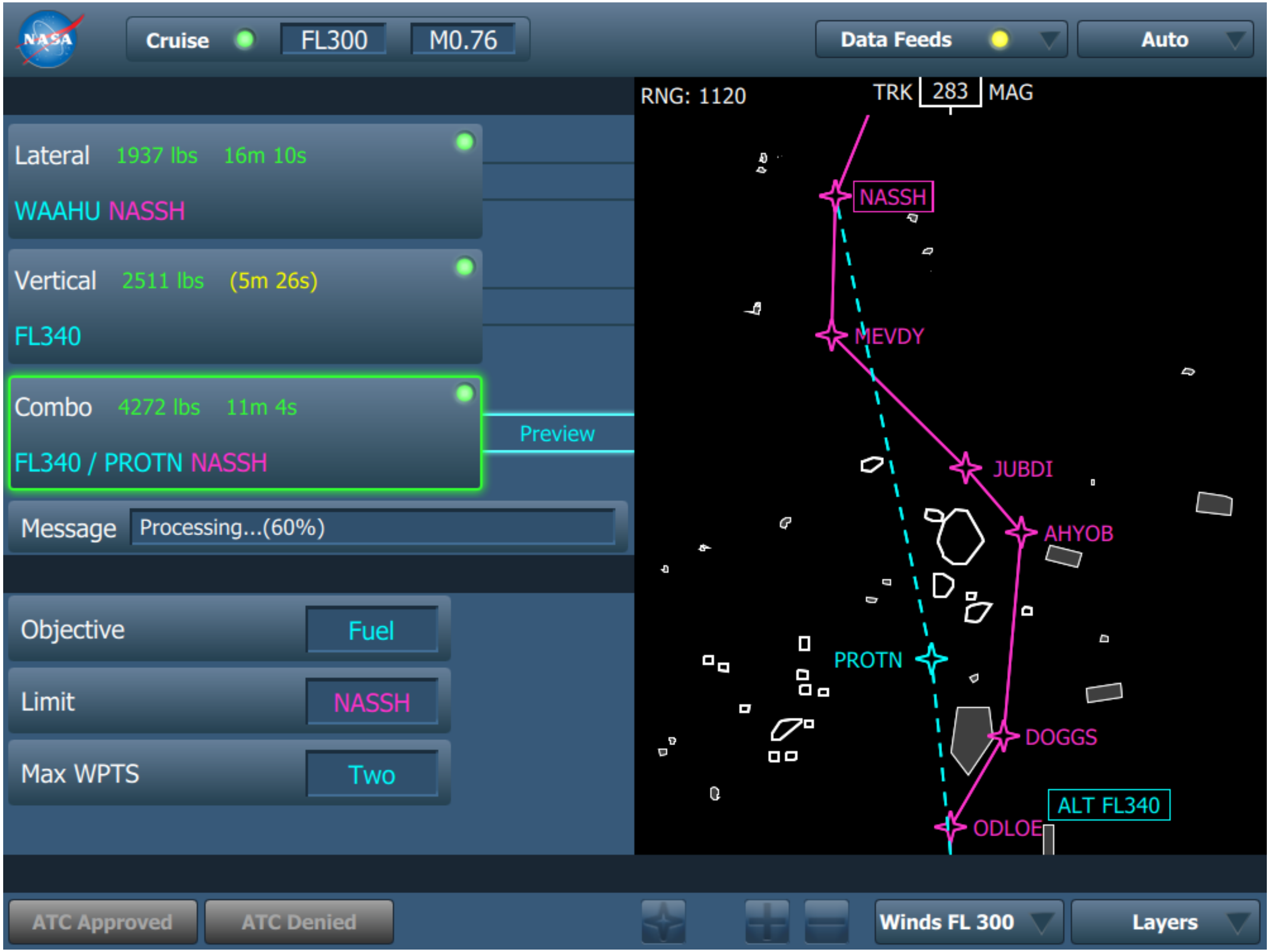
- Touch-screen interface for easy route/altitude entry
- Displays time & fuel outcomes of entered route/alt
- Depicts conflicts with traffic, weather, restricted airspace graphically and in text

Manual Mode

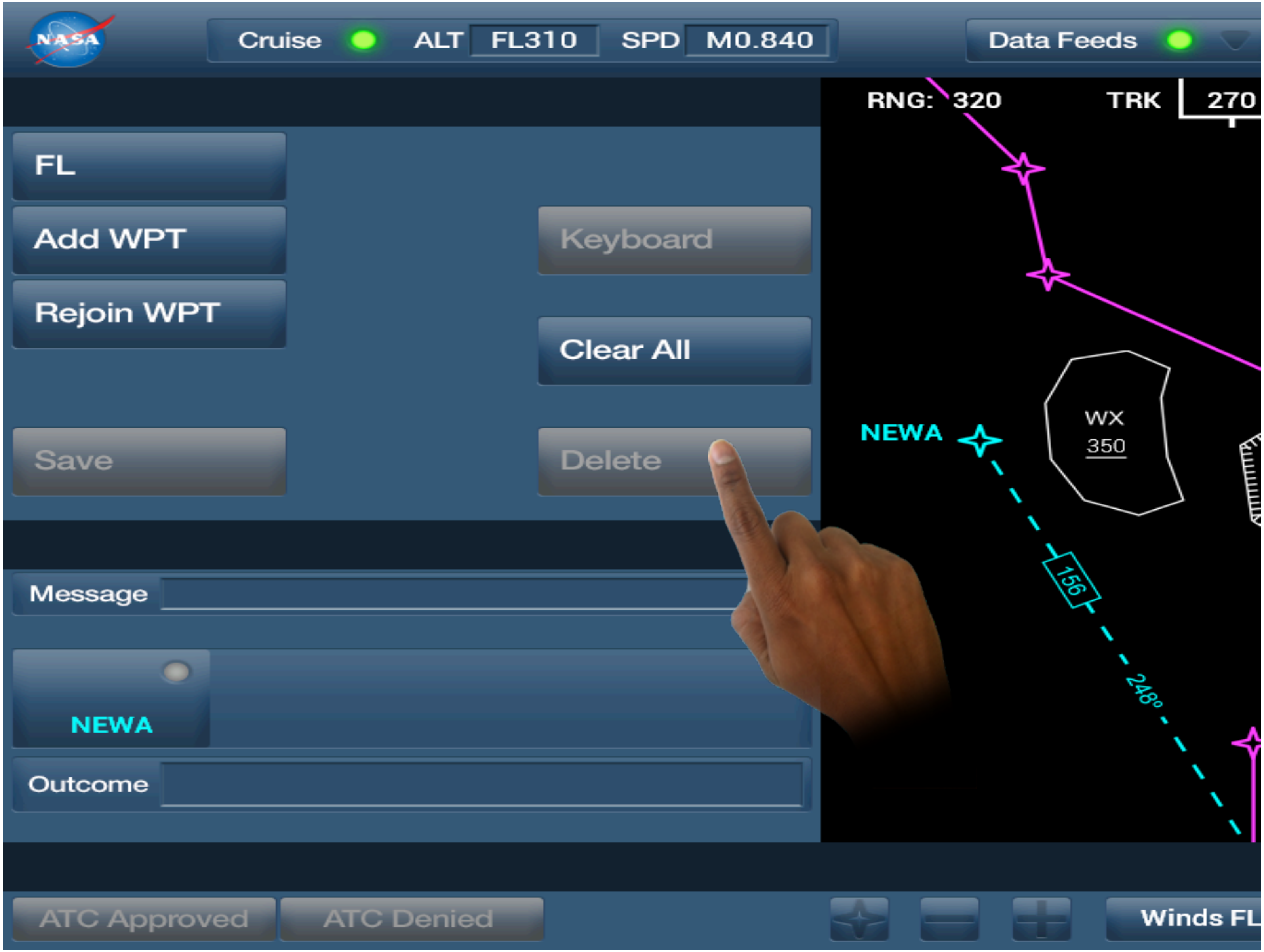


EFB = electronic flight bag

TAP Auto Mode

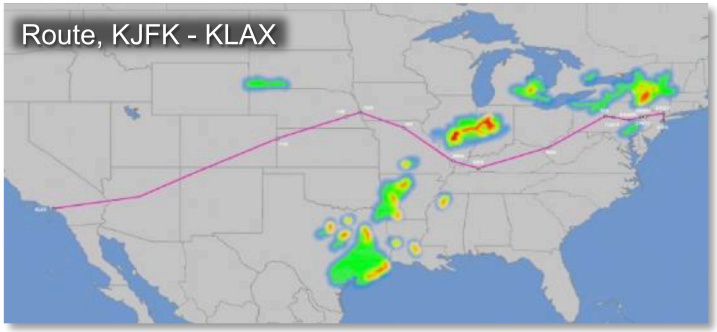


TAP Manual Mode



Simulation Experiments

Aug 2013, Oct-Nov 2014



- *Fixed-based commercial transport sim*
- *24 eval pilots (left seat, pilot flying)*
- *2 simulated flights each, 5-6 use cases*
- *Two HMI designs (separate sims)*

- *Rigorous Human Factors experimental design*
- *Evaluated normal and non-normal flight conditions*

Objectives

1. Assess TASAR effect on workload
2. Assess potential interference with primary flight duties
3. Assess TAP HMI design update
4. Assess CBT effectiveness

Results

1. ***No effect on pilot workload compared to standard flight-deck baseline condition***
2. ***Non-normal event response not adversely affected***
3. ***TAP useful, understandable, intuitive, easy to use***
4. ***Standalone CBT was as effective as live instructor***

CBT = computer based trainer
HITL = human in the Loop
HMI = human Machine Interface
OP = Operator Performance Lab, Univ. of Iowa

National Aeronautics and Space Administration

Airplane State Awareness and Prediction Technologies

Steven D. Young, PhD
NASA Langley Research Center

(Amended version of presentation given at the AIAA SciTech Forum, January 4-8, 2016, San Diego, CA)

Study Process and Findings (2010-2014)

CAST-recruited gov't-industry team:

- Analyzed 18 events from ~10 years prior; Identified 12 recurring problem themes; Suggested >270 intervention strategies

- Assessed each intervention strategy for effectiveness & feasibility; Recommended
  - **13** safety enhancements (SEs), no research req'd
  - **5 research** safety enhancements (SEs)
  - **1 design** SE where research is critical to implementation

- Published plans to achieve each safety enhancement

NASA's contribution:

NASA ARMD Airspace Operations & Safety (AOSP) Program

Airspace Technology Demonstrations (ATD) Project

Technologies for Airplane State Awareness (TASA) Sub-Project

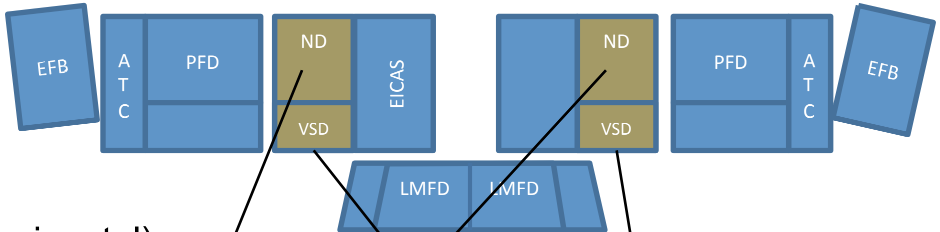
Invalid Source Data	Distraction	Systems Knowledge	Crew Resource Management	Automation Confusion / Awareness	Ineffective Alerting	Inappropriate Control Actions	Total
	x	x	x		x		7
x	x		x		x		6
	x		x	x	x	x	8
	x	x	x	x	x	x	9
	x		x	x	x	x	7
	x	x	x	x	x	x	11
	x		x		x	x	6
	x		x	x	x	x	6
	x		x	x	x	x	8
x	x	x	x	x	x	x	9
x	x		x		x	x	7
	x	x	x	x	x	x	10
	x			x	x	x	6
	x			x	x		7
	x	x	x	x	x	x	9
x	x	x	x	x	x		10
x	x		x	x	x		8
	x		x	x	x		7
5	18	7	16	14	18	12	

Virtual Day-VMC Displays (SE-200)	Attitude & Energy State Techs (SE-207)	Systems State Technologies (SE-208)
Simulator Fidelity (SE-209)	Flight Crew Performance (SE-210)	Training for Attention Management (SE-211)

Desired Outputs

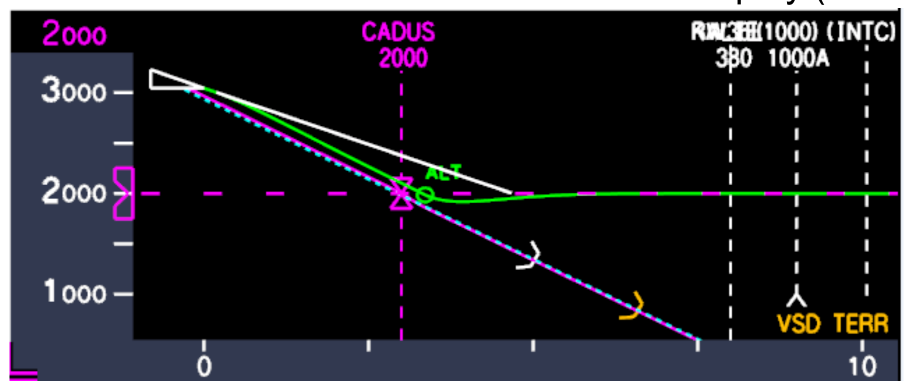
SE-207/208 Research Team

Trajectory & Mode Change Prediction*



Navigation Display (horizontal)

Vertical Situation Display (vertical)

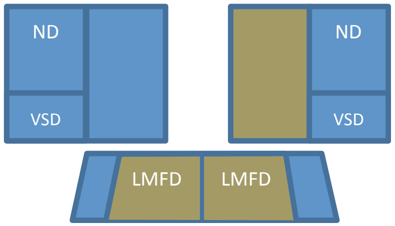


*K. Shish, et. al., “Trajectory Prediction and Alerting for Aircraft Mode and Energy State Awareness,” AIAA 2015-1113, Jan 2015 (Best Paper of Conference Award)

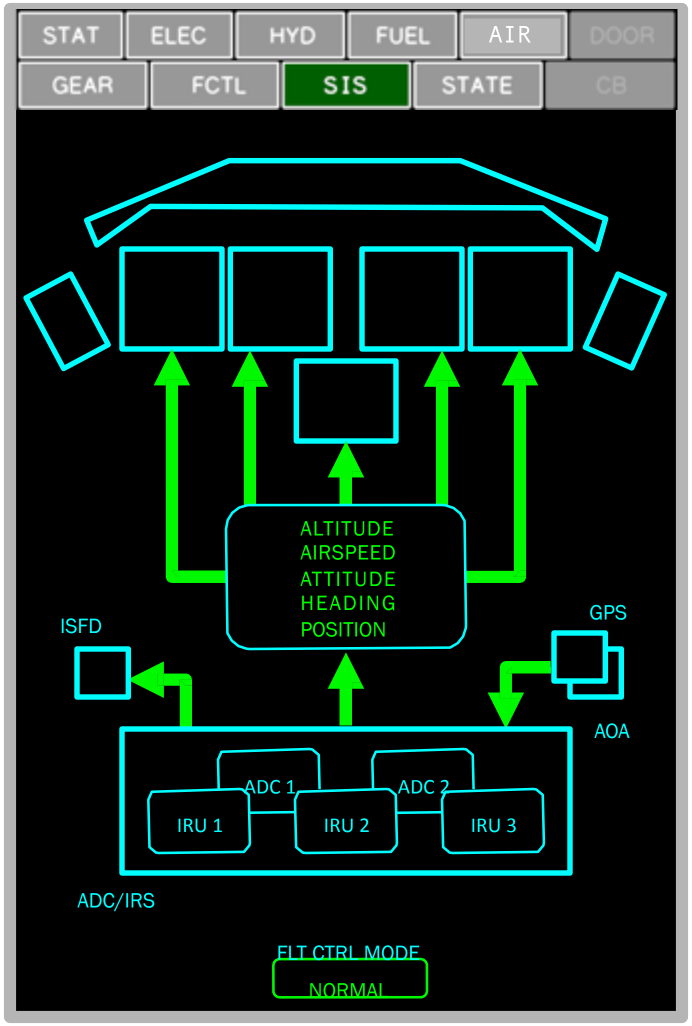
- “Green Line” – represents where the automation will take the aircraft if no intervention by the pilot, and no unexpected conditions are encountered.
- Circle symbol and label – indicates (1) where a mode switch is predicted and what the new mode will be; or (2) where an energy-related problem is predicted to occur. For the latter, colors/salience will change based on proximity/time to alert (IAW 25.1322)

System Interaction Synoptic

Normal



Available on any of these display spaces



1 *Mode control panel*

2 *Display panels*

3 *Flight-critical information*

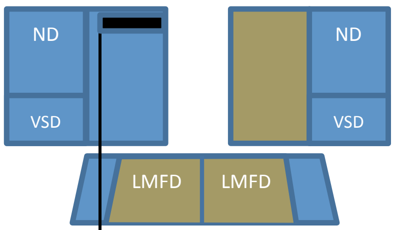
4 *Flight-critical data systems*

5 *:ISFD – standby instrument*
:Flight control mode

System Interaction Synoptic

Non-normal

(example)



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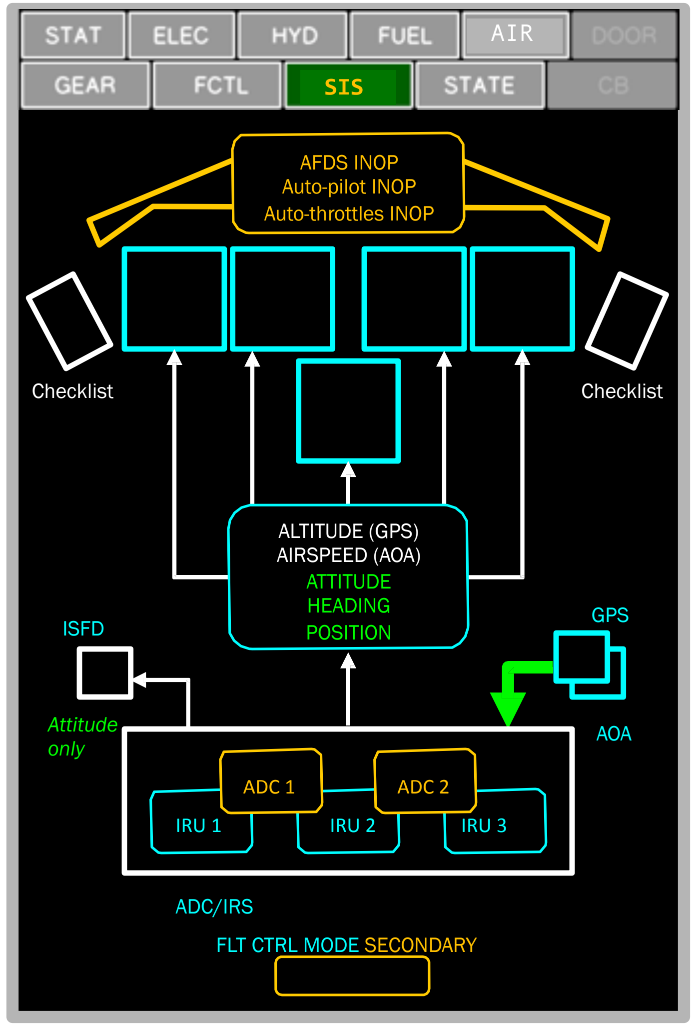
EICAS Msg:

- ❑ NAV AIR DATA SYS



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Associated checklist(s) available on both Electronic Flight Bags (EFBs)

Checklist(s) will be simplified:

1. Removes information now provided on this display
2. Context-relevant data provided rather than lists, or needs to look in reference documents

Research Flight Deck Cab

- Like a B757/B767
  - B757 aerodynamic model and handling qualities
  - Center aisle-stand; throttles
  - Overhead panel
  - FMS/MCP/Autopilot

- Like a B787
  - Four 17" LCDs (vertical)
  - One 17" LCD (horizontal)
  - Dual HUDs and EFBs
  - Narrow CDU keypads*
  - Display control panels
- Like Airbus
  - Sidesticks
  - Rate Command Attitude Hold control law

*with CDU display on LMFD

Status and Next Steps

- AIME testing completed Jan 28
  - 12 airline crews participated over 10 wk period; ~250 flights completed
  - Good cross section of airlines, experience, and type-ratings
  - Good system performance in general; detailed analysis underway
  - Generally positive feedback from crews; usability results being tabulated
  - Many many lessons-learned; Findings to be published (Fall 2016)
  - SciTech 2016 paper invited to AIAA Journal of Aerospace Information Systems
- Work on schedule and progressing to remaining milestones through FY19
- New collaborations in development
  - NRA-based awards (3) specific to SE-208 (pending contract negotiations)
  - FAA interagency agreement being drafted (SE-207, SE-208)

Questions?

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