National Aeronautics and Space Administration

NASA Research to Support the Airlines

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Moffett Field, CA
(in Silicon Valley)

ARMD Video

“NASA Is With You When You Fly”

NASA Aeronautics

- NASA aeronautics has made decades of contributions to aviation
- Nearly every aircraft today has a NASA-supported technology on board
- Aeronautics research is managed by the Aeronautics Research Mission Directorate or ARMD
- ARMD starts by asking:
  - How can we help make air travel safer and more efficient?
  - What's the "cleanest, greenest" way to go?
  - How can we innovate?
  - How do we measure results?
- ARMD is helping to create the Next Generation Air Transportation System or NextGen
  - Goals are to increase the capacity, efficiency and flexibility of the national air space and address noise, emissions, efficiency, performance, and safety challenges

Examples of NASA Aeronautics Projects

- *IBM Watson*
  - Application to AOC and flight deck
- *Flight Awareness Collaboration Tool*
  - Winter weather management
- *Dynamic Weather Routes*
  - Efficient deviations around convective weather
- *Traffic Aware Strategic Aircrew Requests*
  - Flight deck tool for optimizing en route trajectories
- *Airplane State Awareness and Prediction Technologies*
  - Analyzed aircraft accidents and incidents
  - Developed and tested interventions

NASA = National Aeronautics and Space Administration
AOC = Airline Operations Center

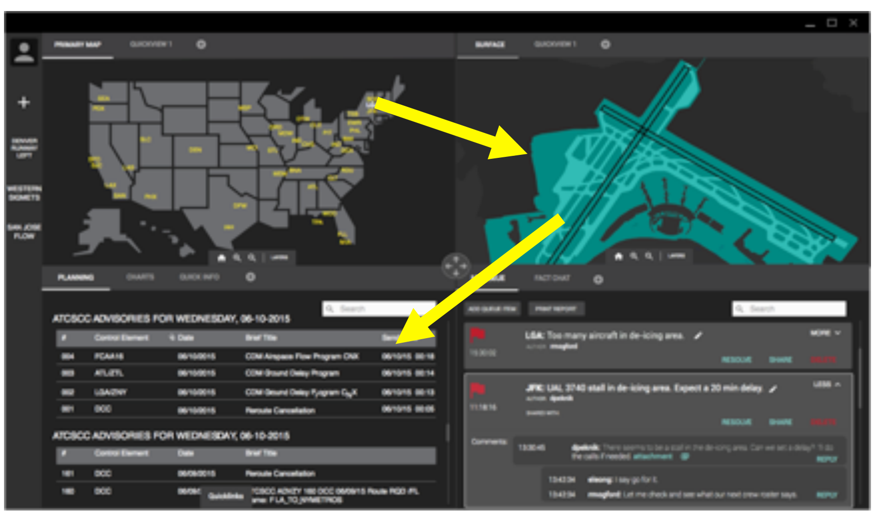
IBM Watson

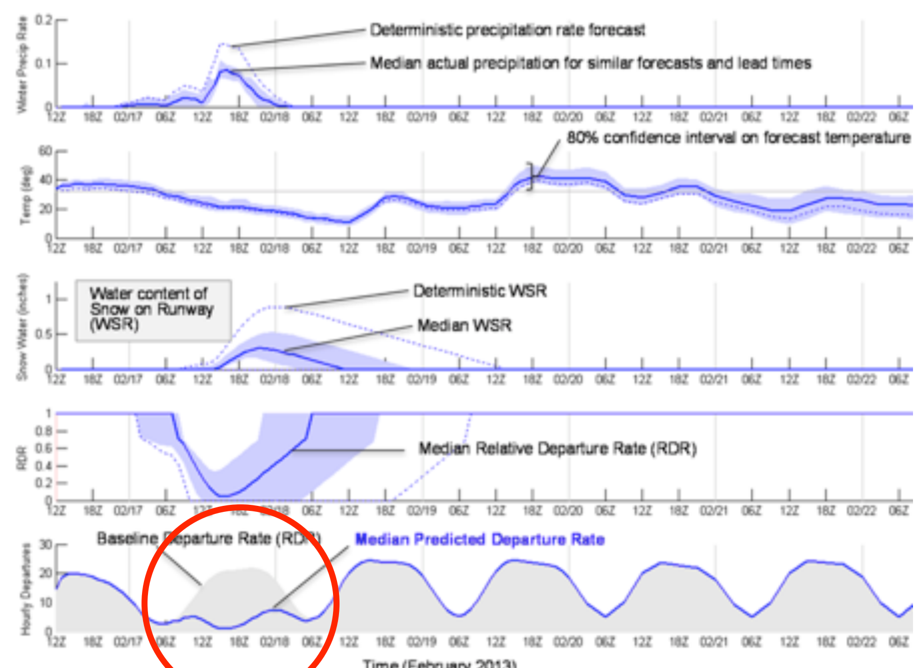
- IBM delivered a report to NASA in FY16 on how to apply Watson to the AOC
  - Support dispatch and maintenance in accessing FAA regulations, airline procedures, aircraft manuals, etc.
  - Extend to ACARS messages and Internet data
- NASA Langley is applying Watson to the flight deck
  - Assist pilot to identify risks and determine/prioritize actions needed to mitigate them
  - Identify, evaluate, and trap errors
  - Continually and autonomously maintain safety-of-flight

FAA = Federal Aviation Administration
ACARS = Aircraft Communications Addressing and Reporting System

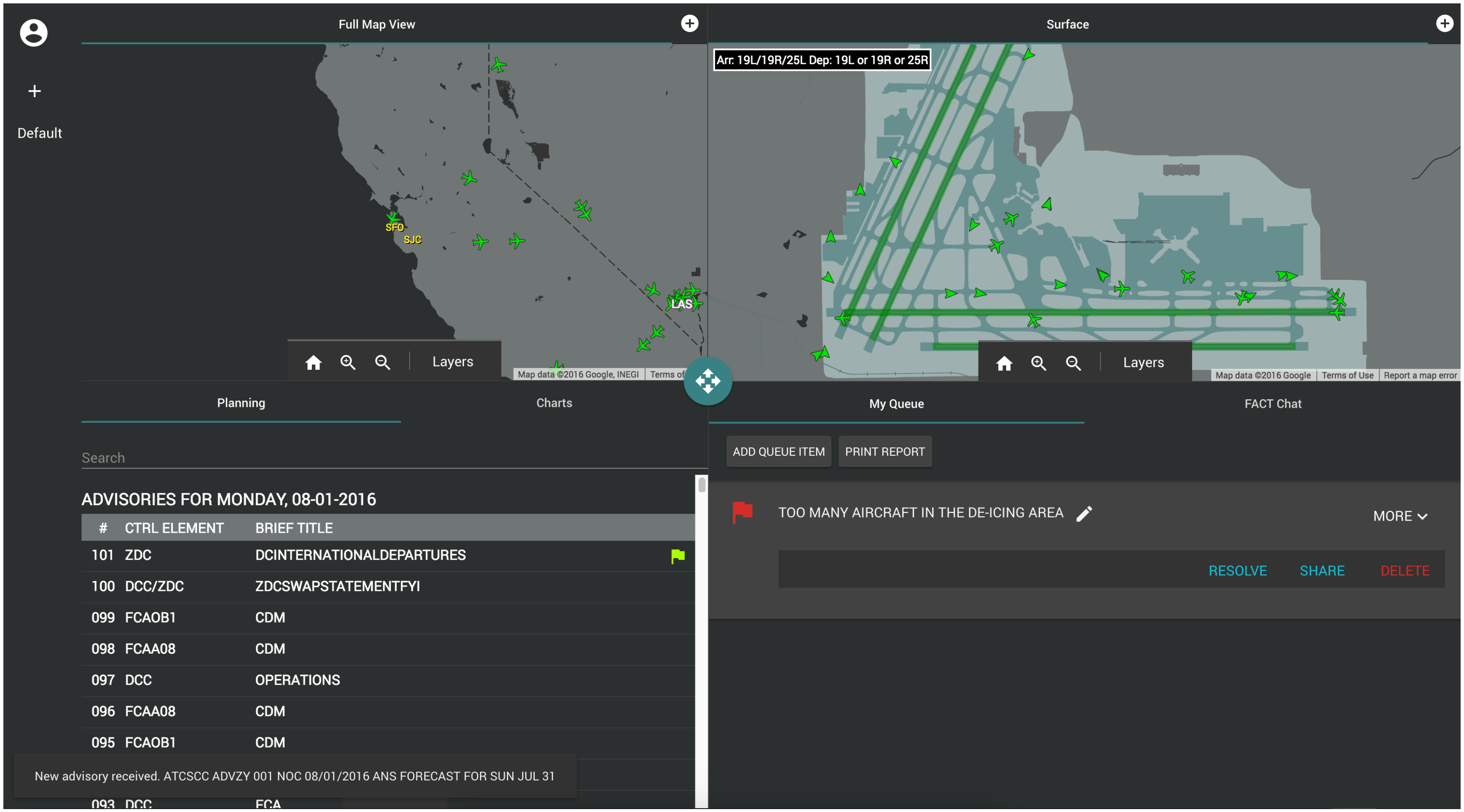
Flight Awareness Collaboration Tool

- 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





FACT Prototype



FACT Progress

- Web-based prototype will be completed in 2017
- Plan to demonstrate FACT to airlines and airports to seek feedback
- Will make modifications and improvements
- FACT platform will be used to host automation tools (e.g., predicting airport capacity, managing snow removal)
- Developing AOC simulator at NASA Ames to evaluate FACT

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
- Research themes
  - AOC simulation
  - Study dispatcher workload, situation awareness, errors
  - Display/system integration
  - Managing/accessing large information databases from multiple sources
  - Preferred routes

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

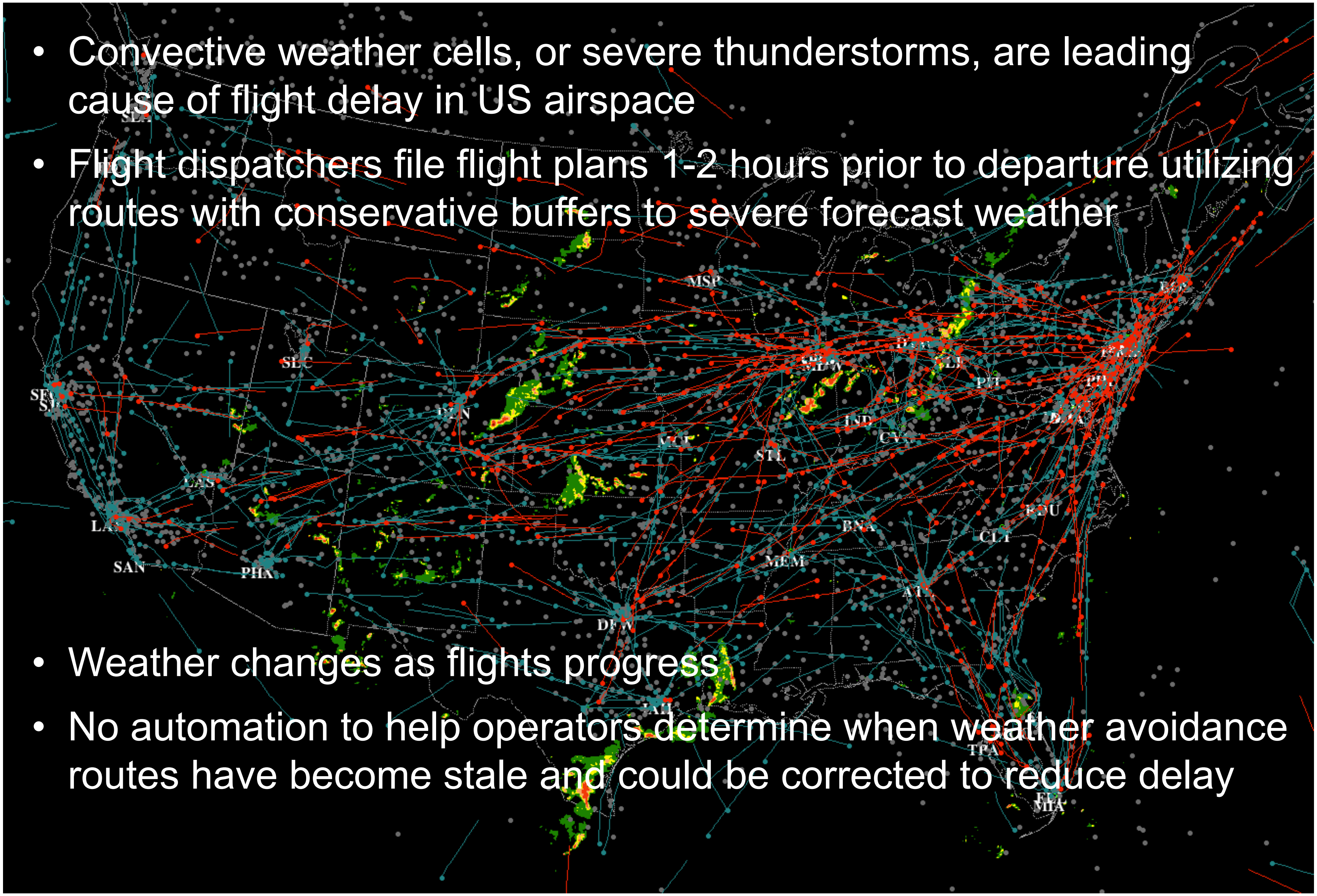
Dave McNally, Kapil Sheth, and Chester Gong
NASA Ames Research Center
Moffett Field, California

Mike Sterenchuk
American Airlines, Integrated Operations Control
Fort Worth, Texas

Scott Sahlman, Susan Hinton, Chuhan Lee
University of California, Santa Cruz
Moffett Field, California

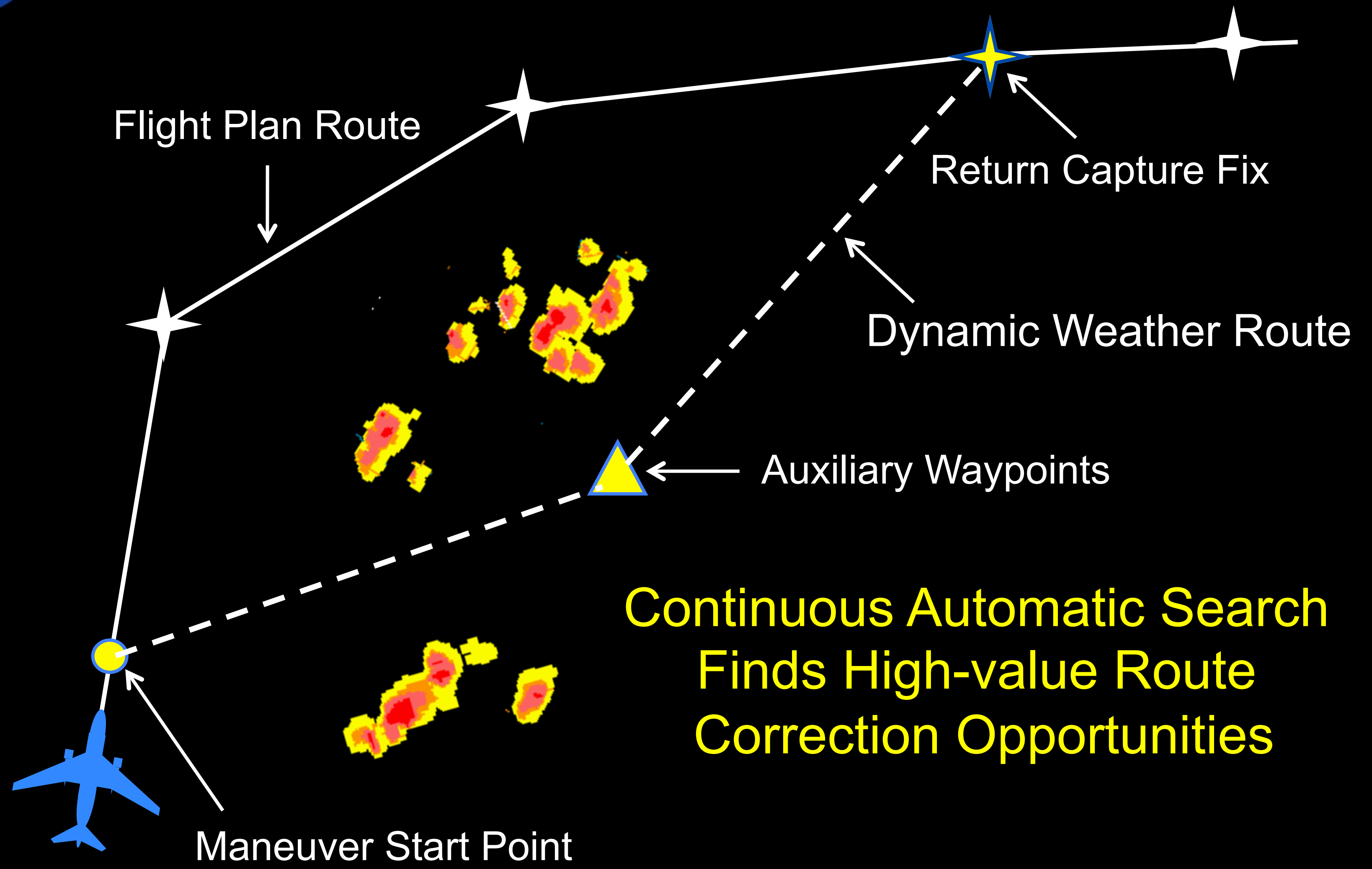
Fu-Tai Shih
SGT, Inc.
Moffett Field, California

What's the Problem?

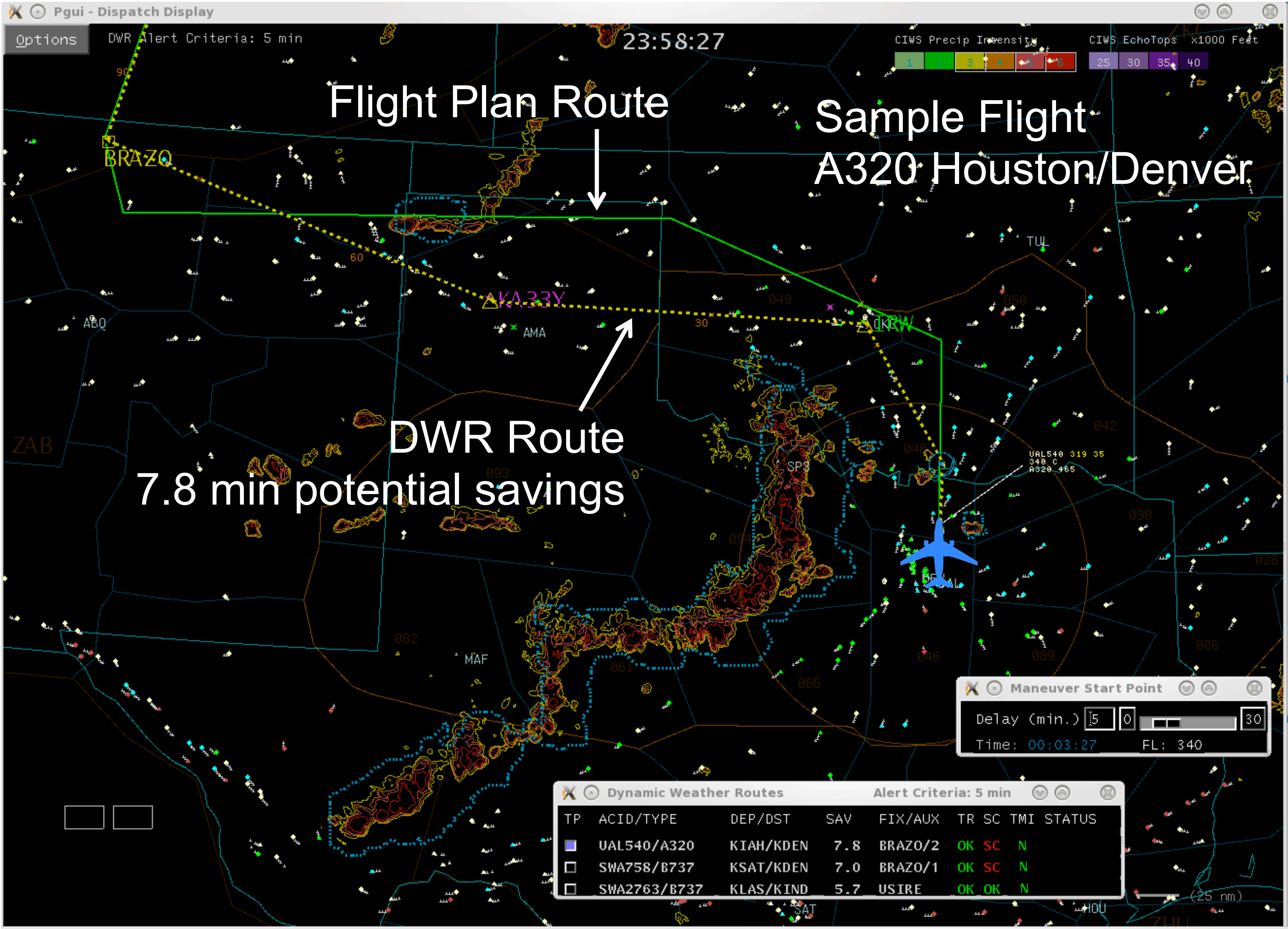


- Convective weather cells, or severe thunderstorms, are leading cause of flight delay in US airspace
- Flight dispatchers file flight plans 1-2 hours prior to departure utilizing routes with conservative buffers to severe forecast weather
- Weather changes as flights progress
- No automation to help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

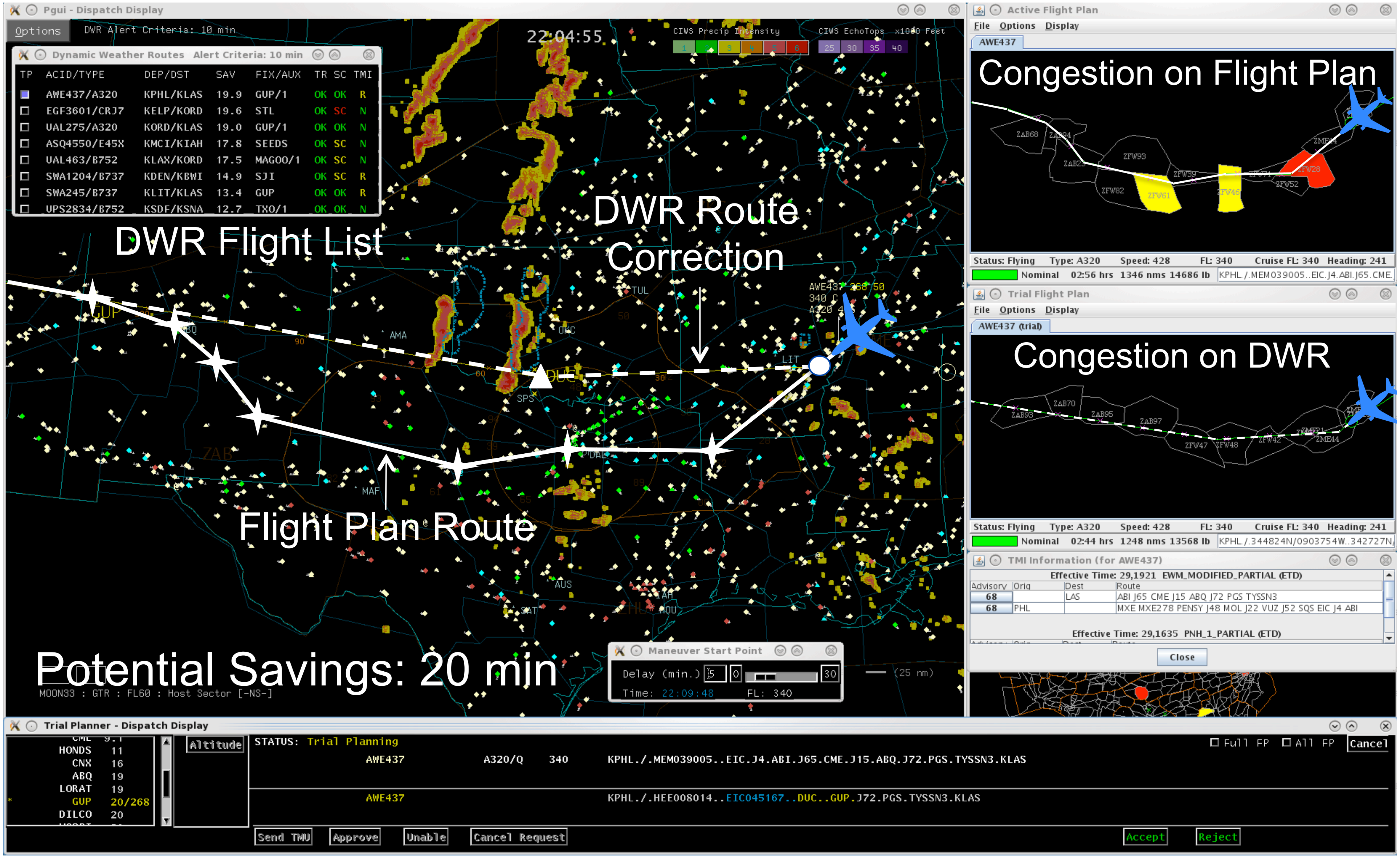
Dynamic Weather Routes (DWR)



Continuous Automatic Search
Finds High-value Route
Correction Opportunities

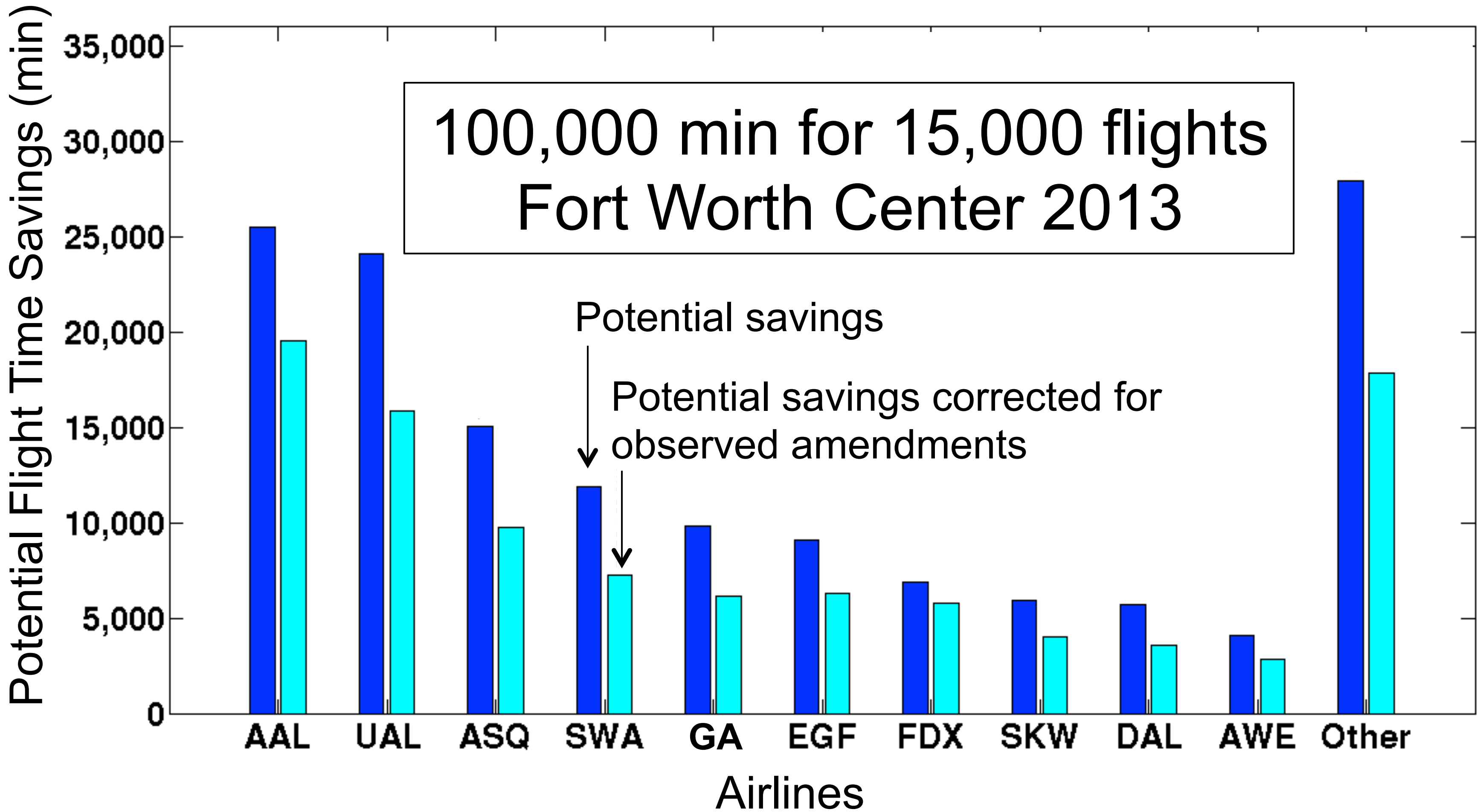

Pgui - Dispatch Display
Options
DWR Alert Criteria: 5 min
23:58:27
CIWS Precip Intensity
CIWS EchoTops x1000 Feet
25 30 35 40
Flight Plan Route
Sample Flight
A320 Houston/Denver
BRAZO
AMA
ABQ
TUL
DWR Route
7.8 min potential savings
ZAB
SPS
MAF
UAL540 319 35
340 C
A320 465
Maneuver Start Point
Delay (min.) 5 0 30
Time: 00:03:27 FL: 340
Dynamic Weather Routes Alert Criteria: 5 min
TP ACID/TYPE DEP/DST SAV FIX/AUX TR SC TMI STATUS
UAL540/A320 KIAH/KDEN 7.8 BRAZO/2 OK SC N
SWA758/B737 KSAT/KDEN 7.0 BRAZO/1 OK SC N
SWA2763/B737 KLAS/KIND 5.7 USIRE OK OK N
SAT
HOU
(25 nm)

DWR User Interface



Potential Benefits Analysis

All Airlines, All Flights, Fort Worth Center 2013

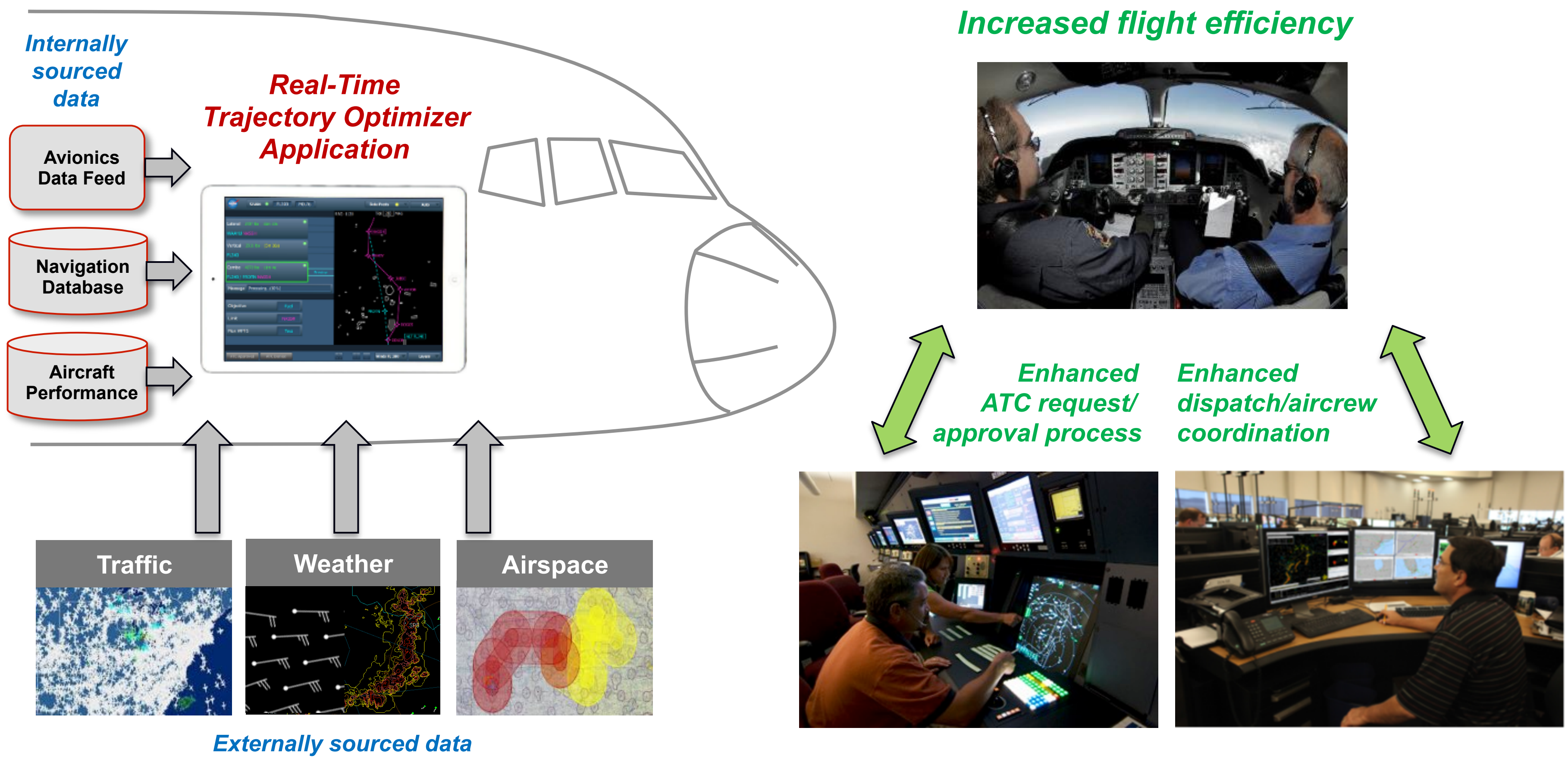


Traffic Aware Strategic Aircrew Requests (TASAR) NASA Flight Deck Application for En Route Flight Optimization

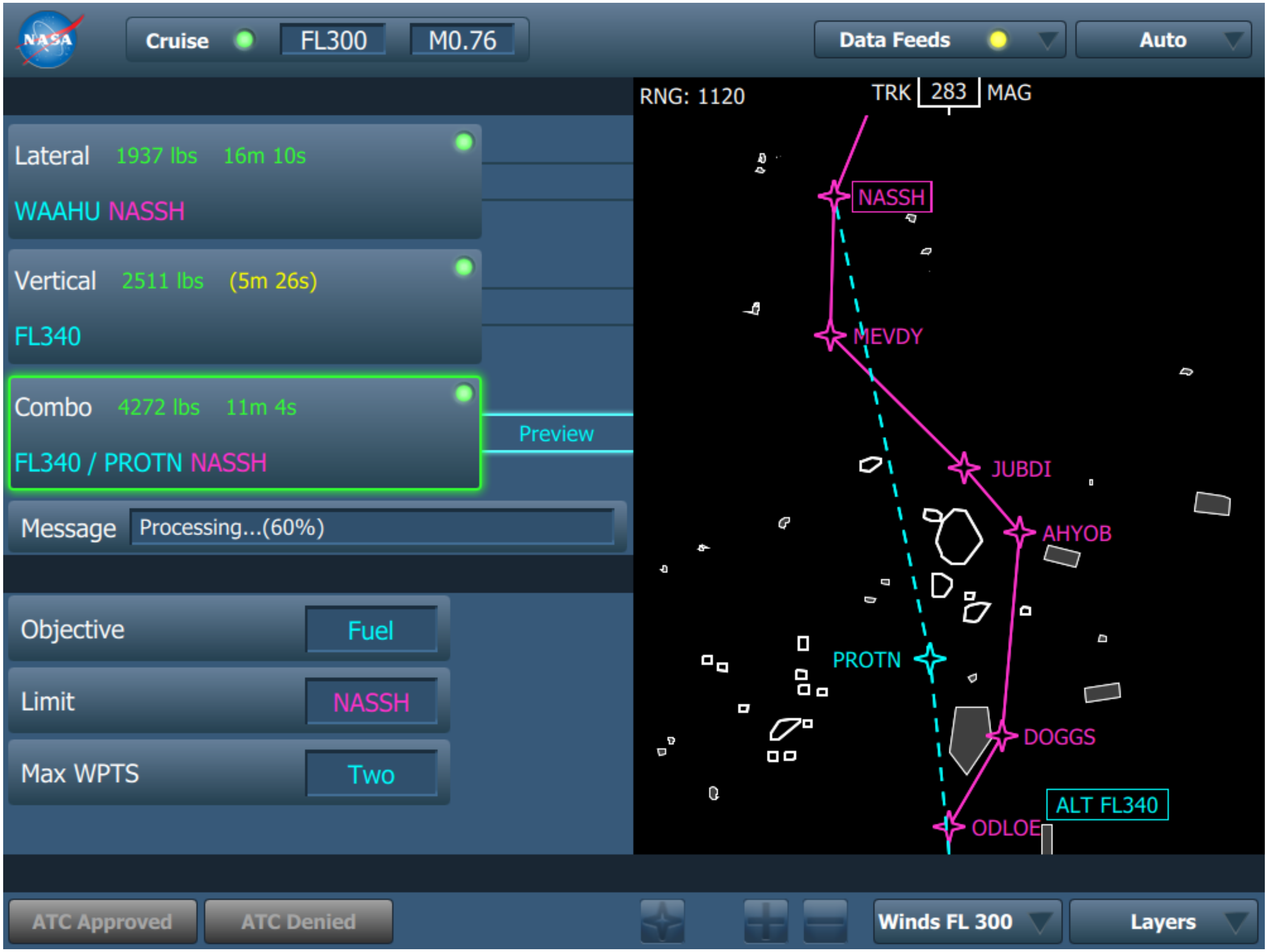
David Wing, TASAR Principal Investigator
NASA Langley Research Center
david.wing@nasa.gov

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

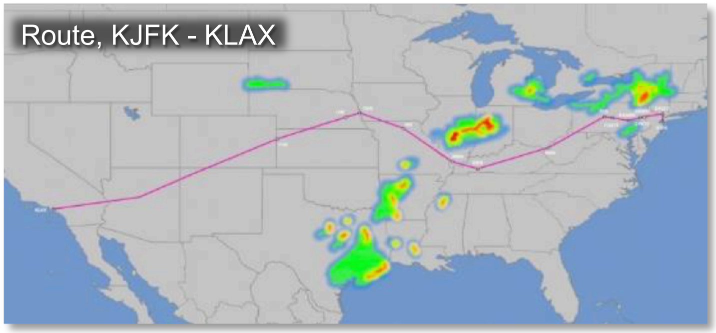


NASA Traffic Aware Planner (TAP) Auto Mode



Simulation Experiments

Aug 2013, Oct-Nov 2014



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

- *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

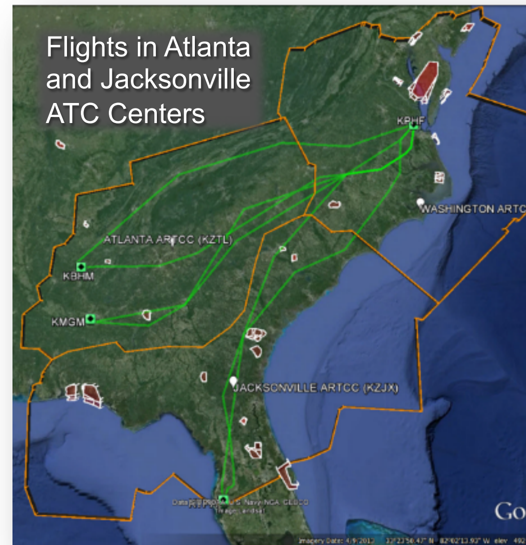
Results

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***

HMI = human machine interface
CBT = computer based trainer
U.I. = University of Iowa

TASAR Flight Trials

November 2013, June 2015



- *54 hours, 21 flights, 17 evaluation pilots*
- *ATC observations, 50 interviews w/ATC*
- *Alaska Airline's EFB & ADS-B hardware*
- *Broadband connection to NOAA winds, FAA SAA status, WSI convection data*

Objectives

1. *Verification of live data interfaces and TAP functionality in flight*
2. *Pilot and controller assessments of TAP and TASAR operations*
3. *Partner airline risk reduction*

NOAA = National Oceanic and Atmospheric Administration
SAA = Special Activity Airspace

Results

1. ***TAP processed live avionics, ADS-B, and internet data, and functioned properly***
2. ***Pilots rated HMI usability high; workload low***
3. ***ATC provided extensive feedback on user request acceptability factors; found most TASAR requests acceptable***
4. ***Airline deployment risk areas reduced: hardware, connectivity, accuracy, human factors***

Reference AIAA-2014-2166

National Aeronautics and Space Administration

Airplane State Awareness and Prediction Technologies

Steven D. Young, PhD
NASA Langley Research Center ARMD

Technical Seminar, May 5, 2016

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

Study Process and Findings (2010-2014)

Commercial Aviation Safety Team (CAST) - recruited from government & industry

- 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 required
  - **5 research** 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 Program

Airspace Technology Demonstrations Project

Technologies for Airplane State Awareness 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)

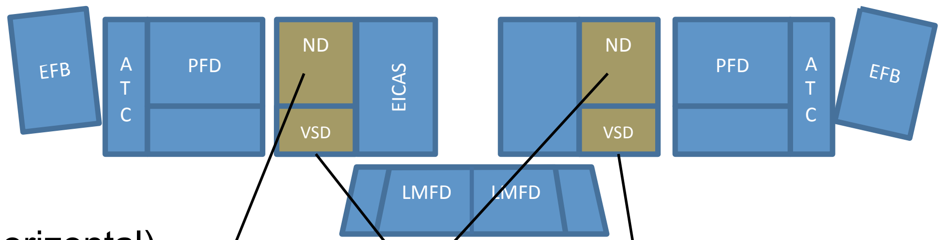
Flight Crew Performance (SE-210)

Training for Attention Management (SE-211)

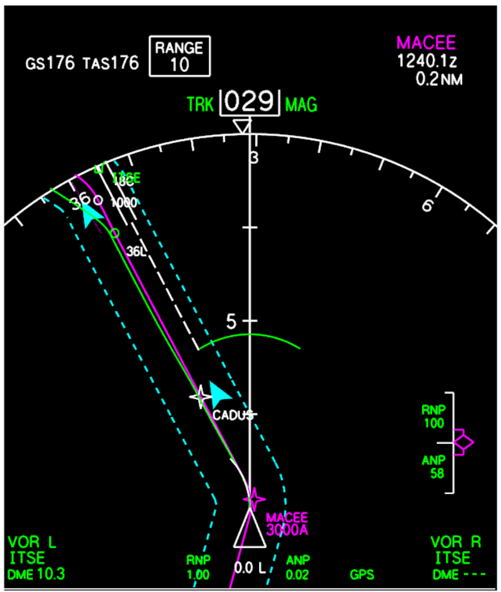
Desired Outputs

ARMD = Aeronautics Research Mission Dir.
VMC = Visual Meteorological Conditions

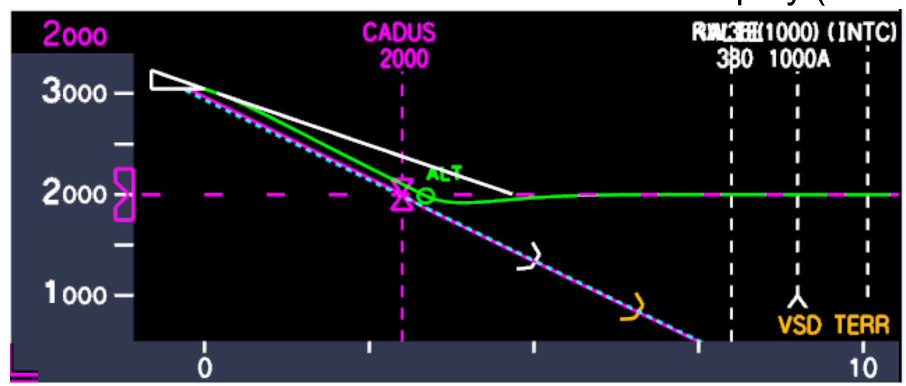
Trajectory & Mode Change Prediction



Navigation Display (horizontal)



Vertical Situation Display (vertical)

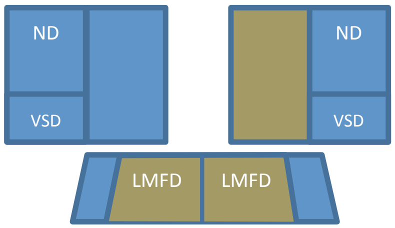


*K. Shish, et. al., "Trajectory Prediction and Alerting for Aircraft Mode and Energy State Awareness," AIAA 2015-1113, Jan 2015 (Best Paper of Conference Award)

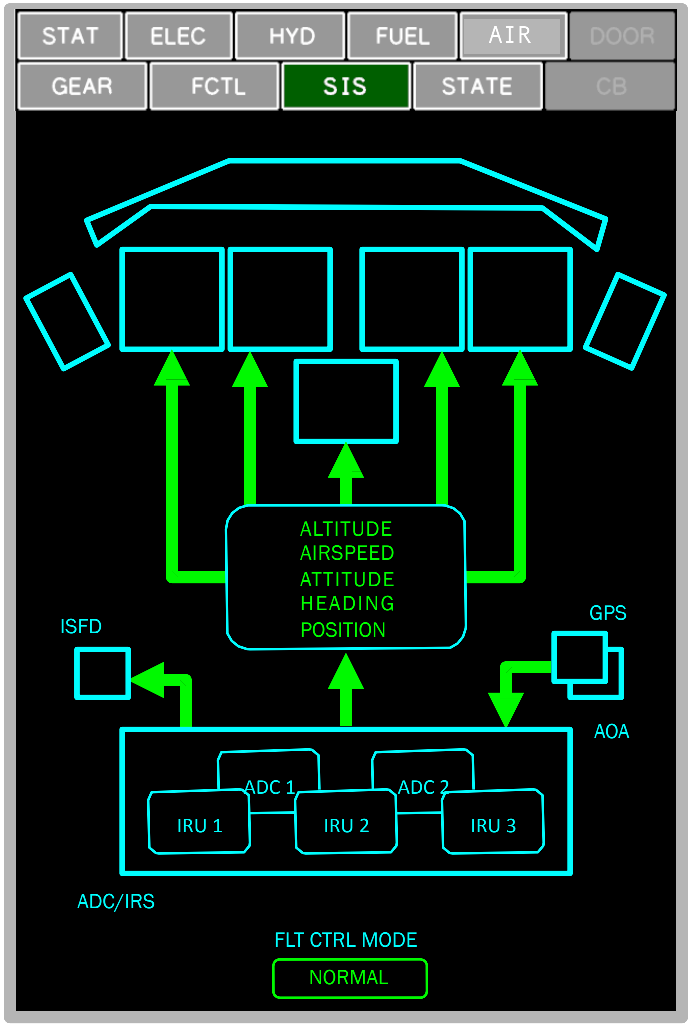
- "Green Line" – represents where the automation will take the aircraft if no intervention by the pilot and no unexpected conditions are encountered.
- Circle symbol and label – indicates (1) where a mode switch is predicted and what the new mode will be; or (2) where an energy-related problem is predicted 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*

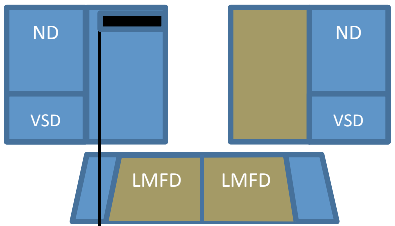
3 *Flight-critical information*

4 *Flight-critical data systems*

5 *ISFD – standby instrument flight control mode*

ISFD = Integrated Standby Flight Display

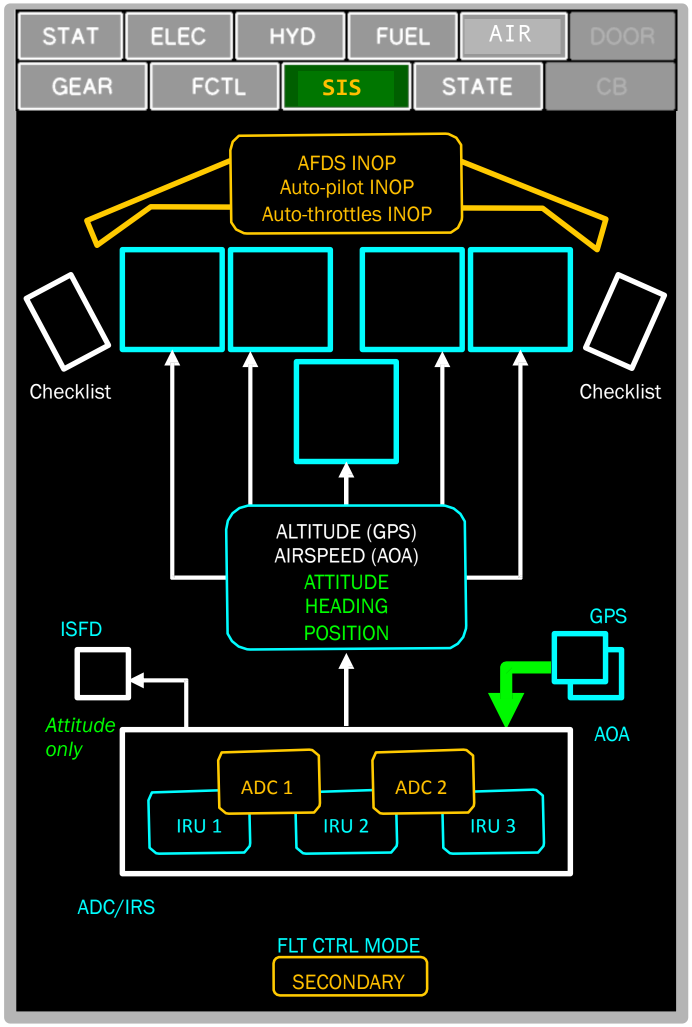
System Interaction Synoptic



Available on any of these display spaces

EICAS Message:

❑ NAV AIR DATA SYS



Non-normal

(example)

6

Associated checklist(s) available on both EFBs

Checklist(s) will be simplified:

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

EICAS = Engine-indicating & Crew-alerting System
AFDS = Autopilot Flight Director System

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” displays (vertical)
  - One 17” display (horizontal)
  - Dual HUDs and EFBs
  - Narrow CDU keypads
  - Display control panels
- Like an Airbus
  - Sidesticks
  - Rate Command Attitude Hold control law

FMS = Flight Management System, MCP = Mode Control Panel
HUD = heads up display, CDU = Control Display Unit

Status and Next Steps

- Simulation testing completed January 28, 2016
  - 12 airline crews participated over 10 week 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
  - NASA Research Agreement-based awards (3) specific to SE-208
  - FAA interagency agreement being drafted (SE-207, SE-208)


National Aeronautics and Space Administration
Questions?
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