



# 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](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

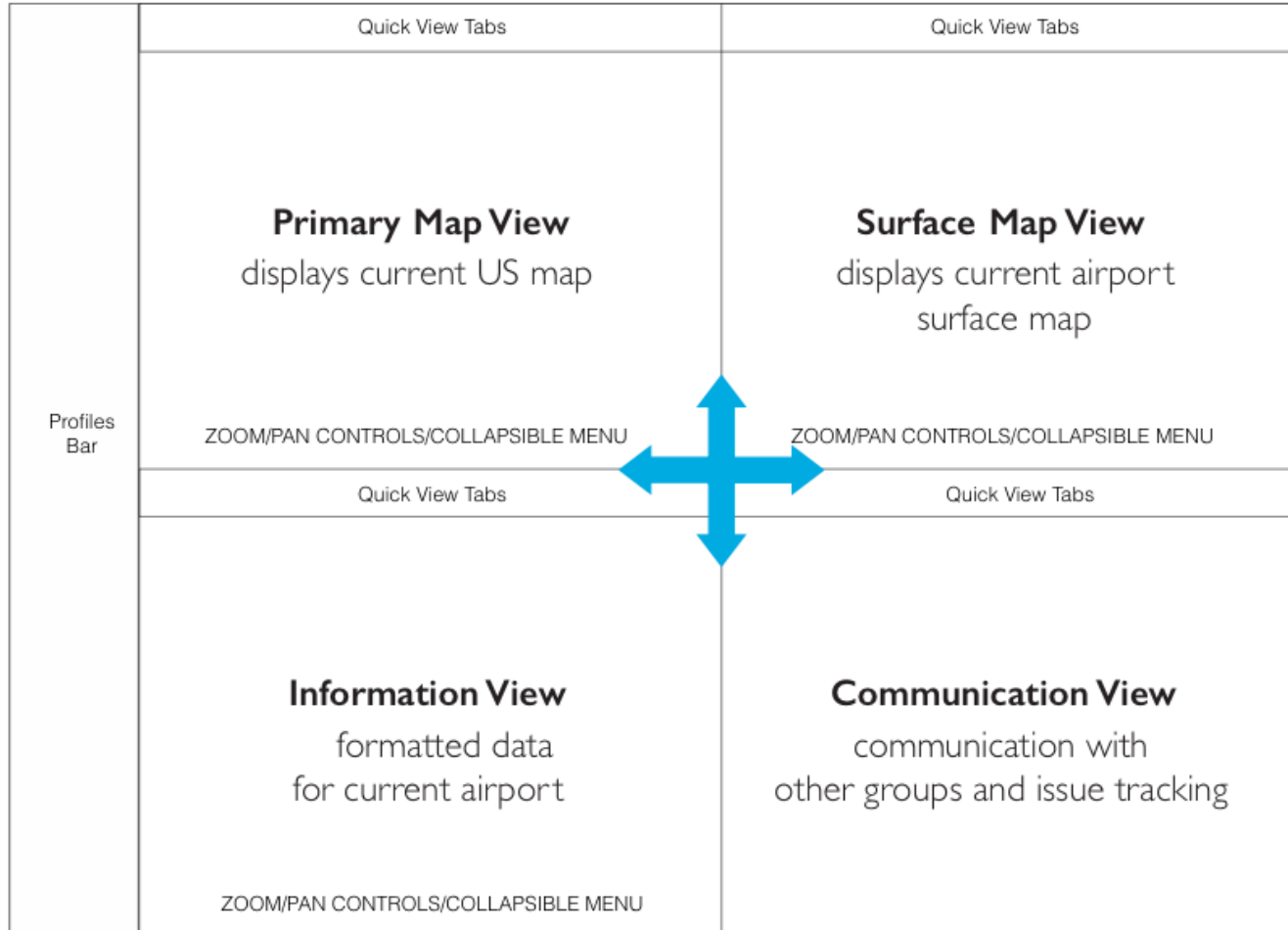
# Winter Weather



- 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

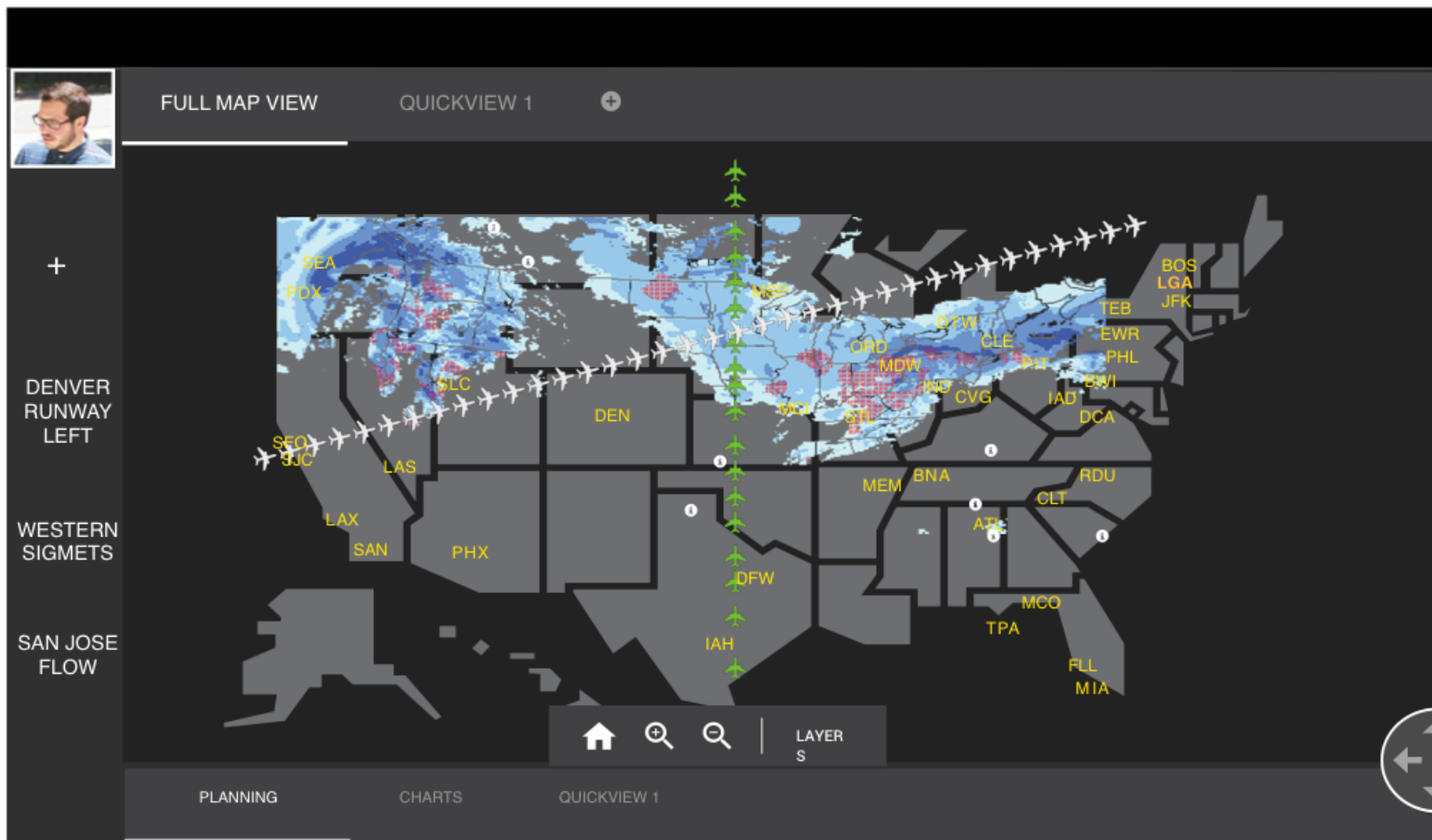


# FACT Design

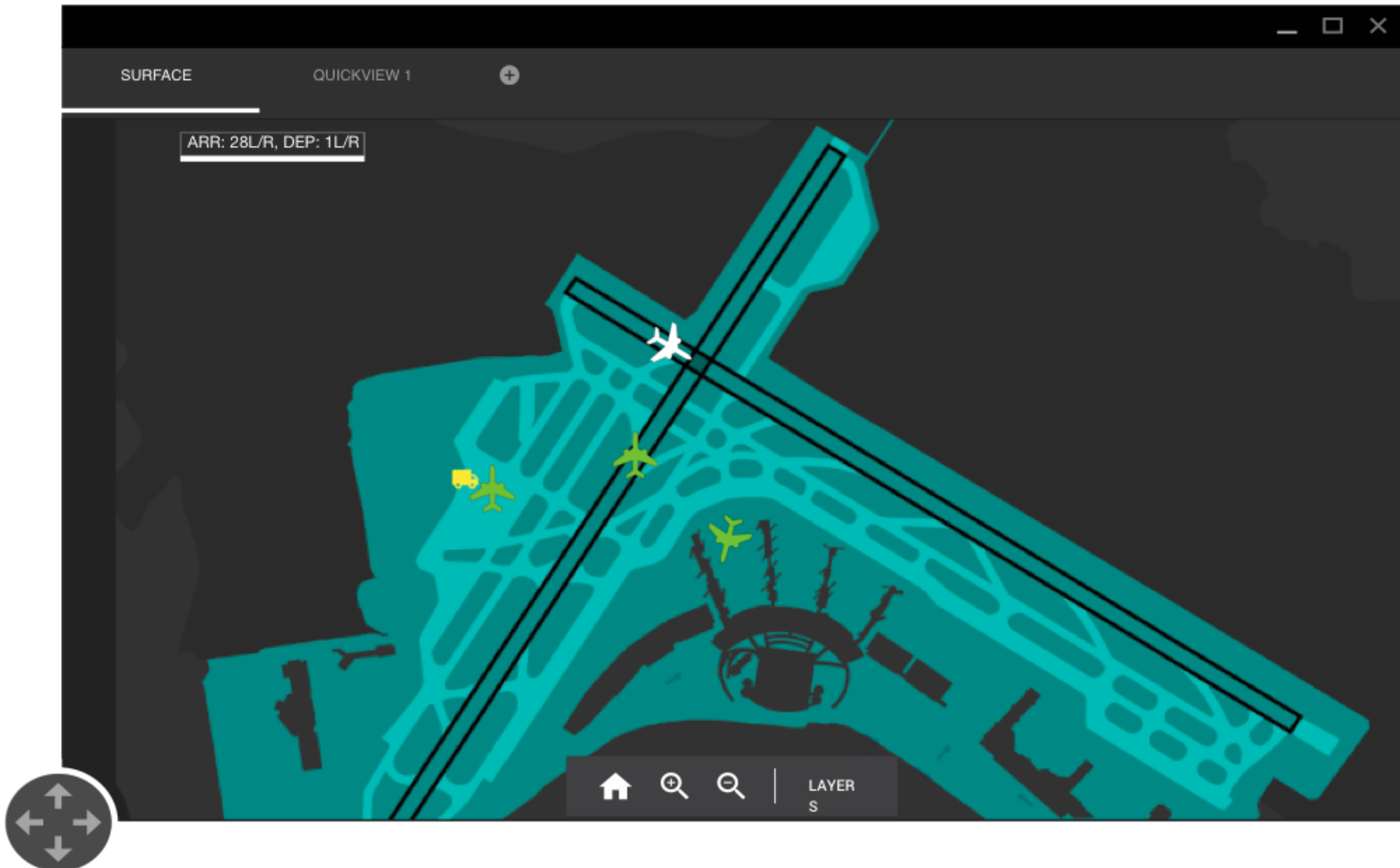




# Primary Map View



# 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 Name: FLA_TO_NYMETROS Constrained area: ZJX/ZMA

# Communication View



MY QUEUE    FACT CHAT

ADD QUEUE ITEM    PRINT REPORT    Search

**LGA:** Too many aircrafts in de-icing area. MORE

15:30:0    **AUTHOR:** rmogford

RESOLVED    SHARE    DELETE

**JFK:** UAL 3740 stall in de-icing area. Expect a 20 min delay. LESS

11:18:16    **AUTHOR:** dpeknik

SHARED WITH: TMC Group    SFO Dispatchers

RESOLVED    SHARE    DELETE

Comments:

13:30:45    **dpeknik:** Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut condimentum vitae ligula a rutrum. [attachment](#) REPLY

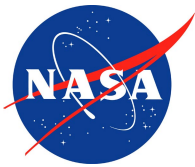
13:42:34    **eleong:** Etiam ac malesuada dolor.

13:42:34    **rmogford:** Nunc porta magna eu enim egestas, id mattis mi rutrum. REPLY

# 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

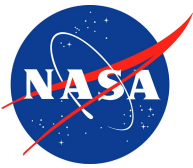
Dave McNally, Kapil Sheth, and Chester Gong  
*NASA Ames Research Center  
Moffett Field, California*

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*

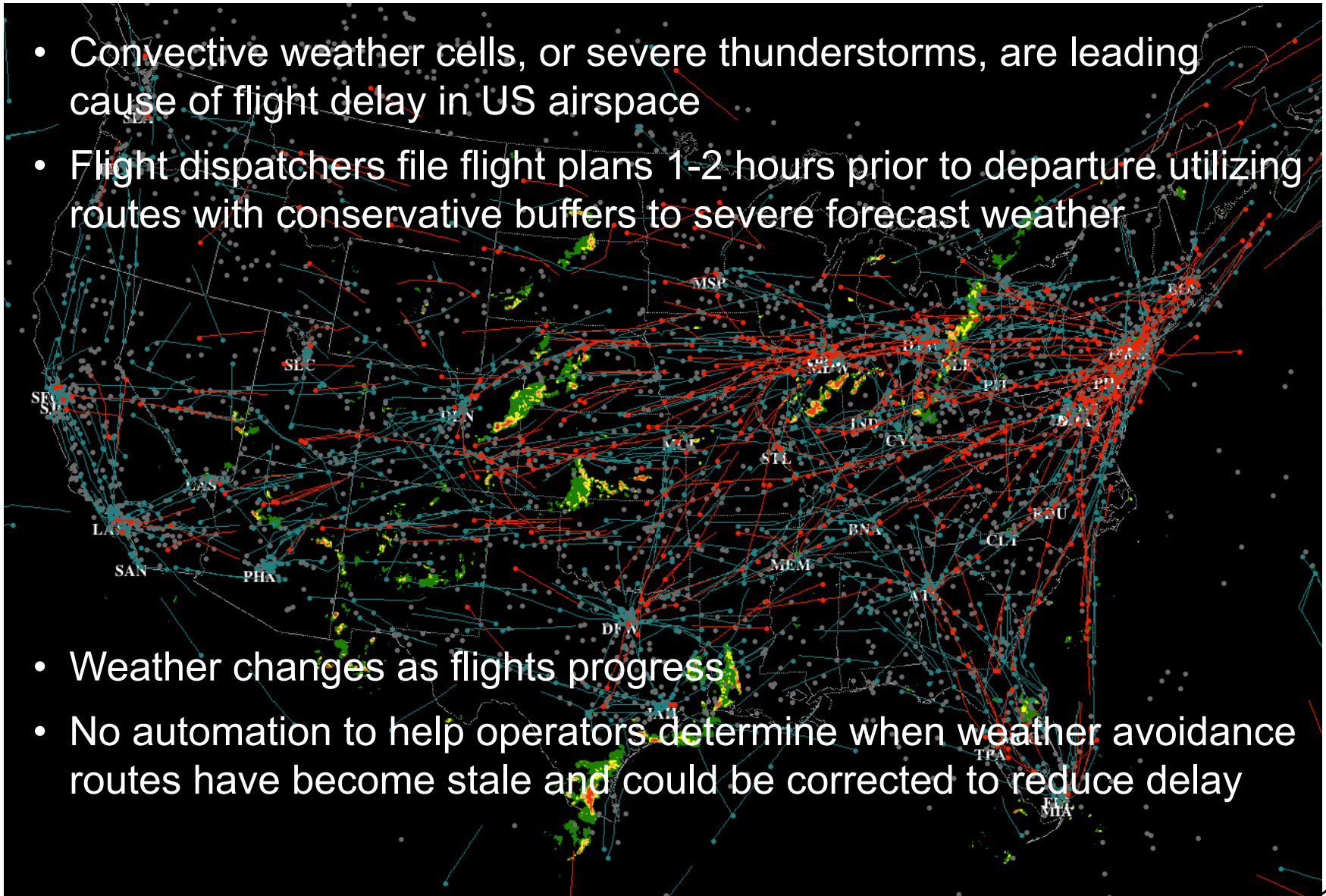


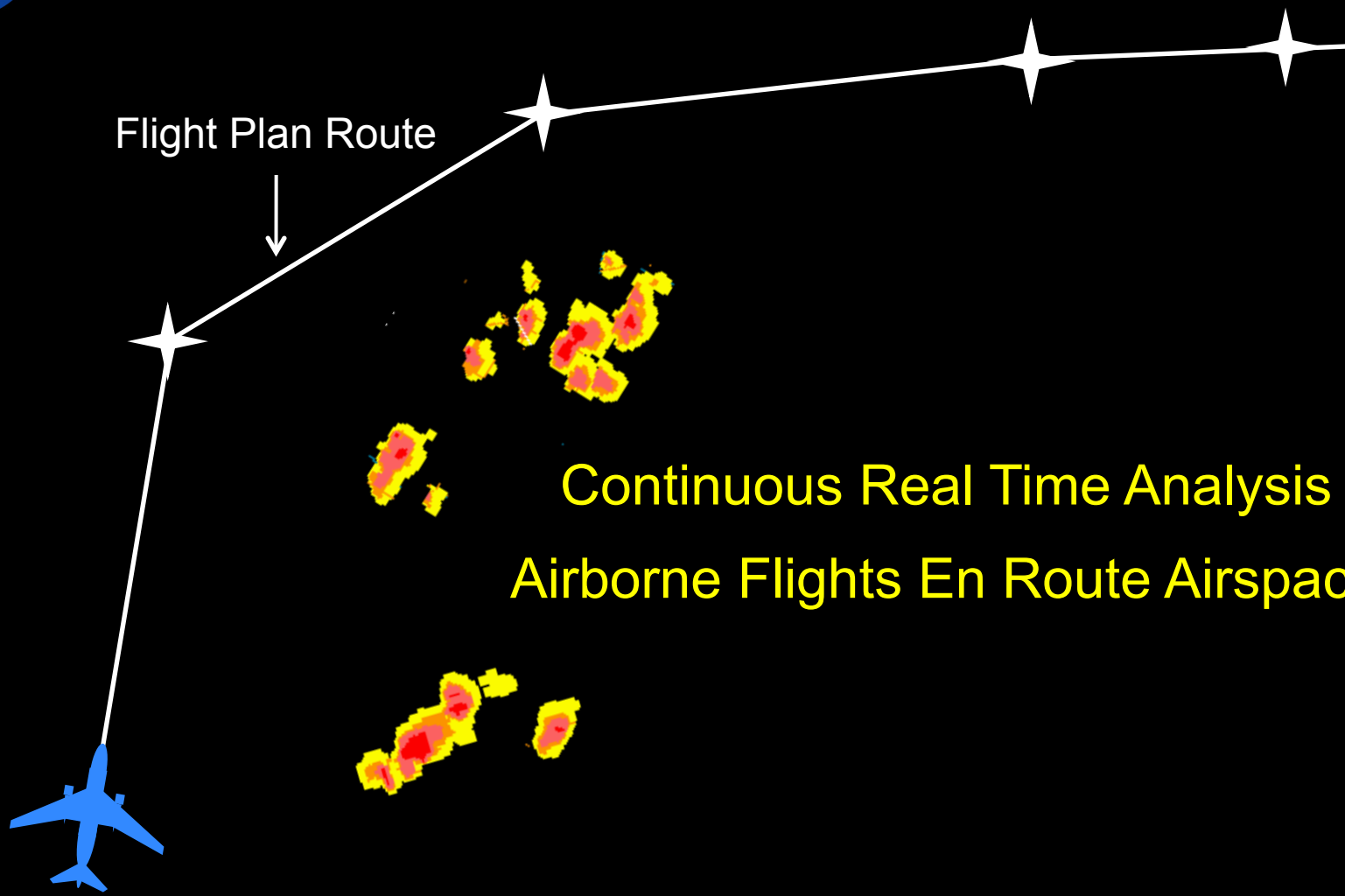
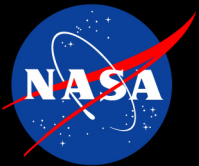


# What's the Problem?

- 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

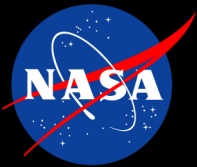
- Weather changes as flights progress
- No automation to help operators determine when weather avoidance routes have become stale and could be corrected to reduce delay



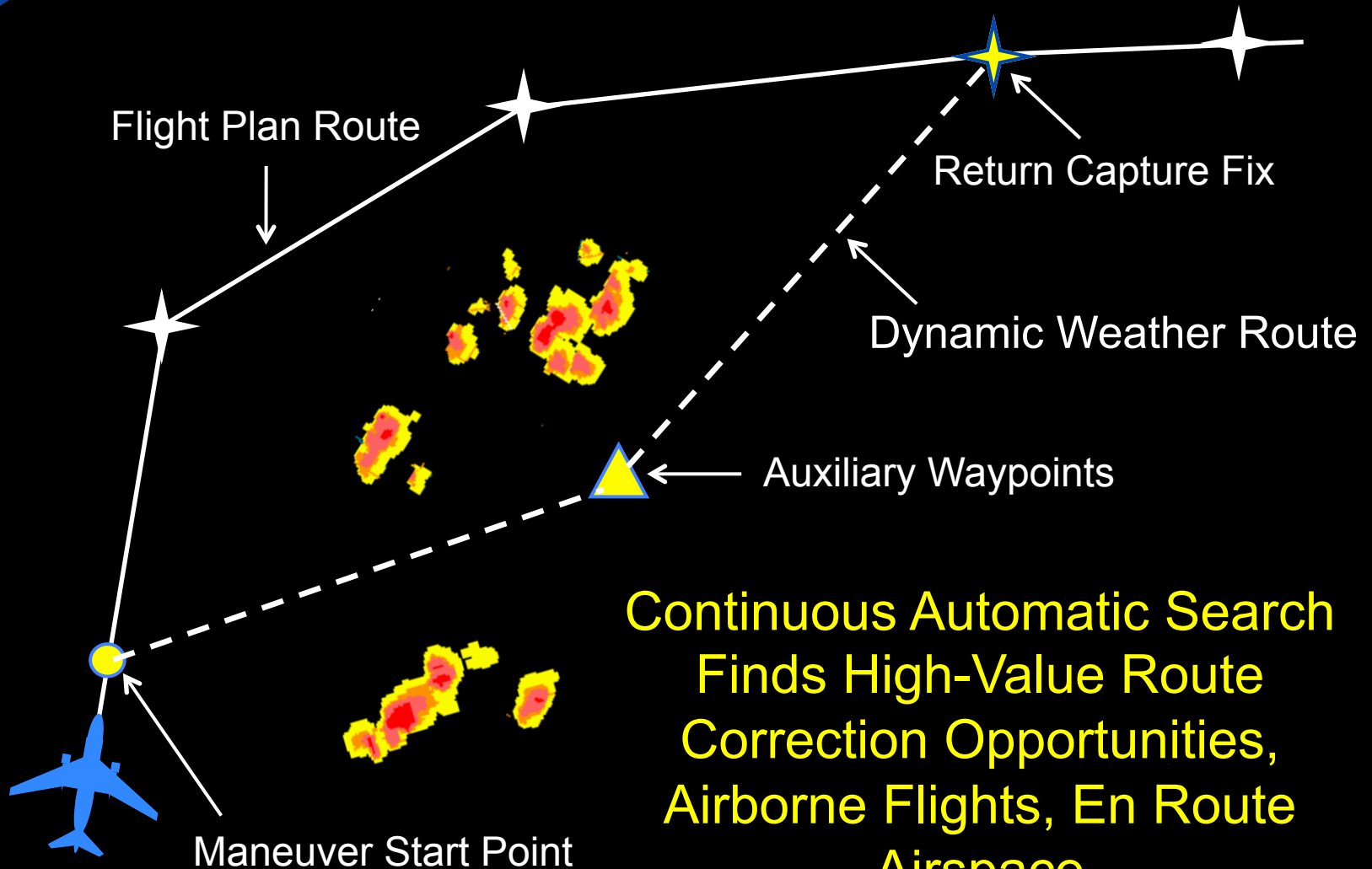


Flight Plan Route

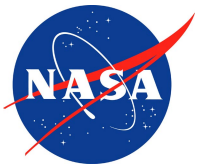
Continuous Real Time Analysis  
Airborne Flights En Route Airspace



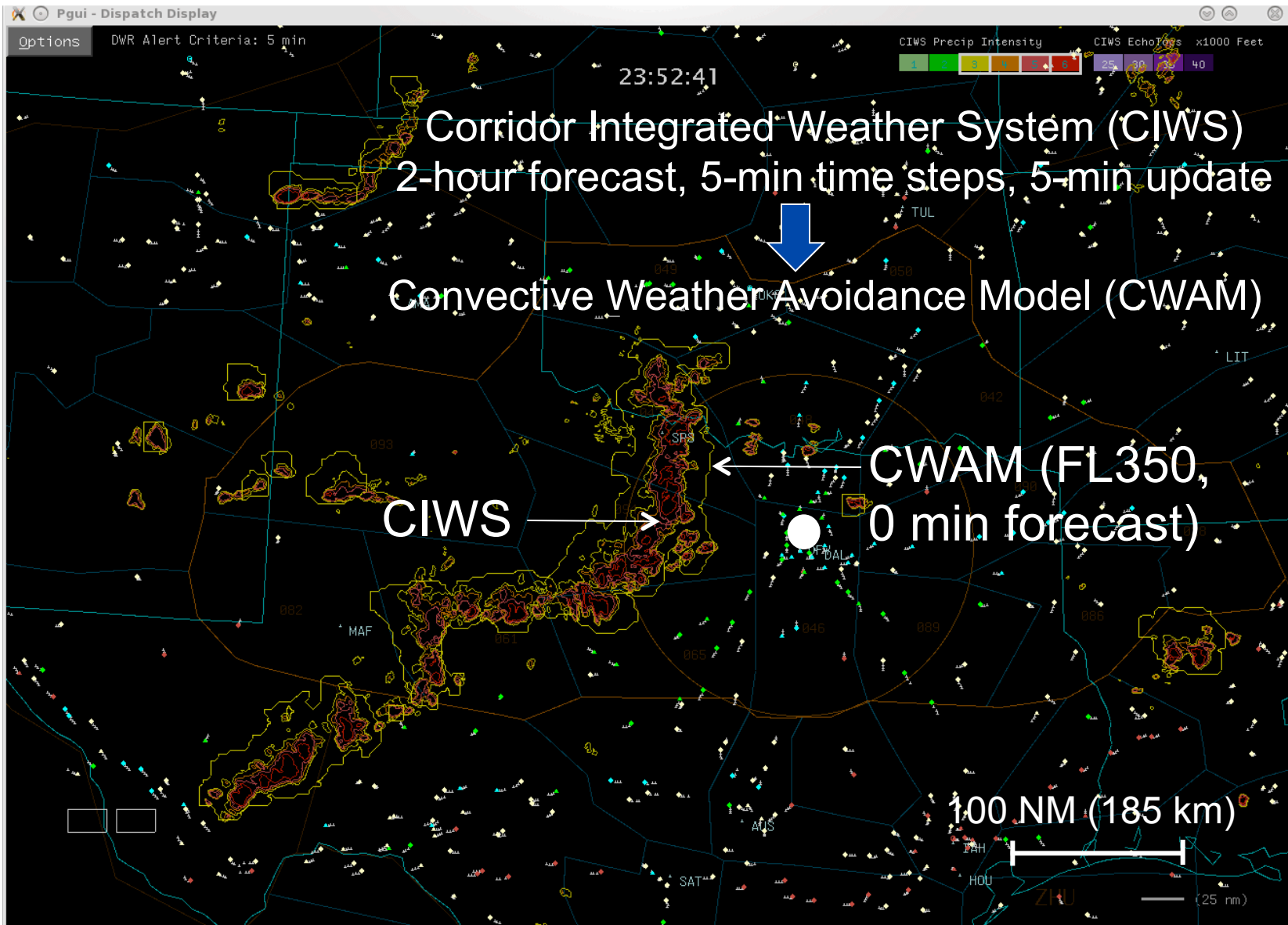
# Dynamic Weather Routes (DWR)



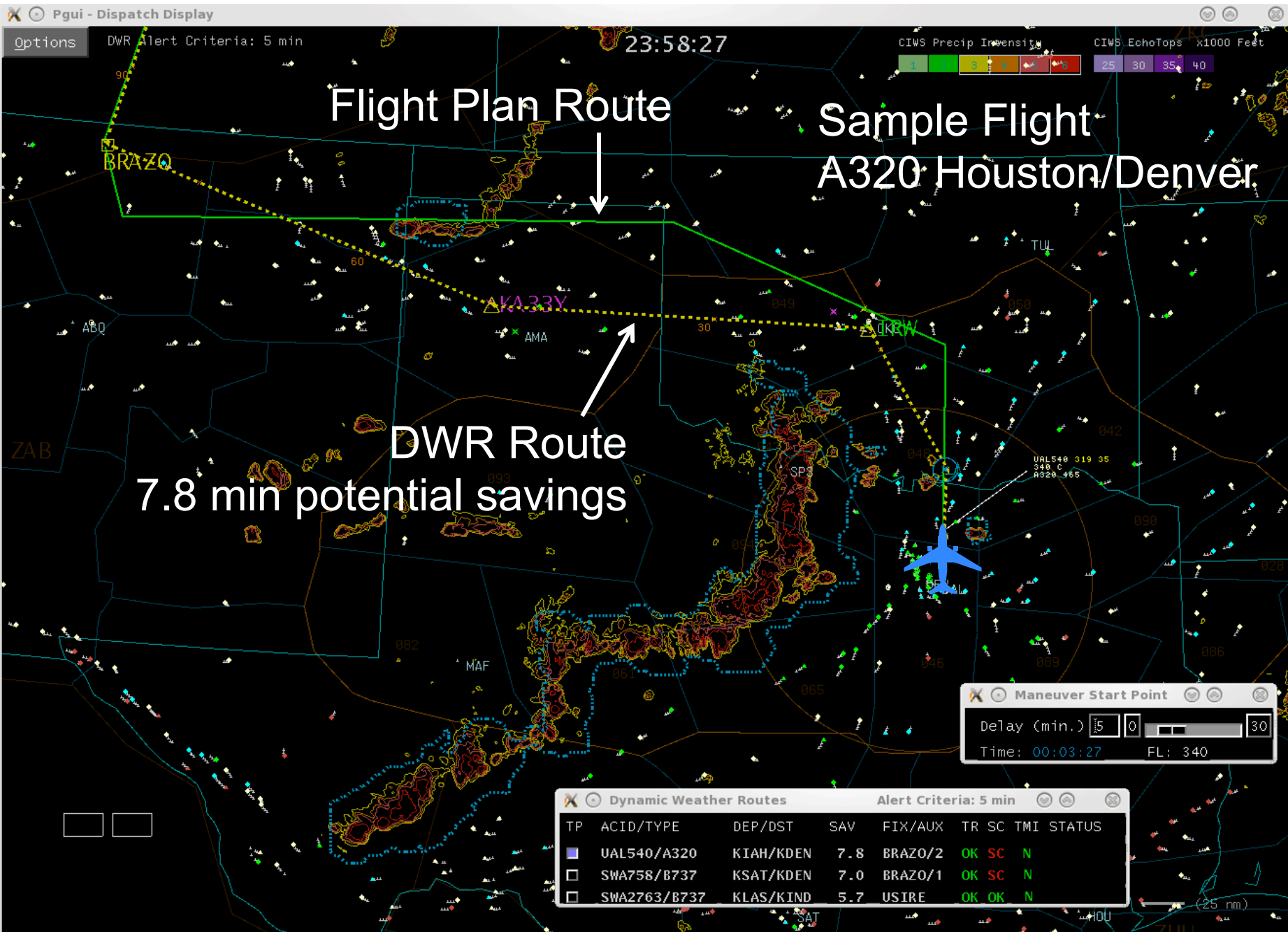
Continuous Automatic Search  
Finds High-Value Route  
Correction Opportunities,  
Airborne Flights, En Route  
Airspace

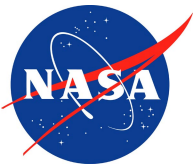


# Weather Model









# DWR User Interface

**Dynamic Weather Routes** Alert Criteria: 10 min

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input checked="" type="checkbox"/>	AWE437/A320	KPHL/KLAS	19.9	GUP/1	OK	OK	R
<input type="checkbox"/>	EGF3601/CRJ7	KELP/KORD	19.6	STL	OK	SC	N
<input type="checkbox"/>	UAL275/A320	KORD/KLAS	19.0	GUP/1	OK	OK	N
<input type="checkbox"/>	ASQ4550/E45X	KMCI/KIAH	17.8	SEEDS	OK	SC	N
<input type="checkbox"/>	UAL463/B752	KLAX/KORD	17.5	MAGOO/1	OK	SC	N
<input type="checkbox"/>	SWA1204/B737	KDEN/KBWI	14.9	SJI	OK	SC	R
<input type="checkbox"/>	SWA245/B737	KLIT/KLAS	13.4	GUP	OK	OK	R
<input type="checkbox"/>	UPS2834/B752	KSDF/KSNA	12.7	TXO/1	OK	OK	N

**DWR Flight List**

**Flight Plan Route**

**DWR Route Correction**

**Potential Savings: 20 min**

Time: 22:04:55

CIWS Precip Intensity

CIWS EchoTops...x1000 Feet

Maneuver Start Point

Delay (min.) [5] [0] [30]

Time: 22:09:48 FL: 340

**Active Flight Plan**

### Congestion on Flight Plan

Status: Flying Type: A320 Speed: 428 FL: 340 Cruise FL: 340 Heading: 241  
Nominal 02:56 hrs 1346 nms 14686 lb [KPHL / MEM039005..EIC.J4.ABI.J65.CME]

### Congestion on DWR

Status: Flying Type: A320 Speed: 428 FL: 340 Cruise FL: 340 Heading: 241  
Nominal 02:44 hrs 1248 nms 13568 lb [KPHL / 344824N/0903754W.342727N]

**TMI Information (for AWE437)**

Advisory	Orig	Dest	Route
68	LAS	ABQ	J15 ABQ J72 PGS TYSSN3
68	PHL	ABQ	MXE MXE278 PENSY J48 MOL J22 VUZ J52 SQS EIC J4 ABI

Effective Time: 29,1921 EWM\_MODIFIED\_PARTIAL (ETD)

Effective Time: 29,1635 PNH\_1\_PARTIAL (ETD)

Close

**Trial Planner - Dispatch Display**

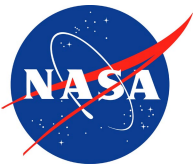
Altitude

STATUS: Trial Planning

AWE437 A320/Q 340 KPHL./..MEM039005..EIC.J4.ABI.J65.CME.J15.ABQ.J72.PGS.TYSSN3.KLAS

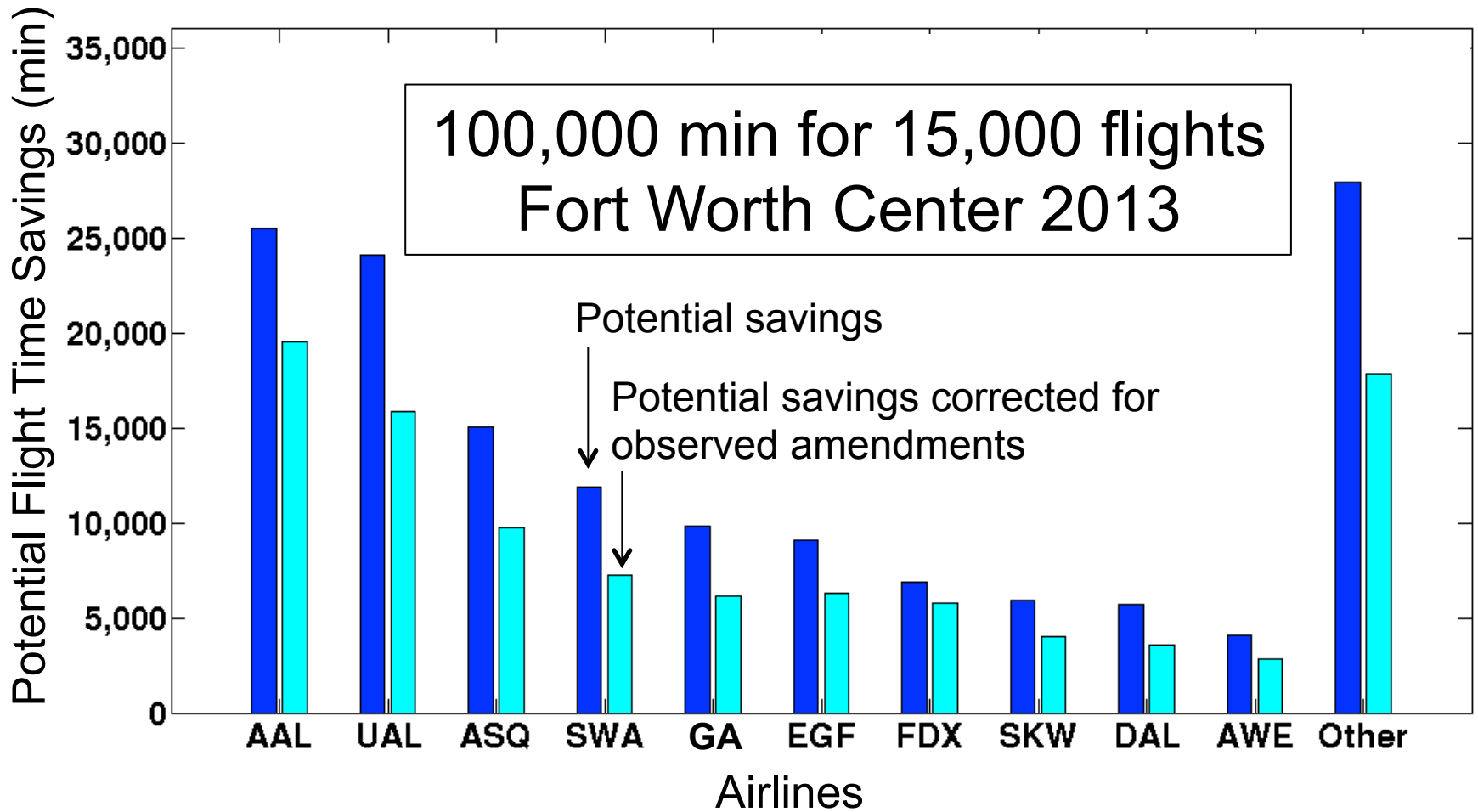
AWE437 KPHL./..HEE008014..EIC045167..DUC..GUP..J72.PGS.TYSSN3.KLAS

Send TMI Approve Unable Cancel Request Accept Reject



# Potential Benefits Analysis

All Airlines, All Flights, Fort Worth Center 2013



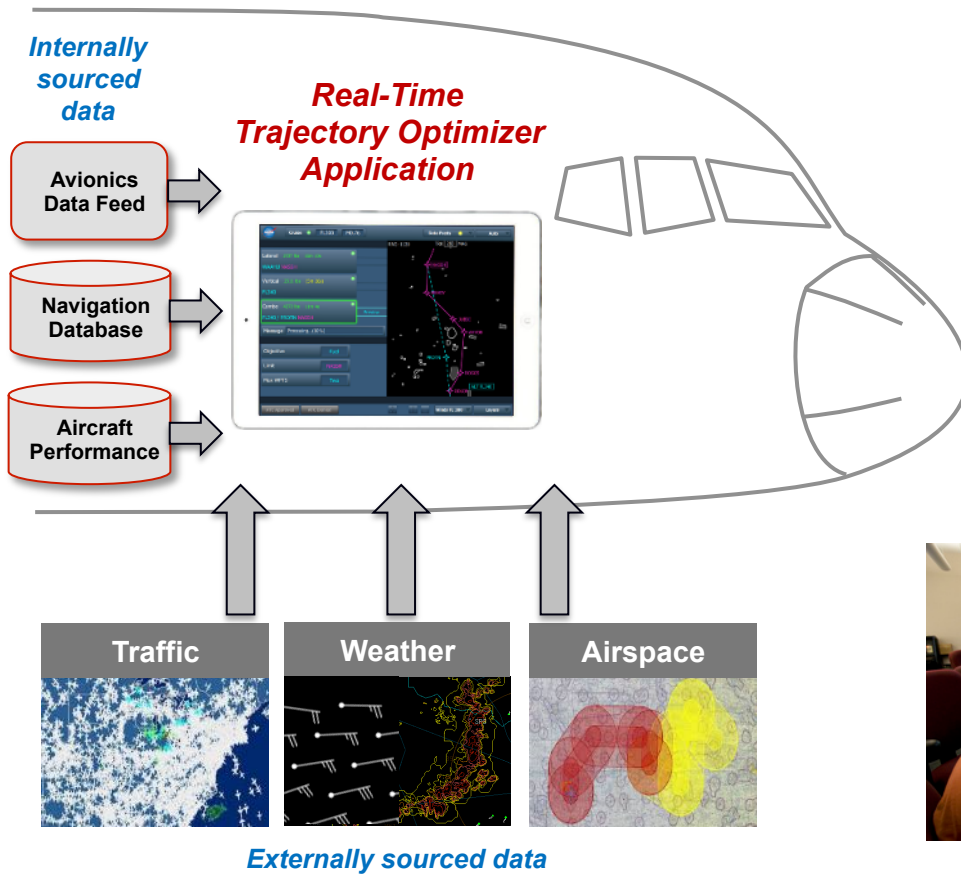
## *TASAR - NASA Flight Deck Application for En Route Flight Optimization*



**David Wing**, TASAR Principal Investigator  
NASA Langley Research Center  
[david.wing@nasa.gov](mailto: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



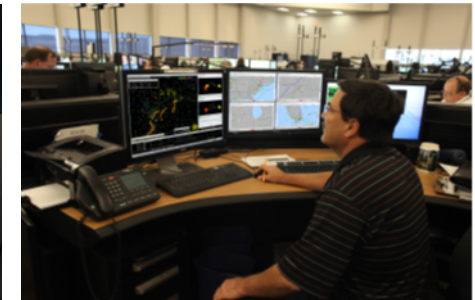
*Increased flight efficiency*



*Enhanced ATC request/ approval process*



*Enhanced dispatch/aircrew coordination*





# NASA Traffic Aware Planner (TAP)

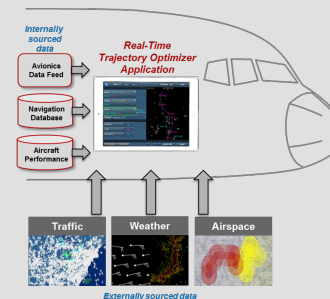
## Flight-Efficiency EFB Application (“Type B”)

Connected to avionics via standard interfaces

Ownship flight data, ADS-B traffic data

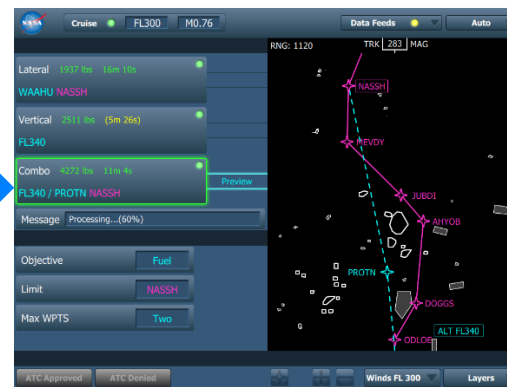
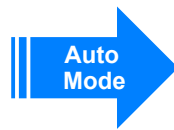
Connected to external data sources via internet

Latest winds, weather, airspace status, etc.



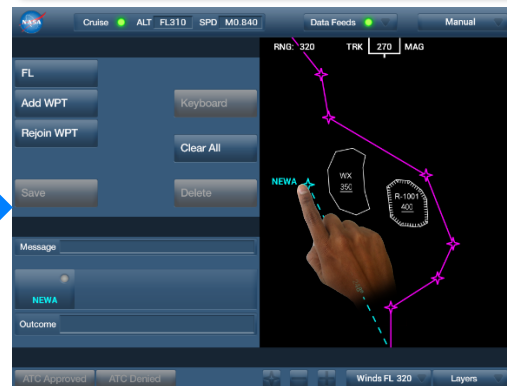
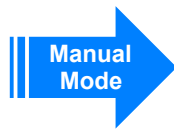
## Computes real-time route optimizations

- 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

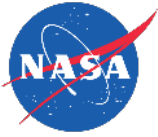


## Analyzes pilot-entered route/alt changes

- 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



# TAP Auto Mode



NASA **Cruise** ● **FL300** **M0.76** **Data Feeds** ● **Auto** ▼

RNG: 1120 TRK **283** MAG

Lateral **1937 lbs** **16m 10s** ●  
WAAHU **NASSH**

Vertical **2511 lbs** **(5m 26s)** ●  
FL340

**Combo** **4272 lbs** **11m 4s** ● **Preview**  
FL340 / PROTN **NASSH**

Message **Processing...(60%)**

Objective **Fuel**

Limit **NASSH**

Max WPTS **Two**

ATC Approved ATC Denied + - **Winds FL 300** ▼ **Layers** ▼



# TAP Manual Mode



The screenshot displays the TASAR interface in Manual Mode. At the top, the NASA logo is on the left, followed by a status bar showing "Cruise" with a green indicator, "ALT FL310", "SPD MO.840", "Data Feeds" with a green indicator, and a "Manual" dropdown menu.

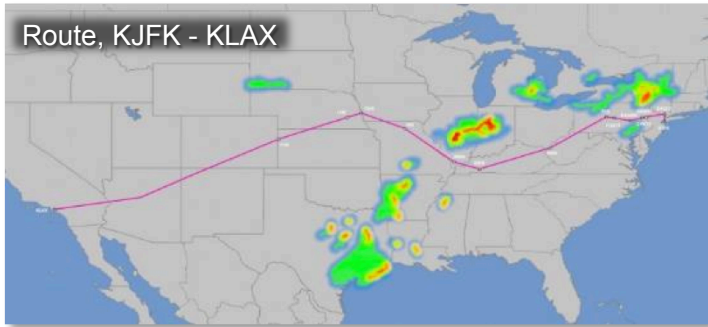
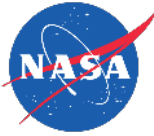
The main interface is split into two panels. The left panel contains several control buttons: "FL", "Add WPT", "Rejoin WPT", "Save", "Keyboard", "Clear All", and "Delete". Below these is a "Message" input field, a "NEWA" button, and an "Outcome" input field.

The right panel shows a map with a pink flight path. The path starts at a point labeled "NEWA" (indicated by a hand pointing to a cyan star) and proceeds through several waypoints marked with pink stars. The path is labeled with "RNG: 320", "TRK 270", and "MAG". Two obstacle symbols are visible: "WX 350" and "R-1001 400". A dashed cyan line with "248°" indicates a heading or bearing.

At the bottom of the interface, there are buttons for "ATC Approved" and "ATC Denied", a compass icon, a zoom in/out icon, a "Winds FL 320" dropdown, and a "Layers" dropdown.

# 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

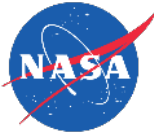
## Results

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  
OPL: Operator Performance Lab, Univ. of Iowa

# TASAR Flight Trials

Nov 2013, Jun 2015



AdvAero Piaggio Avanti

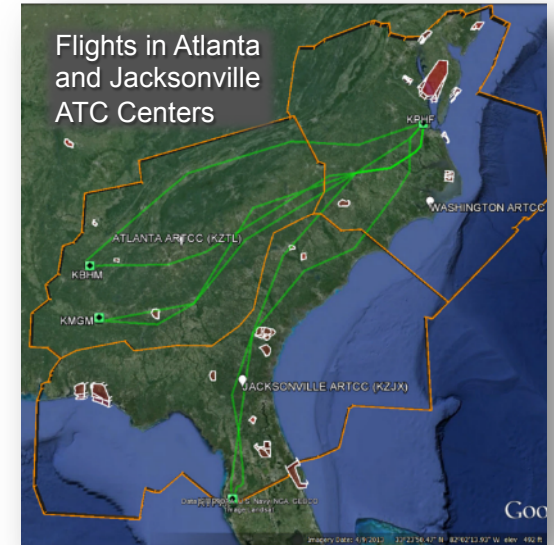
- 54 hours, 21 flights, 17 evaluation pilots
- DC, NY, Boston, Atlanta, Jax Centers
- ATC observations, 50 interviews w/ ATC
- Alaska Airline's EFB & ADS-B hardware
- Broadband connection to NOAA winds, FAA SUA status, WSI convection data



iPad AIR



ATC Observations



Flights in Atlanta and Jacksonville ATC Centers

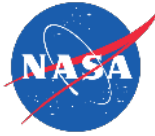
## Objectives

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

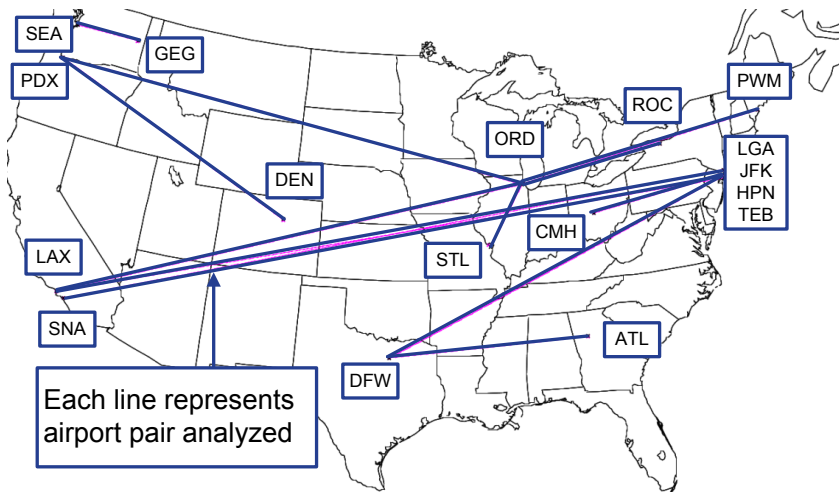
## Results

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

# 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	
	$\Delta T$	$\Delta F$	$\Delta T$	$\Delta F$	$\Delta T$	$\Delta F$
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

$\Delta T$ : Time savings (minutes)  $\Delta F$ : 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





## Airplane State Awareness and Prediction Technologies

Steven D. Young, PhD

NASA Langley Research Center ARMD

Technical Seminar, May 5, 2016



# Study Process and Findings (2010-2014)

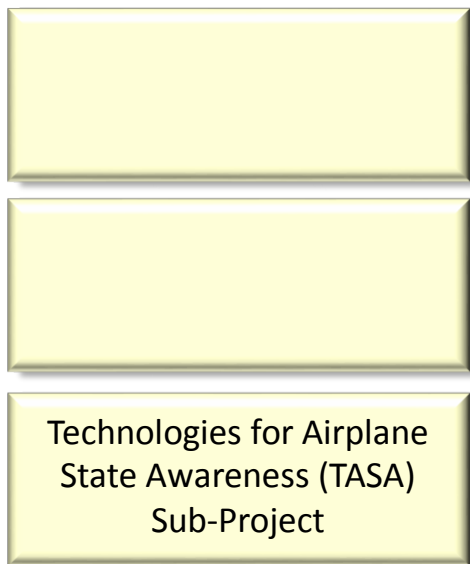
CAST-recruited gov't-industry team:

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

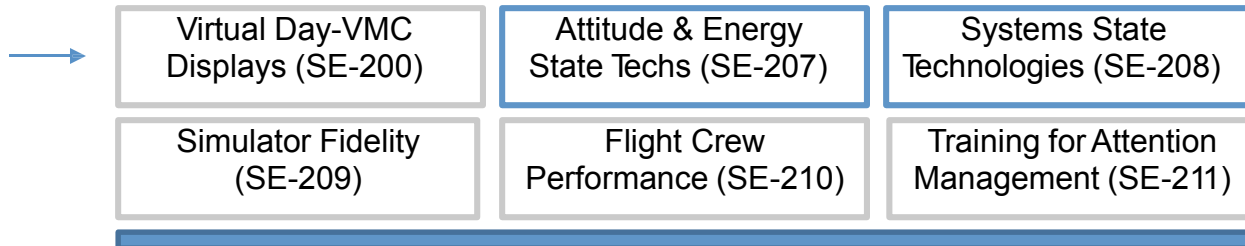
- Assessed each intervention strategy for effectiveness & feasibility; Recommended
  - **13** safety enhancements (SEs), no research req'd
  - **5 research** safety enhancements (SEs)
  - **1 design** SE where research is critical to implementation

- Published plans to achieve each safety enhancement

NASA's contribution:



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



Desired Outputs



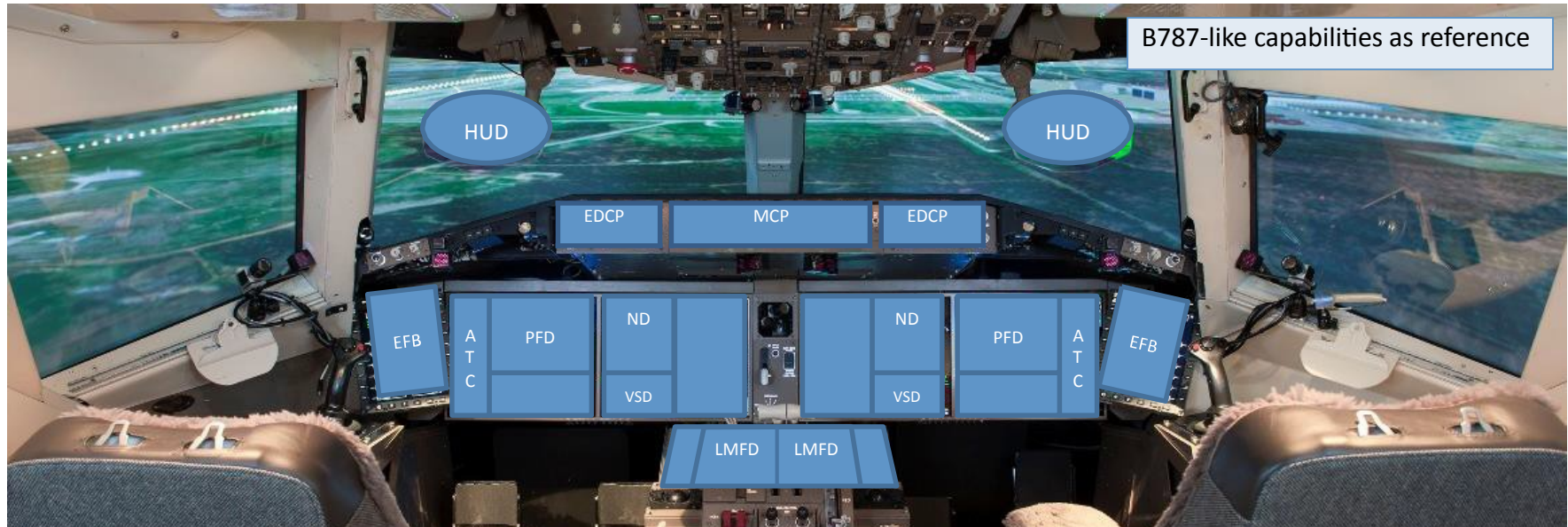
# SE-207/208 Research Team





# 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))

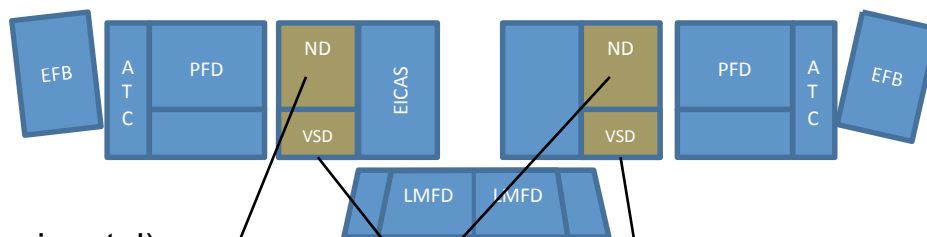


# AIME Objectives

- 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



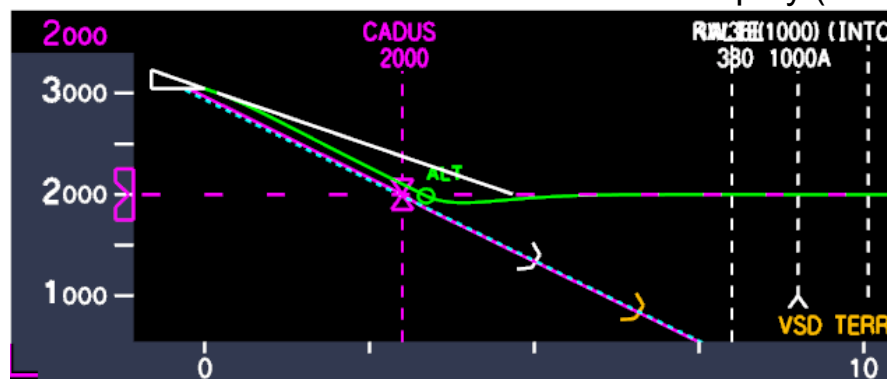
# Trajectory & Mode Change Prediction\*



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)



• "Green Line" – represents where the automation will take the aircraft if no intervention by the pilot, and no unexpected conditions are encountered.

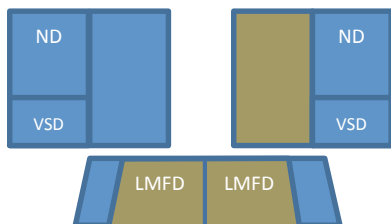


Circle symbol and label – indicates (1) where a mode switch is predicted and what the new mode will be; or (2) where an energy-related problem is predicted to occur. For the latter, colors/salience will change based on proximity/time to alert (IAW 25.1322)

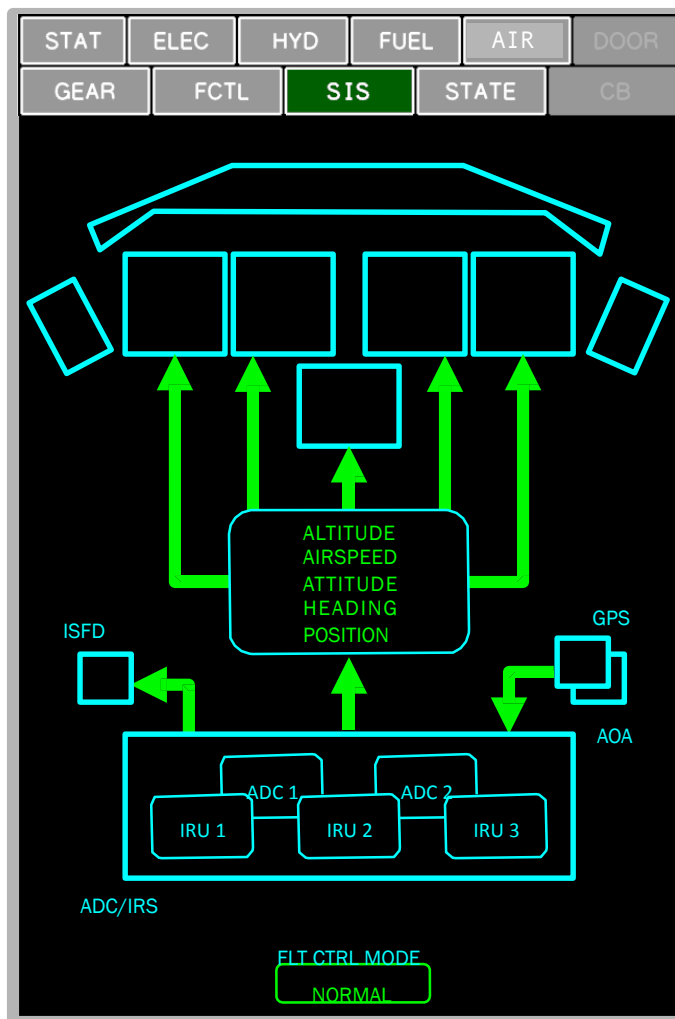


# System Interaction Synoptic

Normal



Available on any of these display spaces



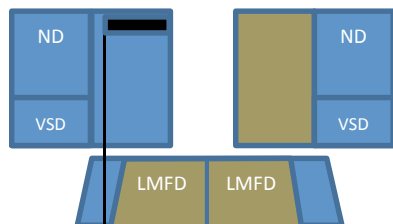
- 1 Mode control panel
- 2 Display panels
- 3 Flight-critical information
- 4 Flight-critical data systems
- 5 :ISFD – standby instrument  
:Flight control mode



# System Interaction Synoptic

Non-normal

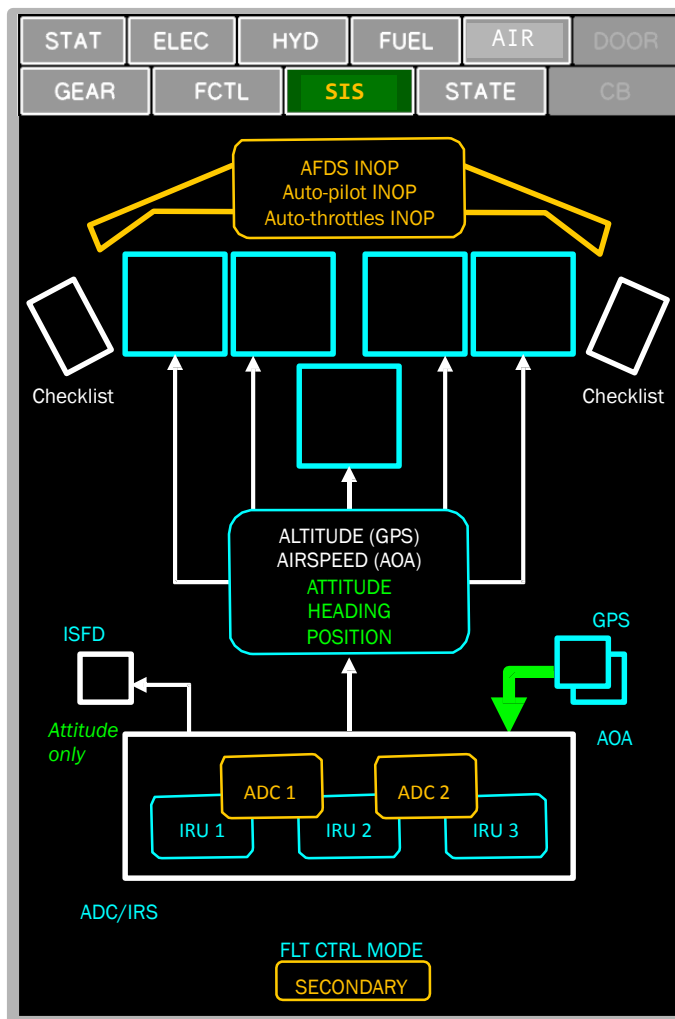
(example)



Available on any of these display spaces

EICAS Msg:

- ❑ NAV AIR DATA SYS



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





# 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](mailto:arc-aow@mail.nasa.gov)