National Aeronautics and Space Administration

# NASA Research to Support the Airlines

Richard Mogford, Ph.D.
NASA Ames Research Center

NASA Is With You When You Fly Video

mailto:https://transfer.ndc.nasa.gov/seos/1000/mpd/ui150620167df442f4192ece2b402adb602686f9a4

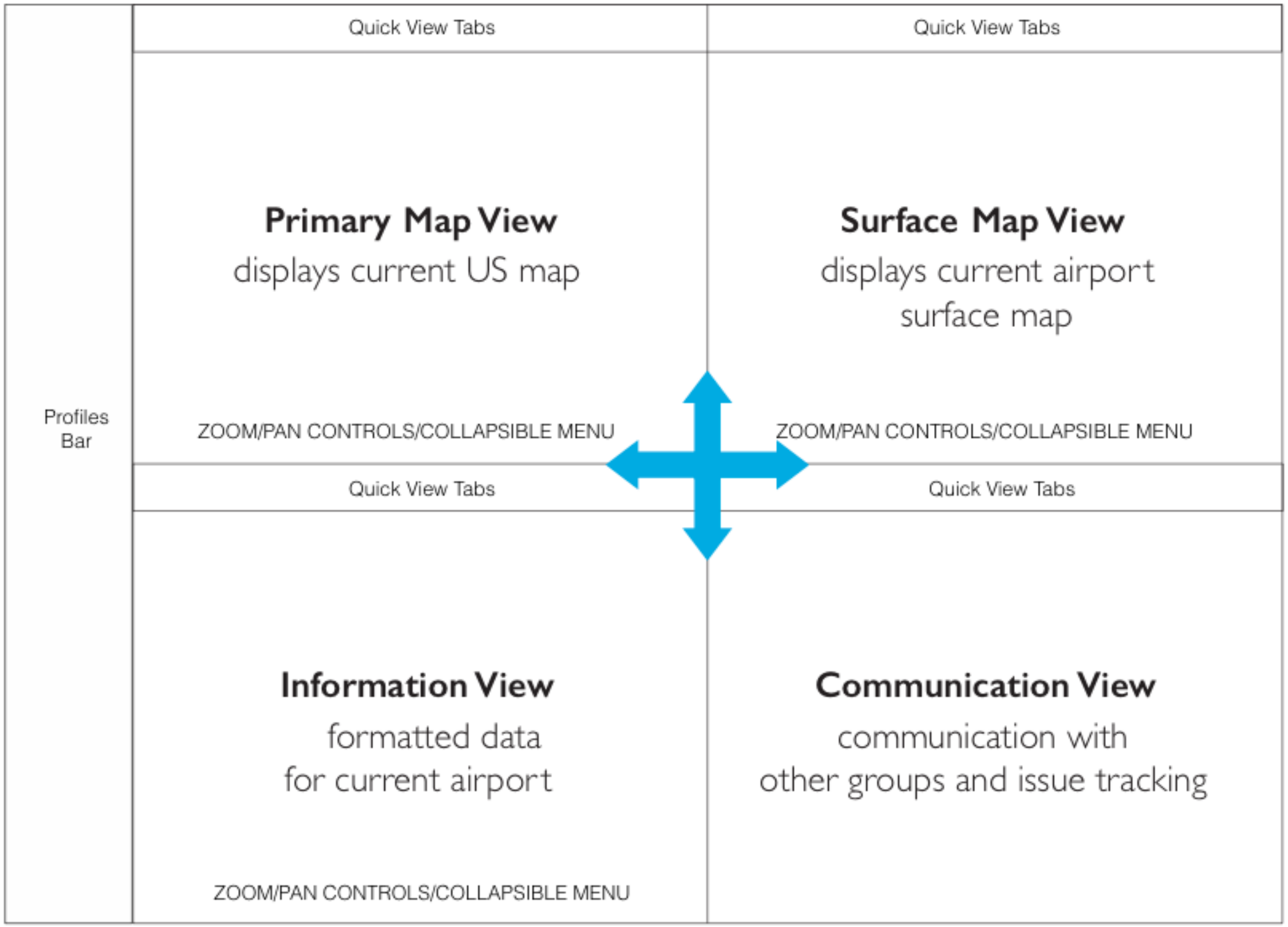
# NASA Aeronautics

- Flight Awareness Collaboration Tool
  - Winter weather management
- Dynamic Weather Routes
  - Efficient deviations around convective weather
- Traffic Aware Strategic Crew Requests
  - Flight deck tool for optimizing en-route trajectories
- Airplane State Awareness and Prediction Technologies
  - Commercial Aviation Safety Team
  - Analyzed aircraft accidents and incidents
  - Developed and tested interventions

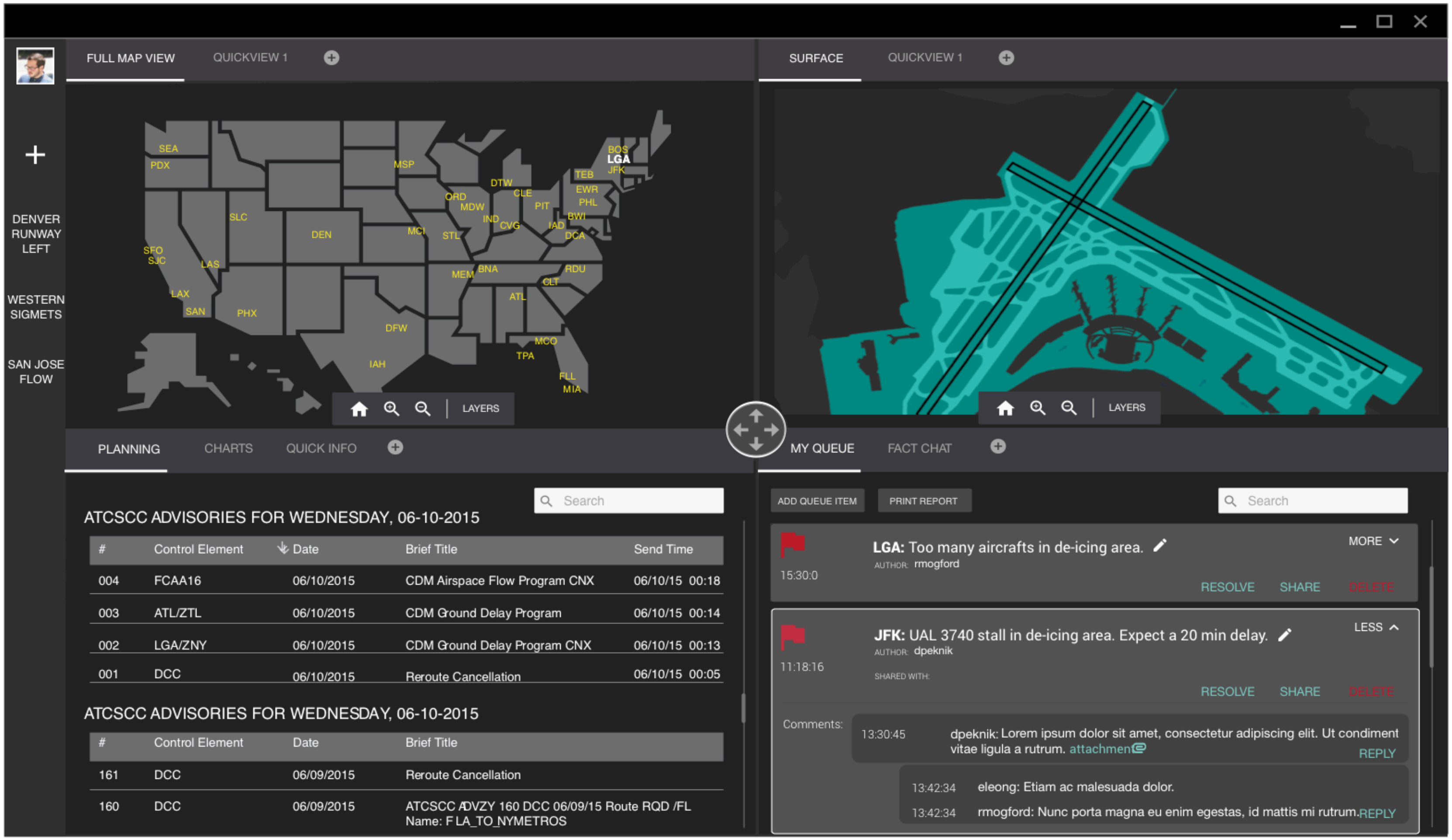
# Winter Weather

- 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 developed and coding for a web-based application is underway
- Space Act Agreement with Virgin America
- User groups at Detroit and JFK airports

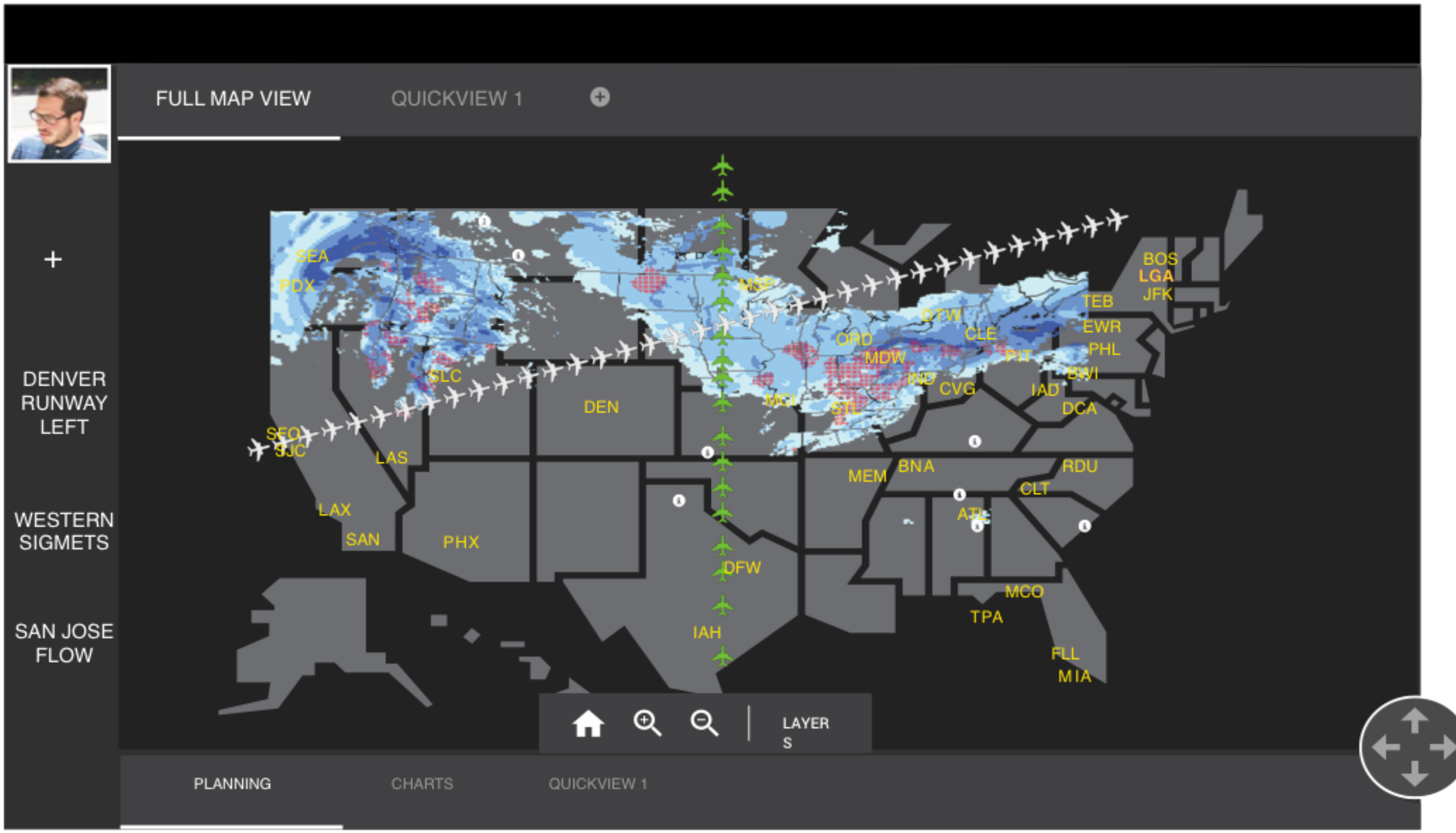
# FACT Design


Quick View Tabs
Quick View Tabs
Primary Map View
displays current US map
Surface Map View
displays current airport surface map
Profiles Bar
ZOOM/PAN CONTROLS/COLLAPSIBLE MENU
ZOOM/PAN CONTROLS/COLLAPSIBLE MENU
Quick View Tabs
Quick View Tabs
Information View
formatted data for current airport
Communication View
communication with other groups and issue tracking
ZOOM/PAN CONTROLS/COLLAPSIBLE MENU

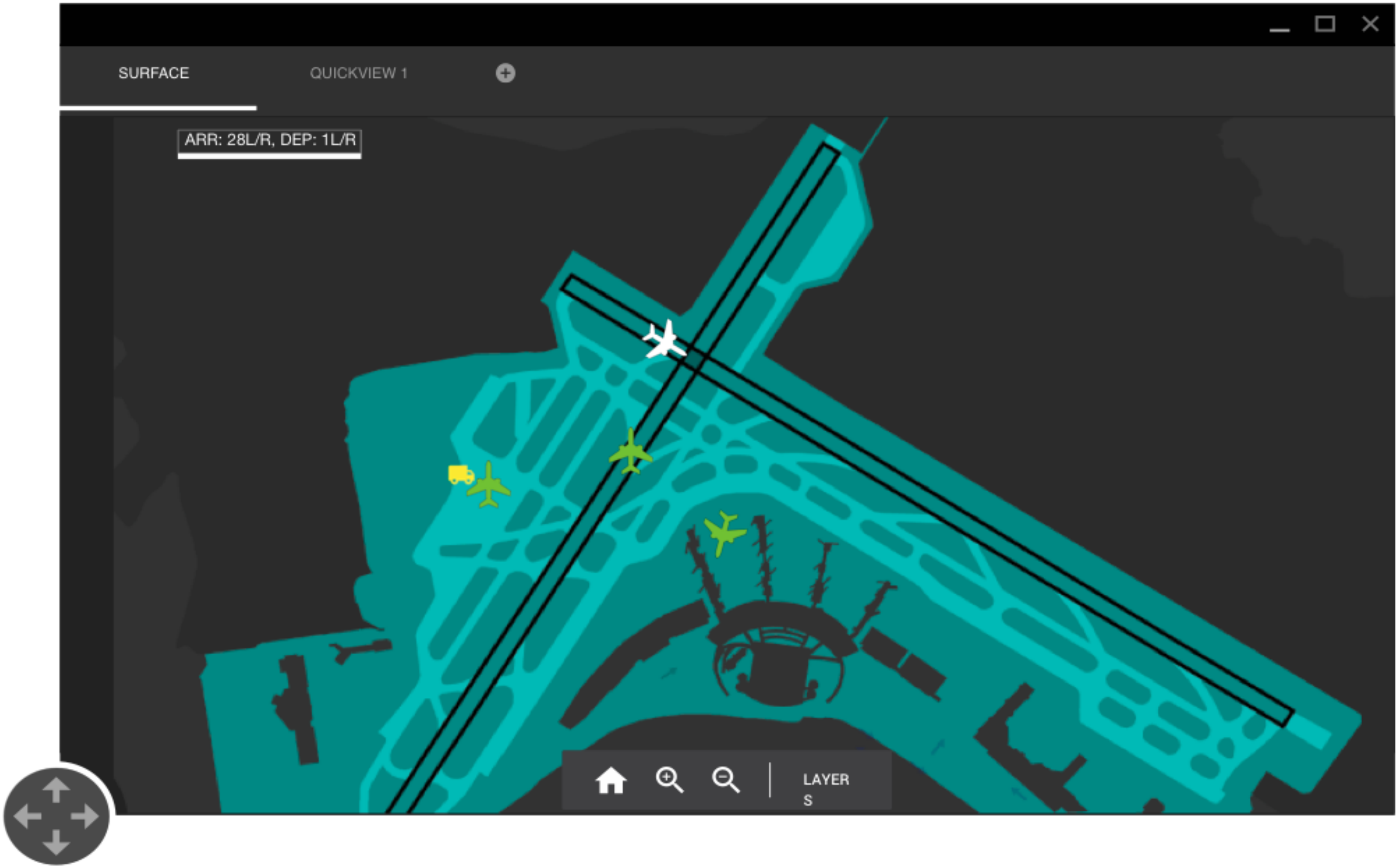
# FACT Design


FULL MAP VIEW
QUICKVIEW 1
SURFACE
QUICKVIEW 1
DENVER RUNWAY LEFT
WESTERN SIGMETS
SAN JOSE FLOW
SEA
PDX
SLC
SFO
SJC
LAS
LAX
SAN
PHX
DEN
MSP
MCI
STL
ORD
MDW
DTW
CLE
IND
CVG
PIT
BOS
LGA
JFK
TEB
EWR
PHL
BWI
IAD
DCA
RDU
CLT
BNA
MEM
ATL
DFW
IAH
MCO
TPA
FLL
MIA
LAYERS
LAYERS
PLANNING
CHARTS
QUICK INFO
MY QUEUE
FACT CHAT
Search
ATCSCC ADVISORIES FOR WEDNESDAY, 06-10-2015
# Control Element Date Brief Title Send Time
004 FCAA16 06/10/2015 CDM Airspace Flow Program CNX 06/10/15 00:18
003 ATL/ZTL 06/10/2015 CDM Ground Delay Program 06/10/15 00:14
002 LGA/ZNY 06/10/2015 CDM Ground Delay Program CNX 06/10/15 00:13
001 DCC 06/10/2015 Reroute Cancellation 06/10/15 00:05
ATCSCC ADVISORIES FOR WEDNESDAY, 06-10-2015
# Control Element Date Brief Title
161 DCC 06/09/2015 Reroute Cancellation
160 DCC 06/09/2015 ATCSCC ADVZY 160 DCC 06/09/15 Route RQD /FL Name: F LA_TO_NYMETROS
ADD QUEUE ITEM
PRINT REPORT
Search
LGA: Too many aircrafts in de-icing area.
AUTHOR: rmogford
15:30:0
MORE
RESOLVE
SHARE
DELETE
JFK: UAL 3740 stall in de-icing area. Expect a 20 min delay.
AUTHOR: dpeknik
11:18:16
SHARED WITH:
LESS
RESOLVE
SHARE
DELETE
Comments:
13:30:45
dpeknik: Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut condiment vitae ligula a rutrum. attachmen
REPLY
13:42:34
eleong: Etiam ac malesuada dolor.
13:42:34
rmogford: Nunc porta magna eu enim egestas, id mattis mi rutrum.
REPLY

# Primary Map View



# Surface Map View



# Information View

PLANNING | CHARTS | QUICKVIEW 1

Search

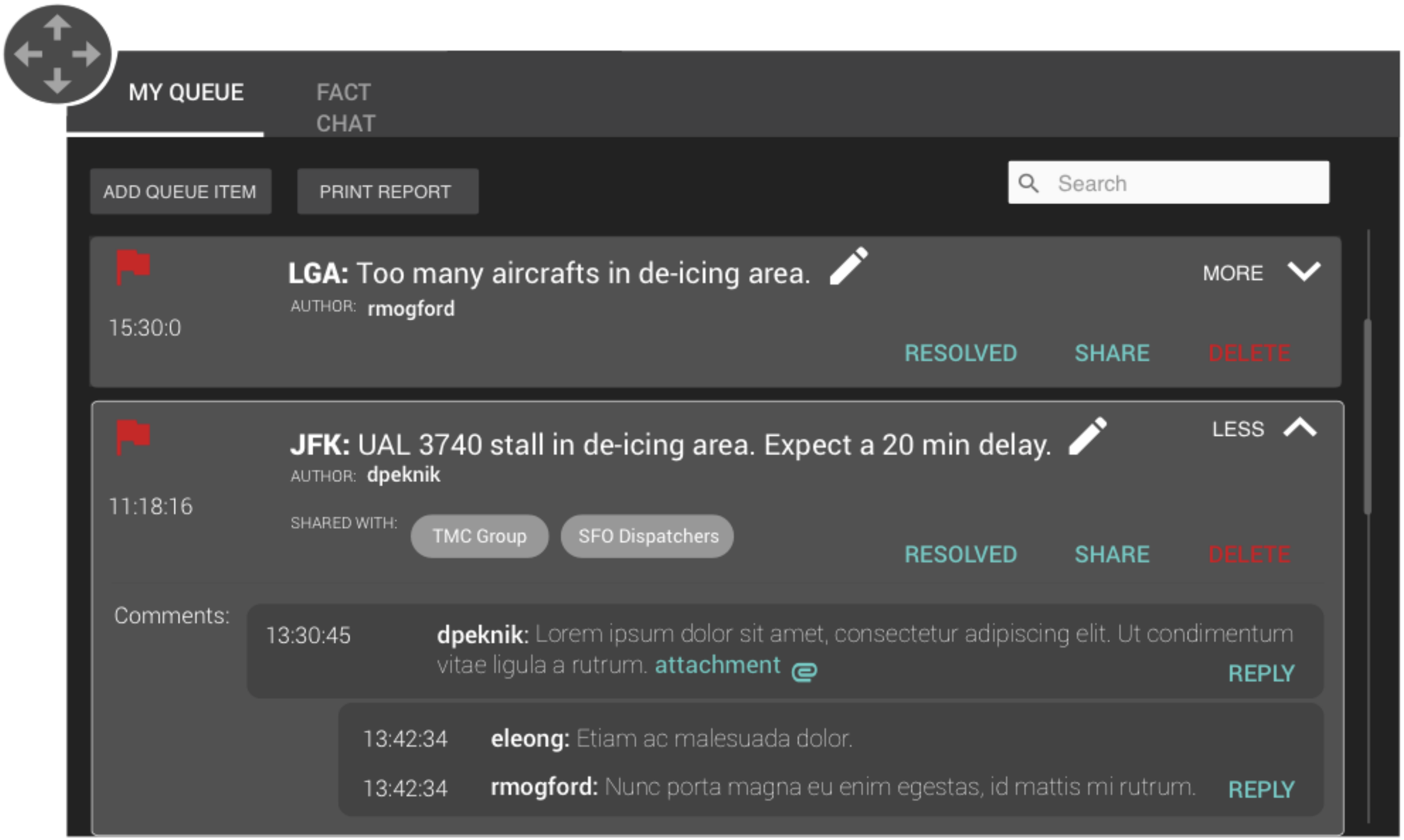
ATCSCC ADVISORIES FOR WEDNESDAY, 06-10-2015

| # | Control Element | Date | Brief Title | Send Time |
|---|---|---|---|---|
| 004 | FCAA16 | 06/10/2015 | CDM Airspace Flow Program CNX | 06/10/15 00:18 |
| 003 | ATL/ZTL | 06/10/2015 | CDM Ground Delay Program | 06/10/15 00:14 |
| 002 | LGA/ZNY | 06/10/2015 | CDM Ground Delay Program CNX | 06/10/15 00:13 |
| 001 | DCC | 06/10/2015 | Reroute Cancellation | 06/10/15 00:05 |

ATCSCC ADVISORIES FOR WEDNESDAY, 06-10-2015

| # | Control Element | Date | Brief Title |
|---|---|---|---|
| 161 | DCC | 06/09/2015 | Reroute Cancellation |
| 160 | DCC | 06/09/2015 | ATCSCC ADVZY 160 DCC 06/09/15 Route RQD /FL<br>Name: FLA_TO_NYMETROS<br>Constrained area: ZJX/ZMA |

# Communication View



# FACT Progress

- Web-based prototype will be completed in July 2016
- Plan to demonstrate FACT to airlines and airports to seek feedback
- Will make modifications and improvements
- Basic FACT platform will be used to host automation tools (e.g., predicting airport capacity)
- Developing AOC simulator at NASA Ames

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

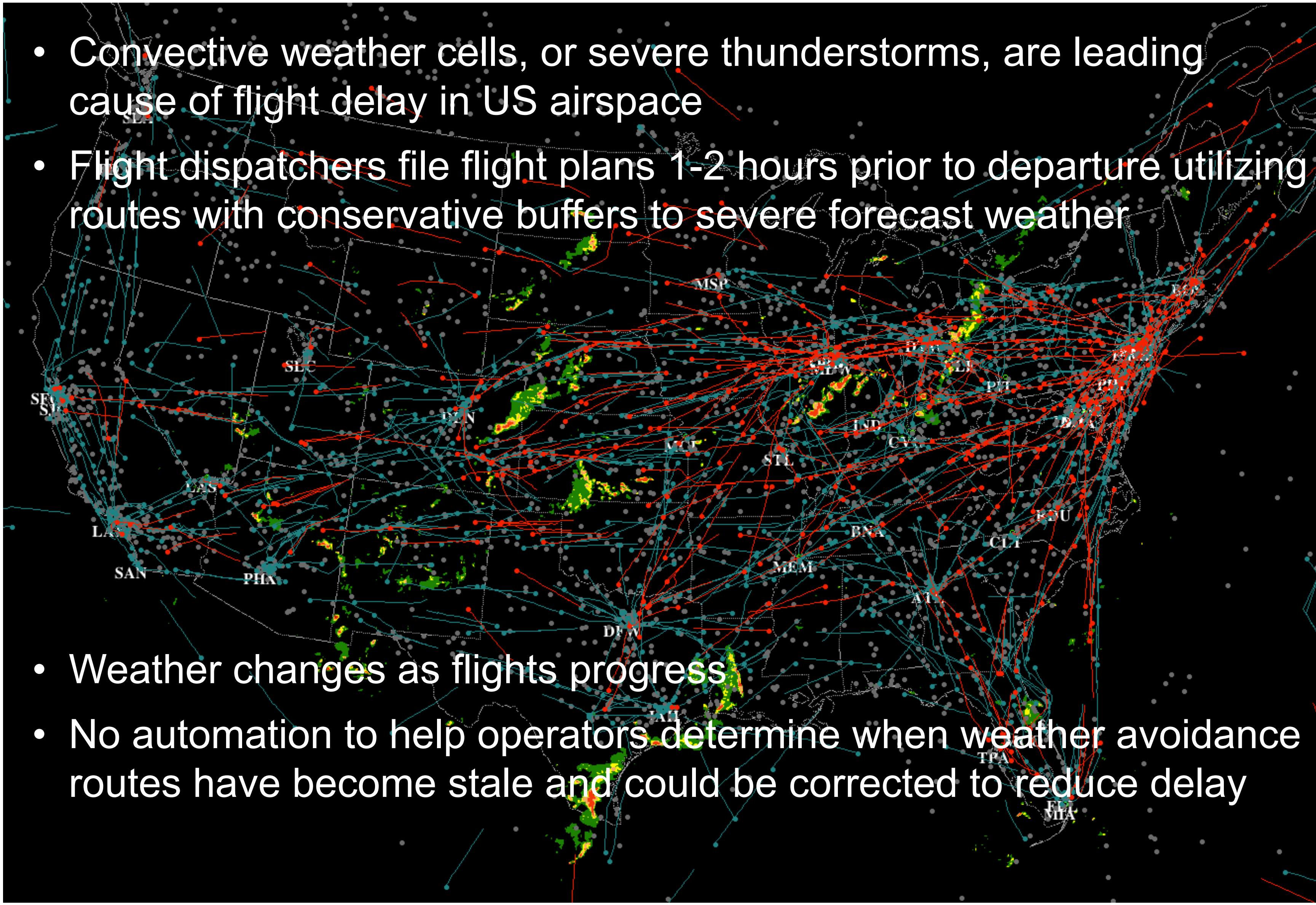
Dave McNally, Kapil Sheth, and Chester Gong
*NASA Ames Research Center*
*Moffett Field, California*

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

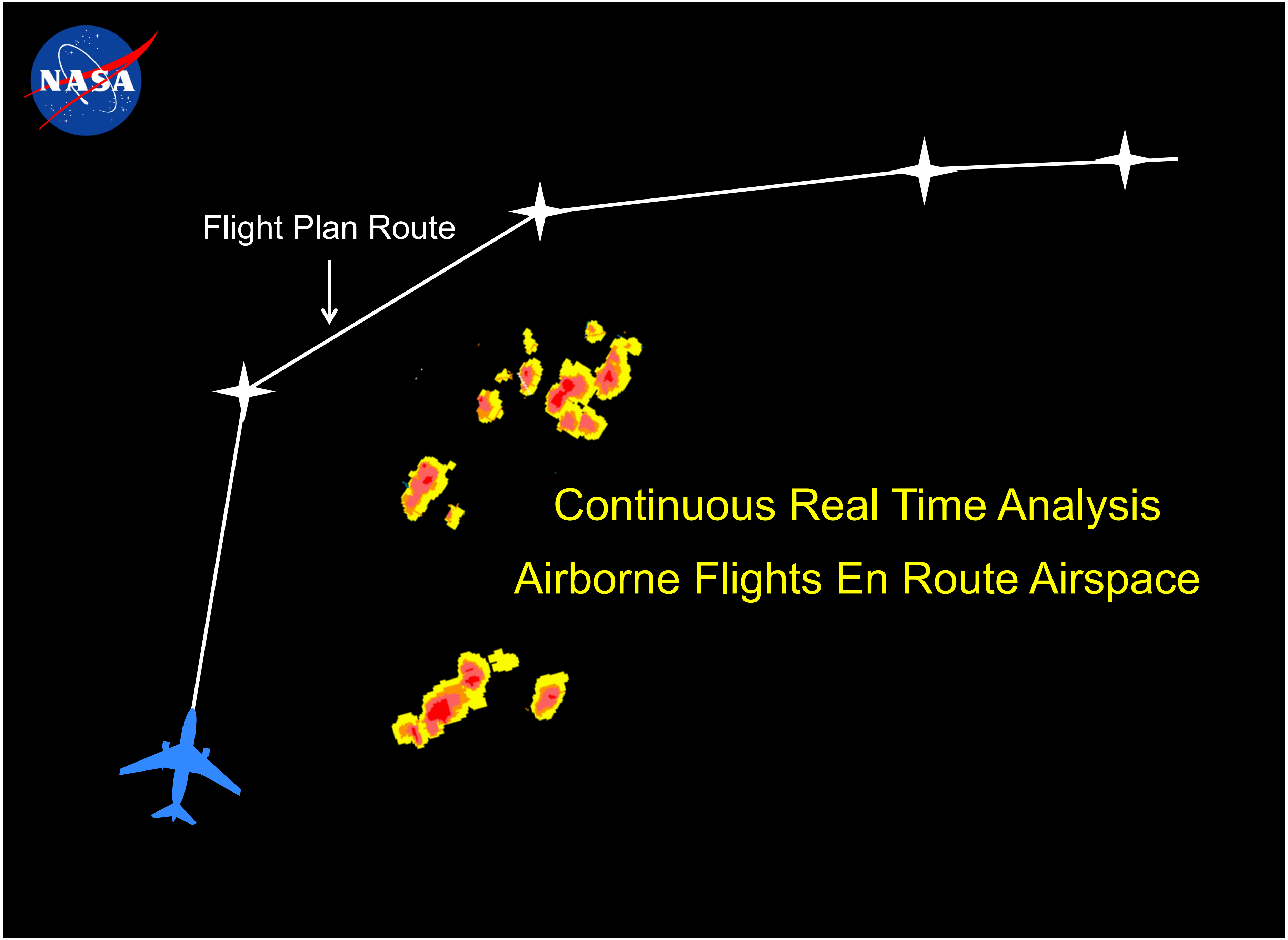
Scott Sahlman, Susan Hinton, Chuhan Lee
*University of California, Santa Cruz*
*Moffett Field, California*

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

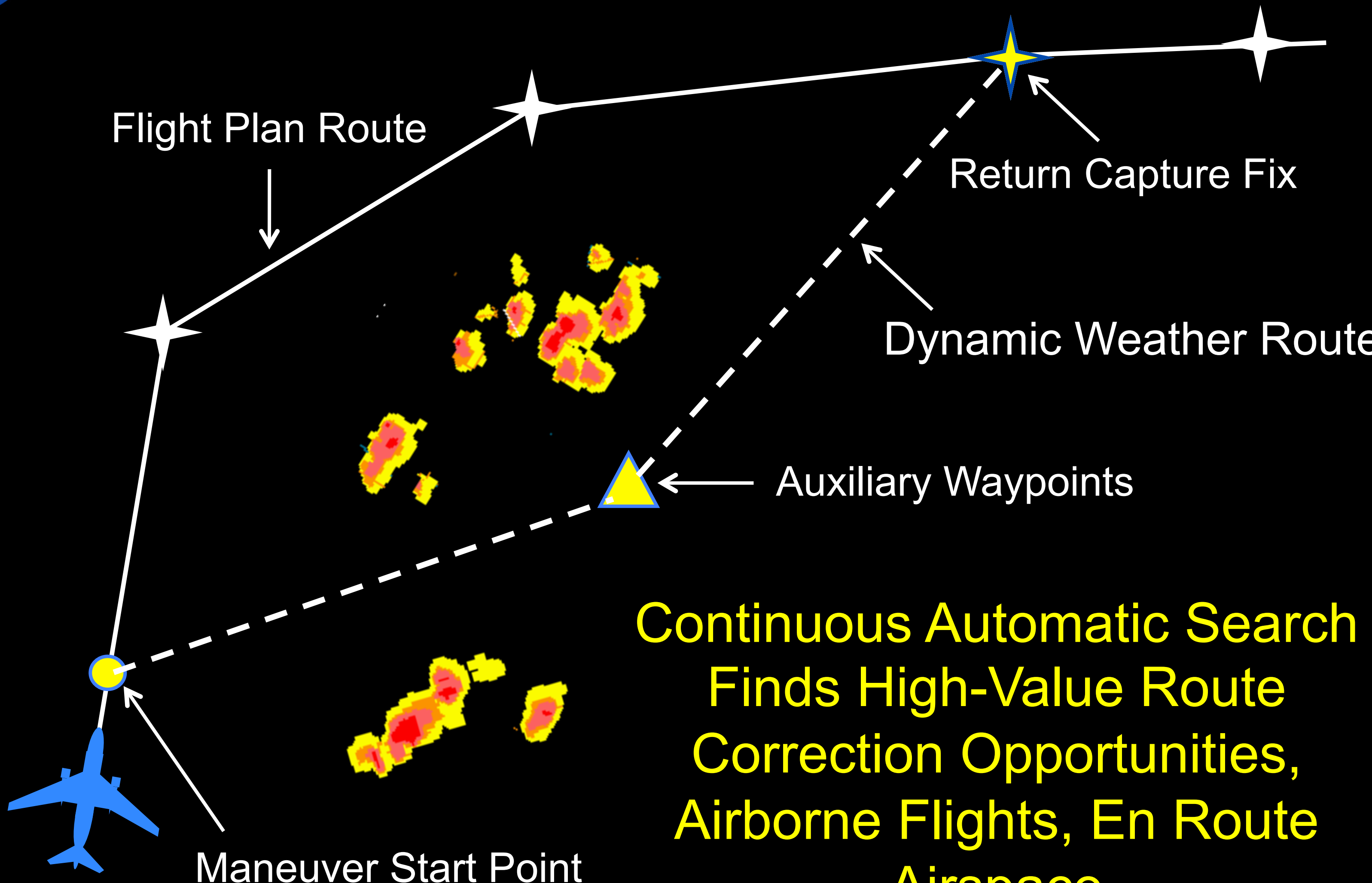
# What's the Problem?




- 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

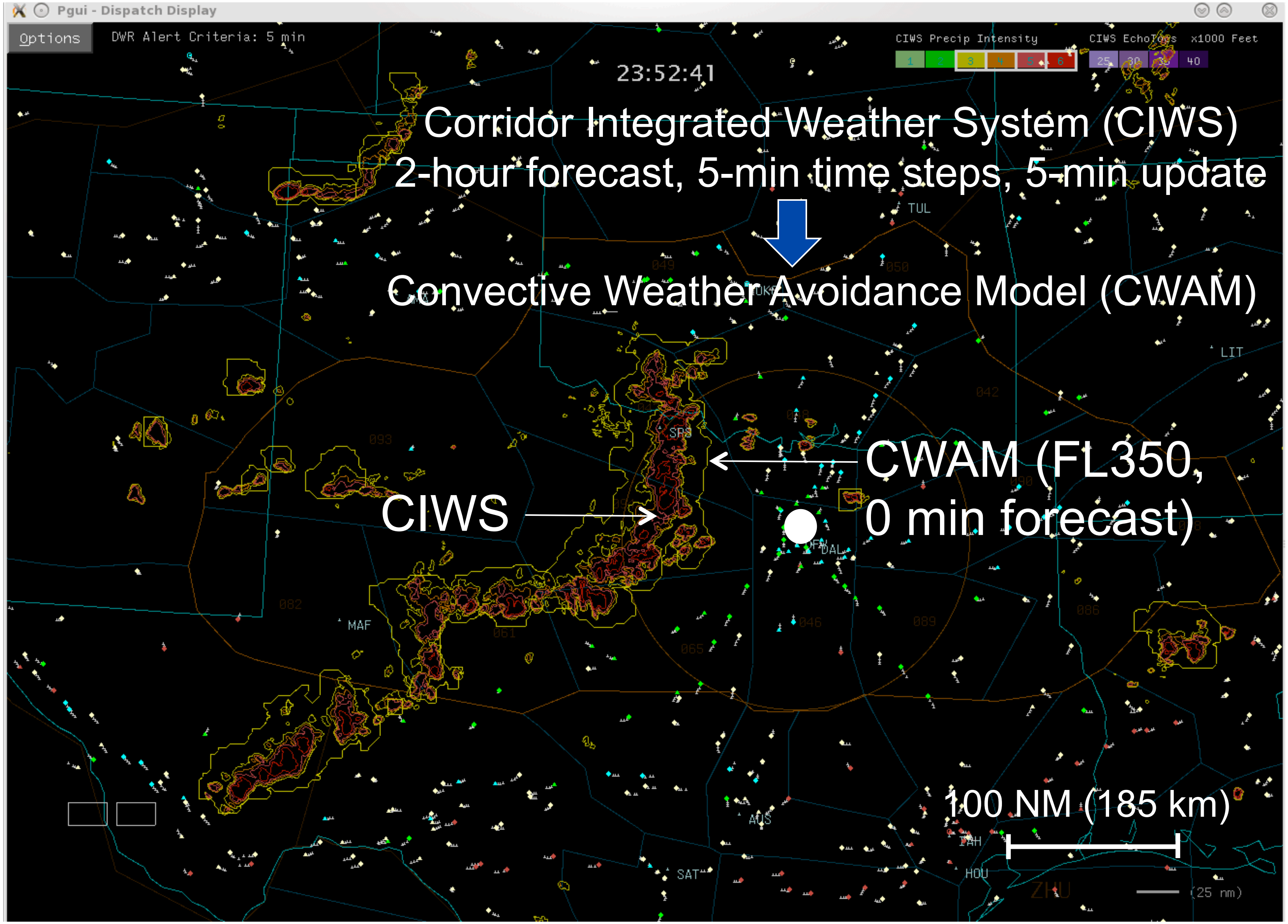

Flight Plan Route
Continuous Real Time Analysis
Airborne Flights En Route Airspace

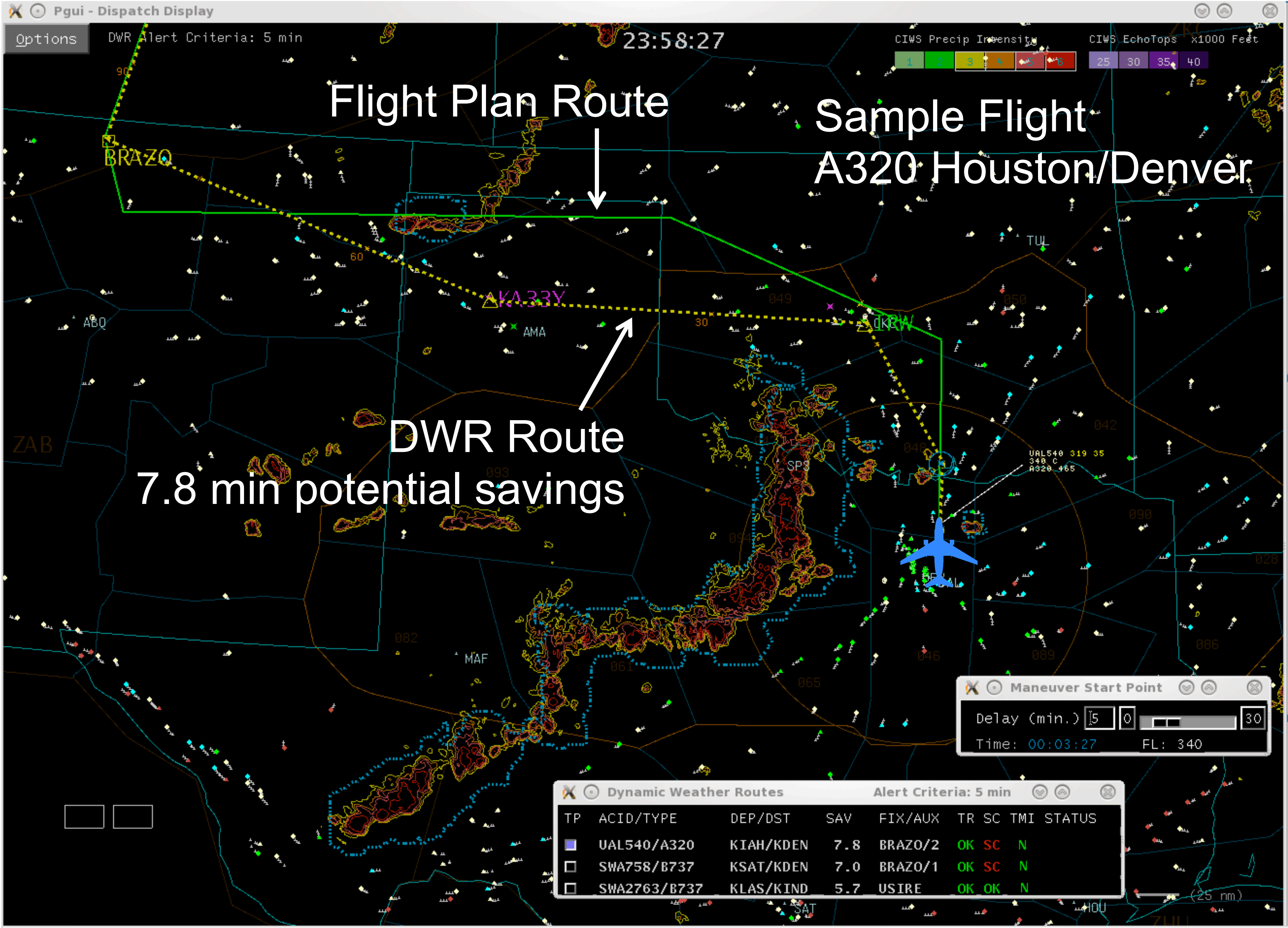
# Dynamic Weather Routes (DWR)



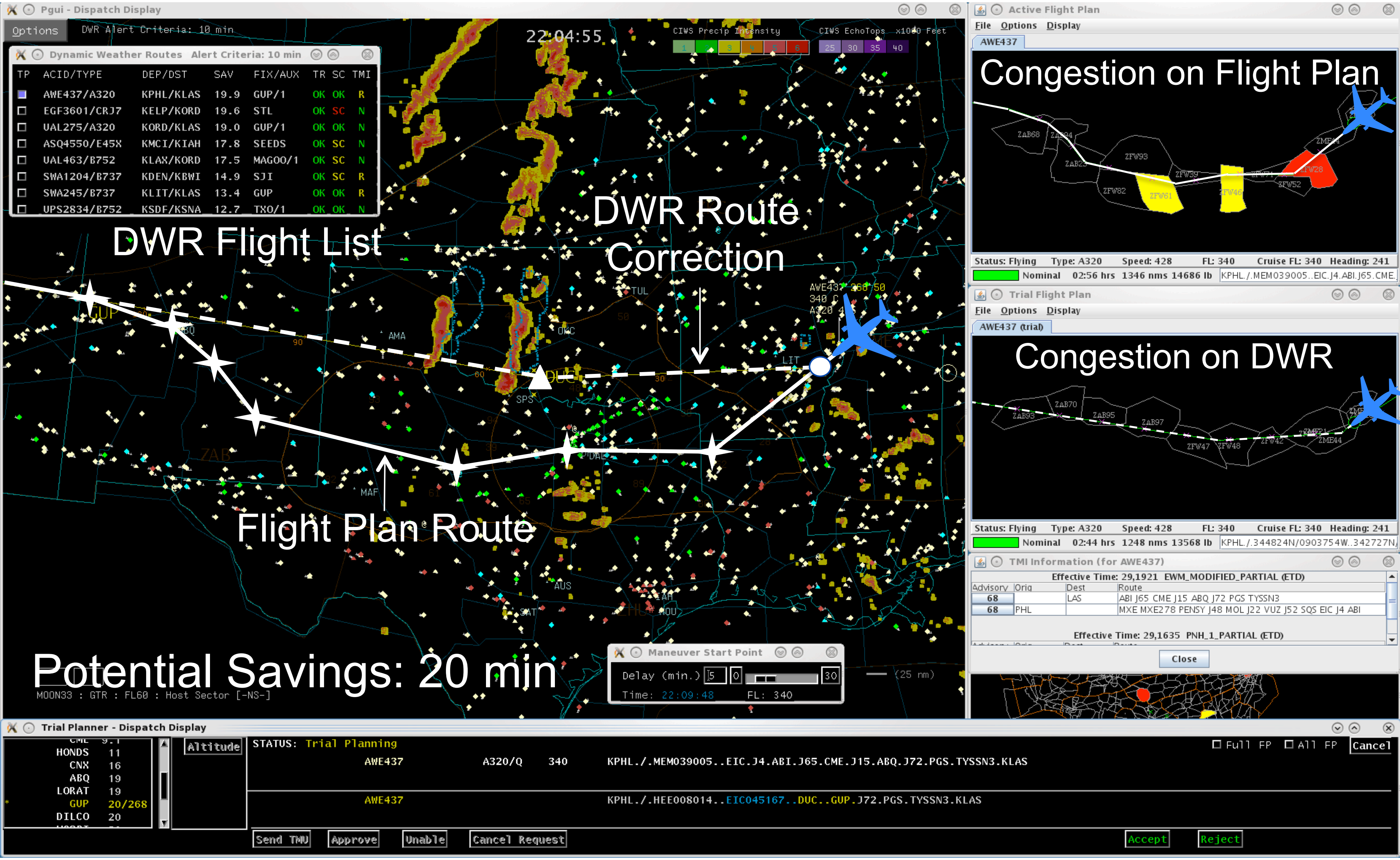

Continuous Automatic Search Finds High-Value Route Correction Opportunities, Airborne Flights, En Route Airspace

# Weather Model



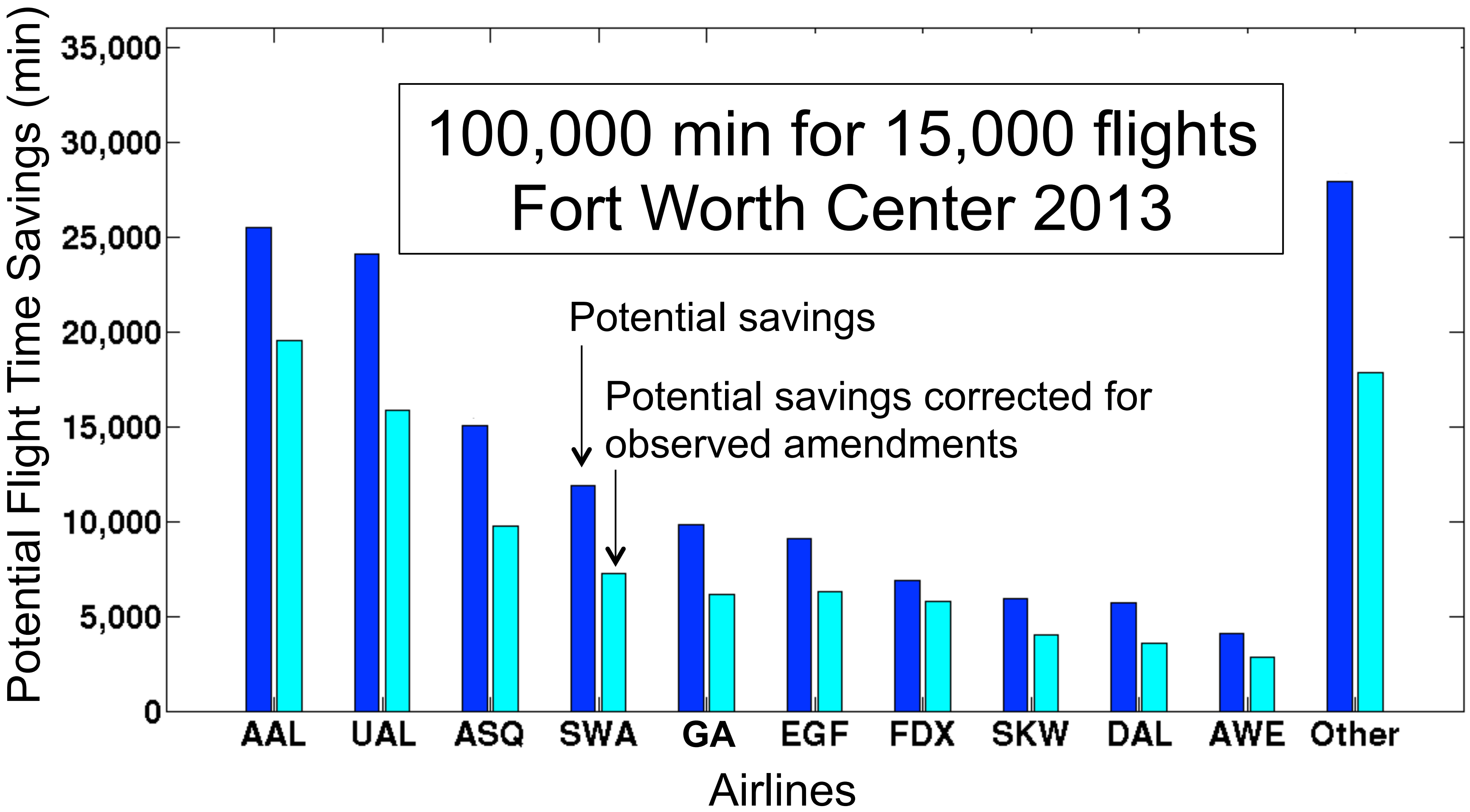

Pgui - Dispatch Display
Options
DWR Alert Criteria: 5 min
23:58:27
CIWS Precip Intensity
CIWS EchoTops x1000 Feet
Flight Plan Route
Sample Flight
A320 Houston/Denver
BRAZO
KA33Y
AMA
ABQ
TUL
DWR Route
7.8 min potential savings
ZAB
MAF
SPS
UAL540 319 35
340 C
A320 465
Maneuver Start Point
Delay (min.) 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

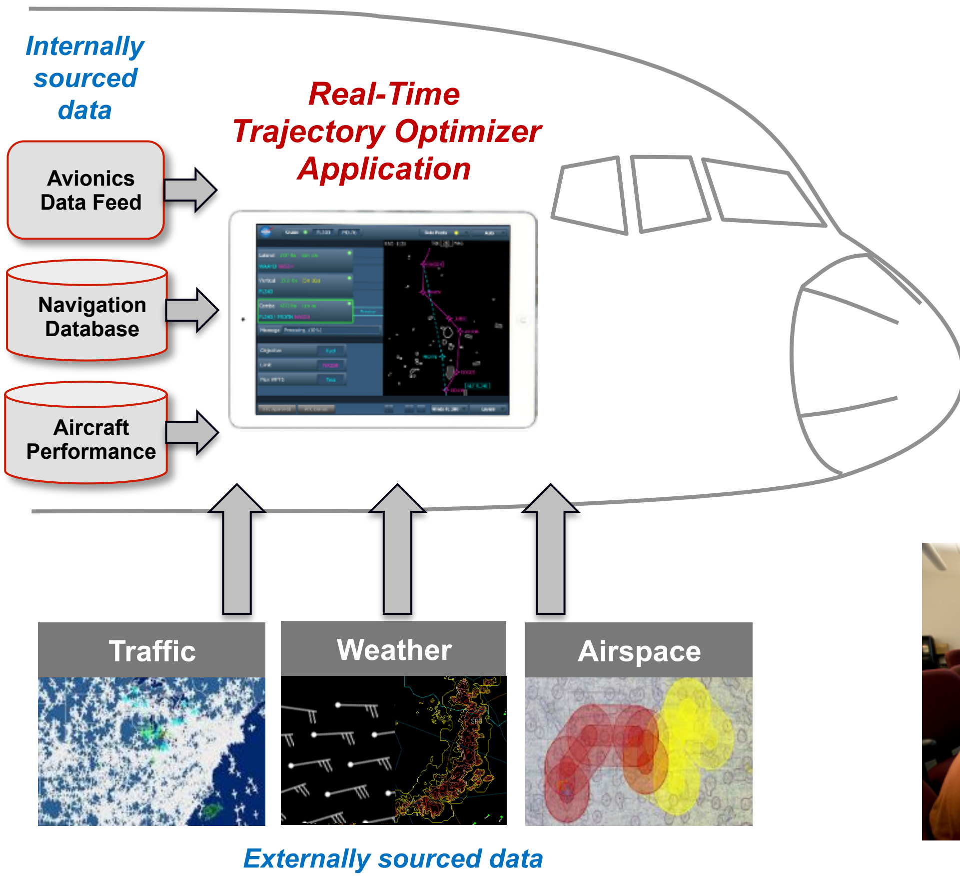


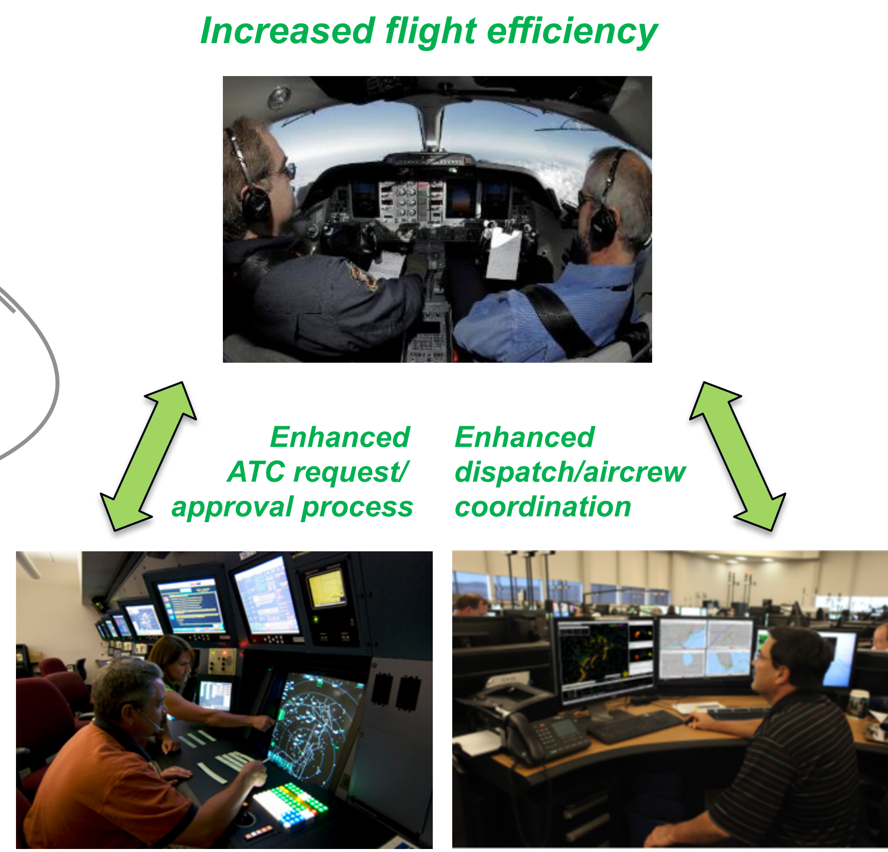
# *TASAR - NASA Flight Deck Application for En Route Flight Optimization*

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

# *"Traffic Aware Strategic Aircrew Requests"*

**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)

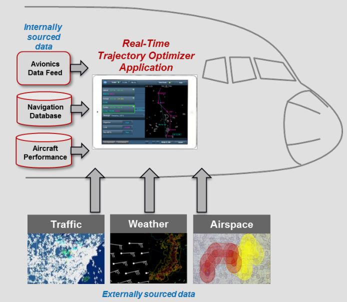
## Flight-Efficiency EFB Application ("Type B")

**Connected to avionics via standard interfaces**

*Ownship flight data, ADS-B traffic data*

**Connected to external data sources via internet**

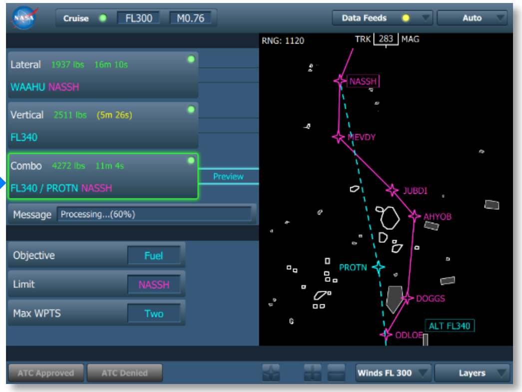
*Latest winds, weather, airspace status, etc.*




## 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: lateral, vertical, combo
- Computes time & fuel outcomes of each solution
- Displays solutions and outcomes to the pilots for selection and ATC request

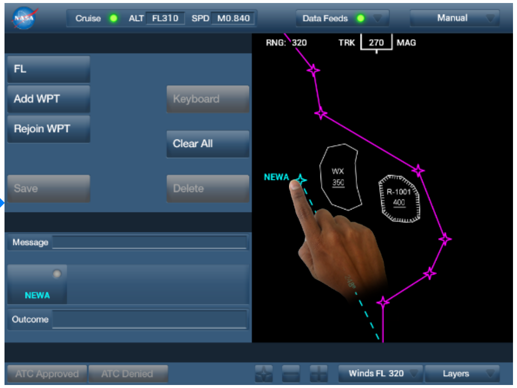
Auto Mode



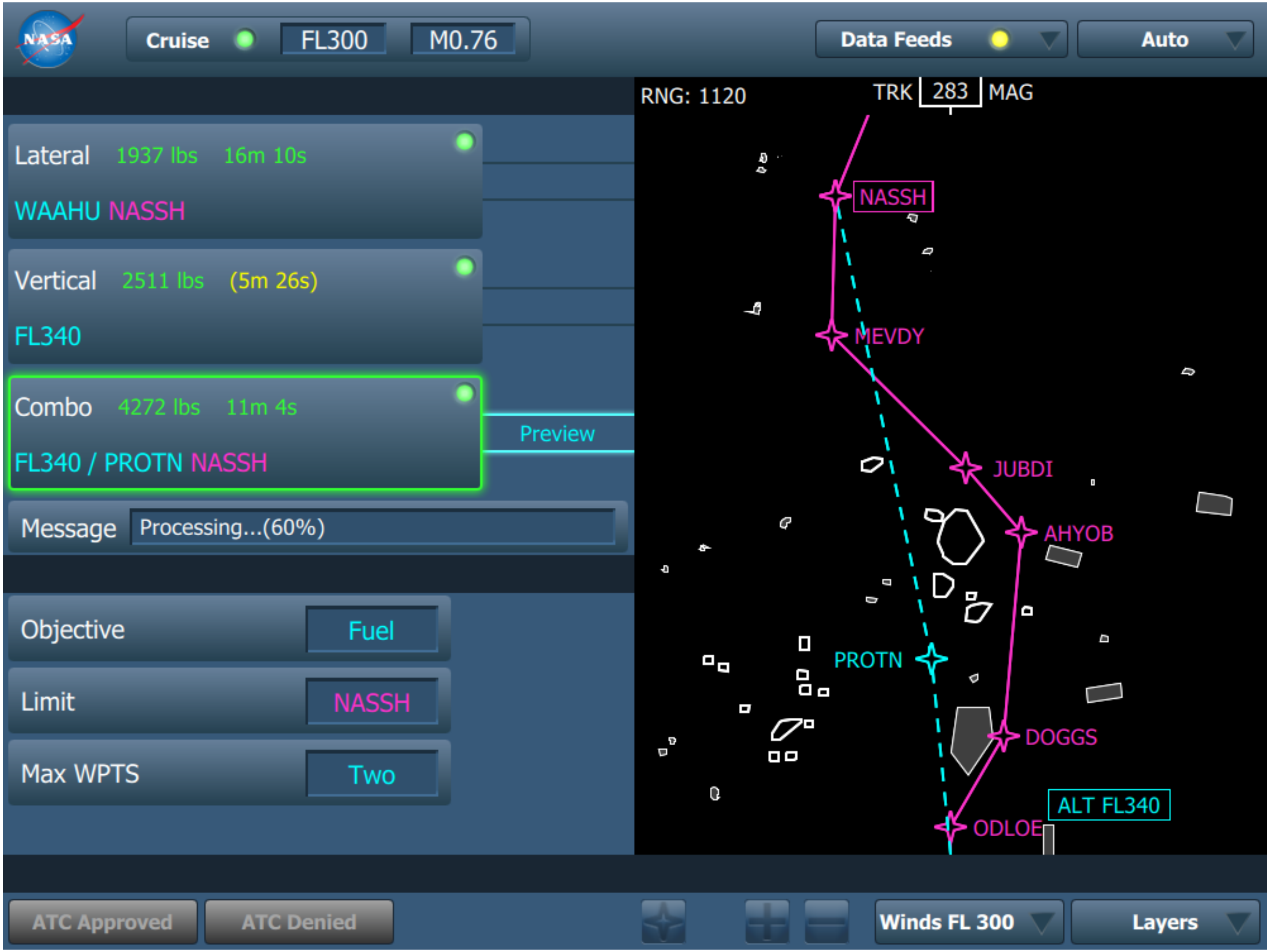

## Analyzes pilot-entered route/alt changes

- 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

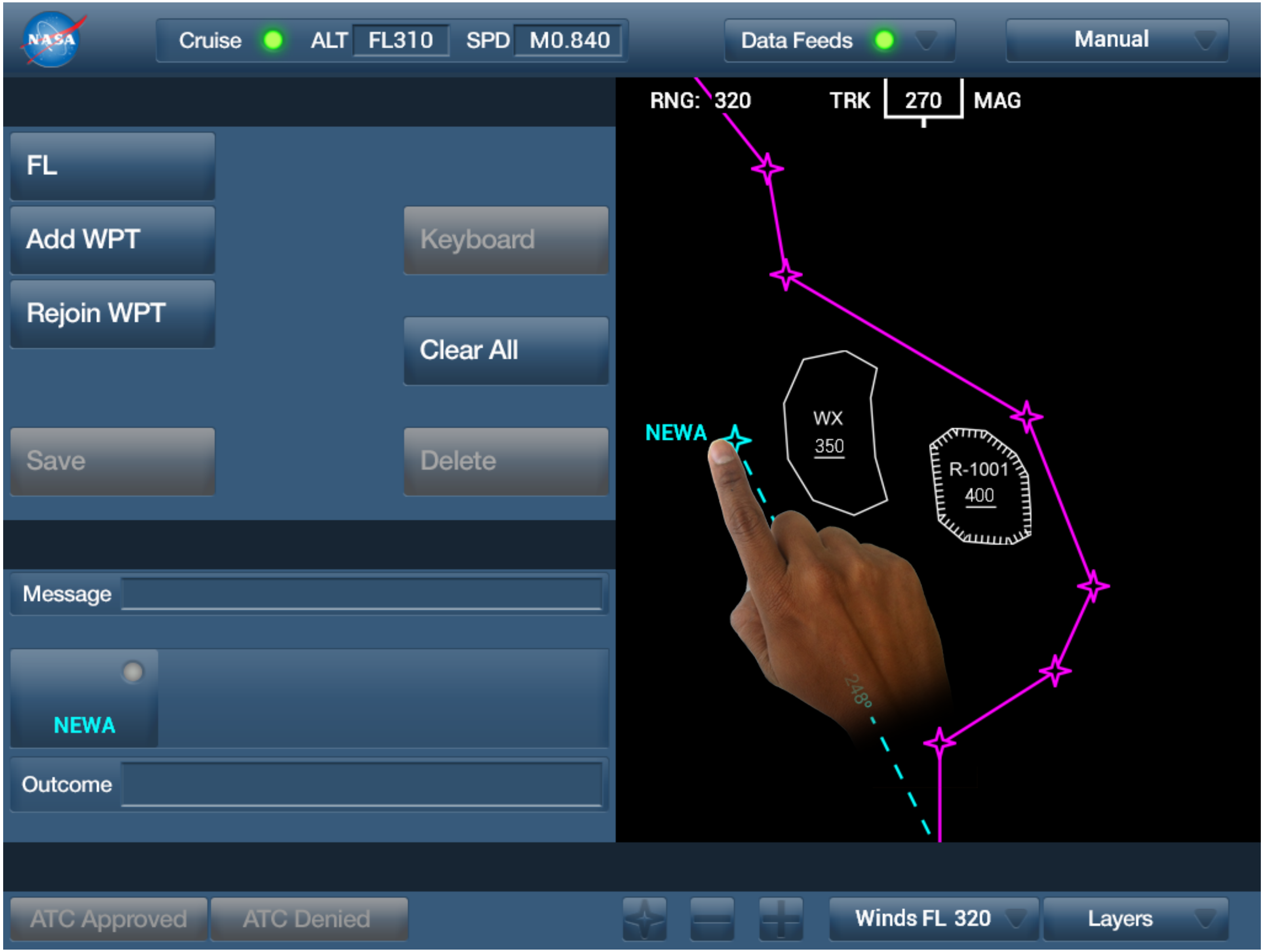
Manual Mode



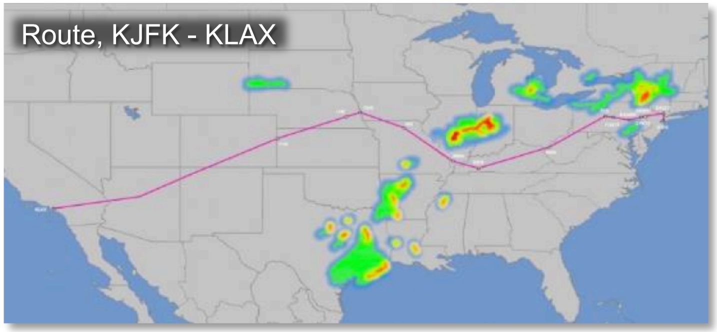
# TAP Auto Mode



# *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*

<u>Objectives</u>

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

***<u>Results</u>***

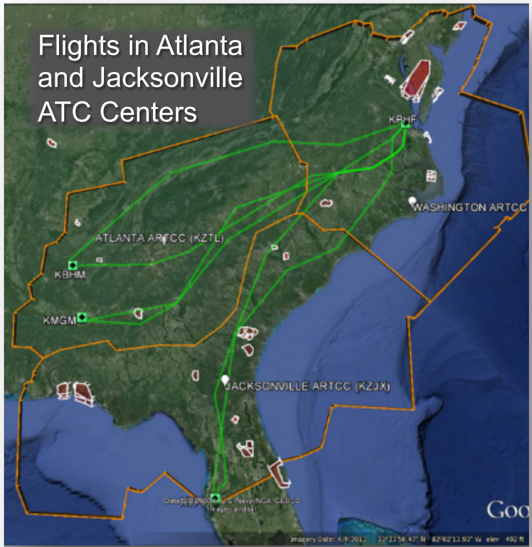
1. ***No effect on pilot workload compared to standard flight-deck baseline condition***
2. ***Non-normal event response not adversely affected***
3. ***TAP useful, understandable, intuitive, easy to use***
4. ***Standalone CBT was as effective as live instructor***

CBT: Computer based trainer
HITL: Human in the Loop
HMI: Human Machine Interface
OPL: Operator Performance Lab, Univ. of Iowa

# *TASAR Flight Trials*

*Nov 2013, Jun 2015*




- *54 hours, 21 flights, 17 evaluation pilots*
- *DC, NY, Boston, Atlanta, Jax Centers*
- *ATC observations, 50 interviews w/ ATC*
- *Alaska Airline's EFB & ADS-B hardware*
- *Broadband connection to NOAA winds, FAA SUA 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*

## ***Results***

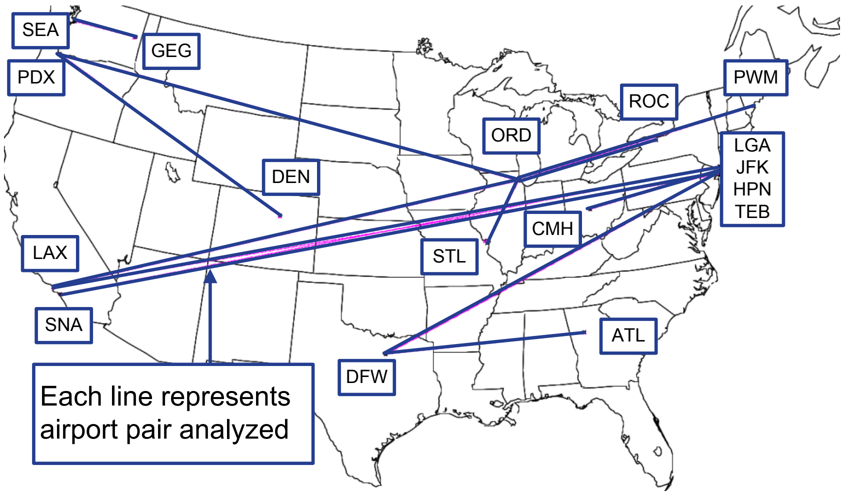
1. ***TAP processed live avionics, ADS-B, and internet data, and functioned properly***
2. ***Pilots rated HMI usability high; workload low***
3. ***ATC provided extensive feedback on user request acceptability factors; found most TASAR requests acceptable***
4. ***Airline deployment risk areas reduced: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



**Reference AIAA-2014-2166**

# Preliminary TASAR Benefits Estimate

**All Airspace User Classes are Projected to Benefit**




**Mean savings per flight**

| Class of Airspace User | Optimization Objective | | | | | |
|---|---|---|---|---|---|---|
| | (1) Save Time | | (2) Save Fuel | | (3) 50/50 Weighted | |
| | ΔT | ΔF | ΔT | ΔF | ΔT | ΔF |
| Network | **4.2** | -122 | 3.4 | **575** | 3.6 | 543 |
| Low Cost | **2.9** | -123 | 2.5 | **406** | 2.6 | 344 |
| Regional | **1.0** | -88 | 0.8 | **137** | 1.0 | 66 |
| Business | **1.2** | -22 | 1.6 | **64** | 1.5 | 53 |

**ΔT: Time savings (minutes) ΔF: Fuel savings (pounds)**

Fast-time simulation study (2012)

- Historical trajectories between 12 representative airport pairs analyzed
- 510 flights between July 11-20, 2012
- 300-2000 TASAR-like alternative trajectories evaluated for each flight
  - At five minute intervals
- Convective weather on East Coast, Midwest

Conservative measures applied

- No requests during initial climb
- No requests with conflicts
- One request per sector
- No requests near handoff
- No requests within 200 nmi of destination

Three flight optimization objectives studied

- (1) Save Time, (2) Save Fuel, and (3) 50/50 Weighted



Reference AIAA-2012-5684

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)

*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:*

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 | |

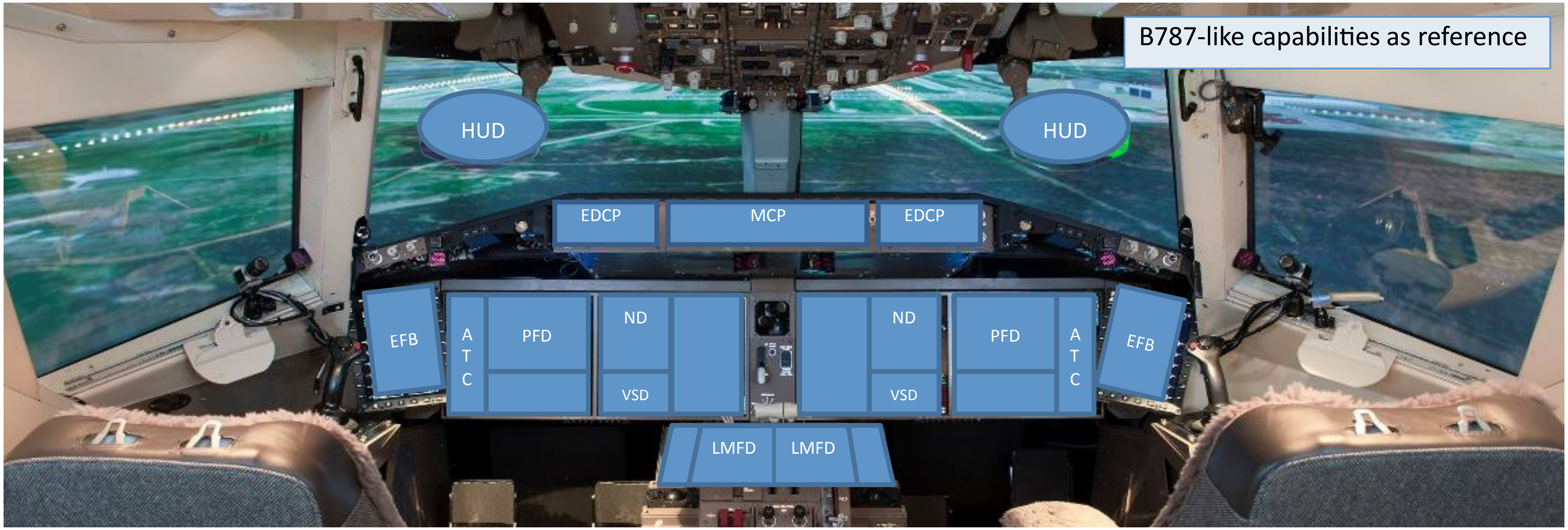
| | | |
|---|---|---|
| Virtual Day-VMC Displays (SE-200) | Attitude & Energy State Techs (SE-207) | Systems State Technologies (SE-208) |
| Simulator Fidelity (SE-209) | Flight Crew Performance (SE-210) | Training for Attention Management (SE-211) |

Desired Outputs

# SE-207/208 Research Team

# Scope

*Automation and Information Management Experiment (AIME)*



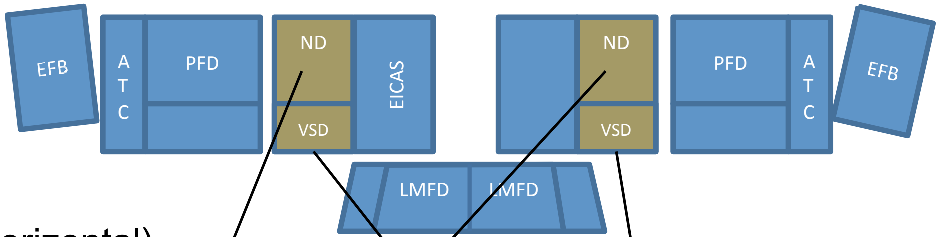

- CAST Implementation Plan: "Systems that predict the aircraft energy state and/or autoflight configuration if the current course of action is continued and provide appropriate alerting" (SE-207, Output 3)
- CAST Implementation Plan: "Displays that present the future expected state of automated systems in an intuitive manner; providing info on both the mode currently selected and impending mode transitions expected per design" (SE-208, Output 1(a))
- CAST Implementation Plan: "Displays that show, in a simple, integrated manner (e.g, a synoptic), the flight-critical data systems in use by automated systems and primary flight instruments, for both the mode currently selected and impending mode transitions expected per design" (SE-208, Output 1(b))


http://www.skybrary.aero/bookshelf/books/2999.pdf
http://www.skybrary.aero/bookshelf/books/3000.pdf

# AIME Objectives

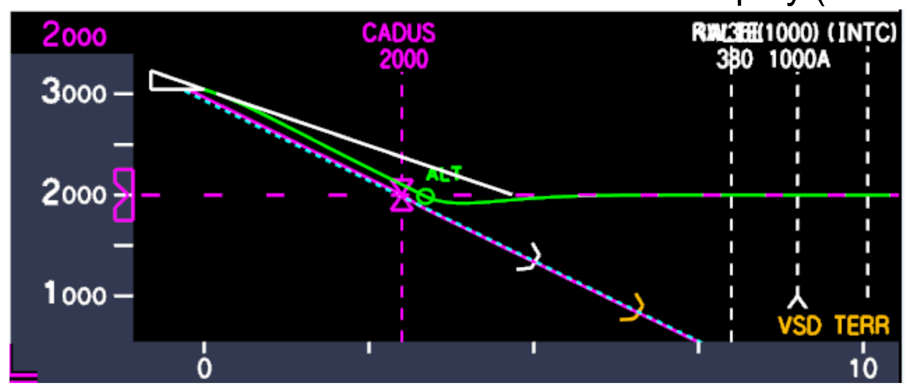
- Development and Demonstration
  - Raise the TRL for new technology via testing and demo in a high-fidelity flight sim environment (e.g. confirm performance across span of targeted conditions)
  - Collect data for V&V of a design model that can be used off-line for analyzing uncertainty effects on system performance (e.g. Monte Carlo sims)
- Achieve Project Milestone (ATD.TASA.SAPT.3)
  - Evaluate the usability and acceptability of new technology concepts
  - Is project on correct path, or need a change of direction?
- Discovery ("learn by doing")
  - Design characteristics requiring refinement for future studies
  - Unknown unknowns related to state awareness and prediction
- Advance test infrastructure capability for future experiments
  - Evaluate the use of the eye-tracking system and physio measurement system for potential to validate design effectiveness, and to detect attention issues
  - Establish confidence in test platform performance given new modifications
  - Identify gaps and capabilities to be improved for subsequent studies

# Trajectory & Mode Change Prediction*




Navigation Display (horizontal)


Vertical Situation Display (vertical)

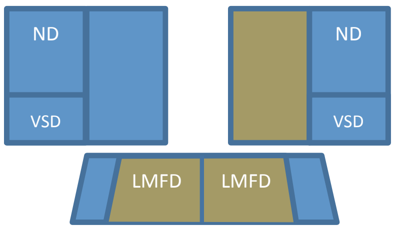



*K. Shish, et. al., "Trajectory Prediction and Alerting for Aircraft Mode and Energy State Awareness," AIAA 2015-1113, Jan 2015 (Best Paper of Conference Award)

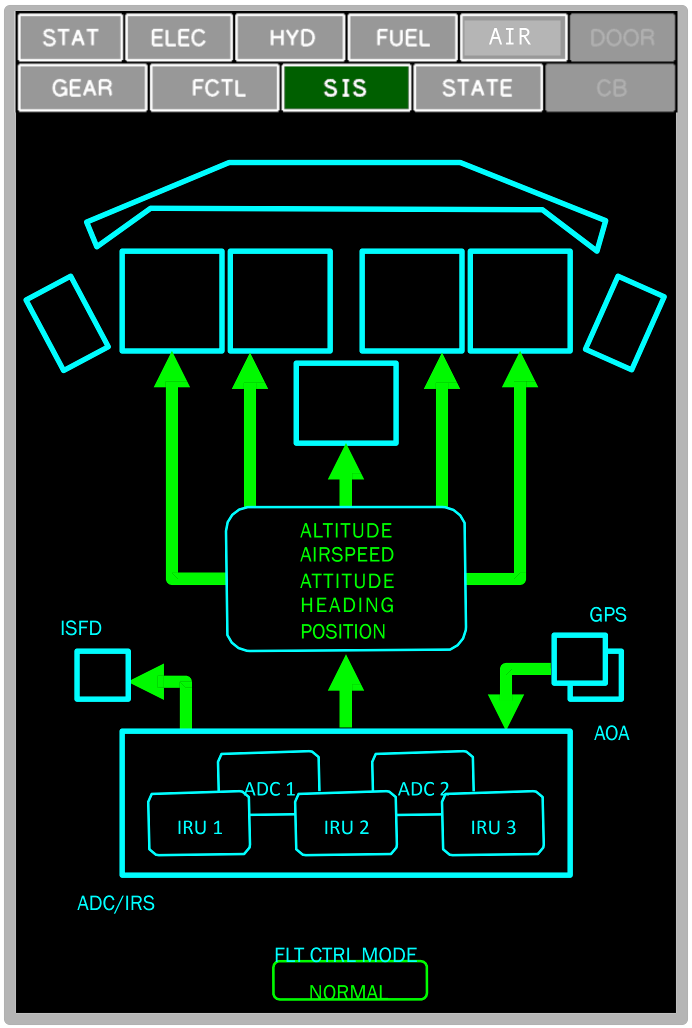
1. "Green Line" – represents where the automation will take the aircraft if no intervention by the pilot, and no unexpected conditions are encountered.
2. Circle symbol and label – indicates (1) where a mode switch is predicted and what the new mode will be; or (2) where an energy-related problem is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

# System Interaction Synoptic

Normal

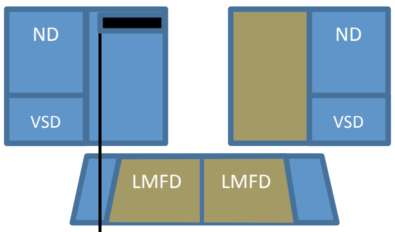



Available on any of these display spaces




1. *Mode control panel*
2. *Display panels*
3. *Flight-critical information*
4. *Flight-critical data systems*
5. *:ISFD – standby instrument*
   *:Flight control mode*

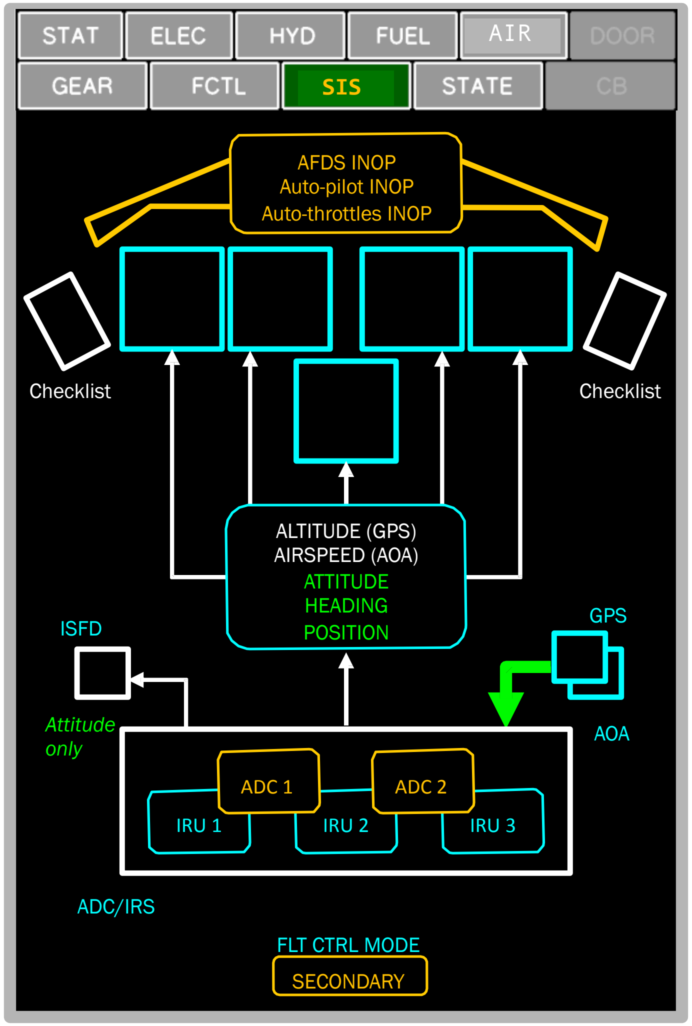
# System Interaction Synoptic




Available on any of these display spaces

**EICAS Msg:**

❑ NAV AIR DATA SYS




Non-normal

(example)

6

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 (RFD) 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 thru 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)

# Airline Operations Workshop

- To be held at NASA Ames
  - August 2, 3, and 4
  - Registration is free
- Objectives:
  - Present NASA research that supports airline operations
  - Learn about industry innovations
  - Gather recommendations from industry for future NASA work
- Information
  - http://hsi.arc.nasa.gov/workshop/aow/index.php
  - arc-aow@mail.nasa.gov