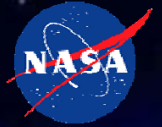


National Aeronautics and Space Administration



Airspace Technology Demonstrations (ATD) Project

Airspace Technology Demonstration 3 (ATD-3) Sub-Project

ATD Industry Day – ATD-3 Overview Brief

Mike Madson

ATD Deputy Project Manager

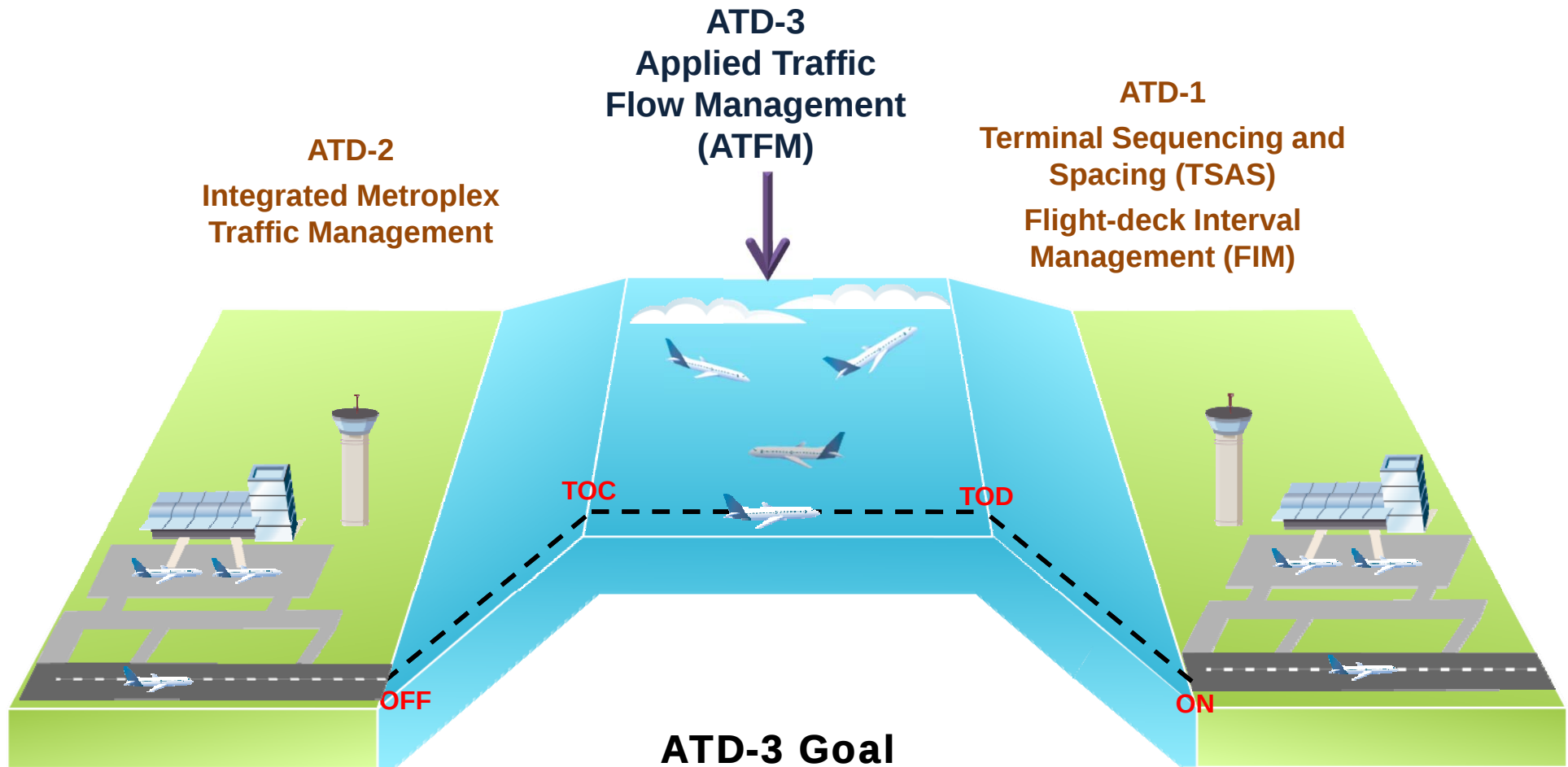
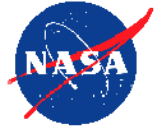
ATD-3 Sub-Project Manager (Acting)

January 13, 2016

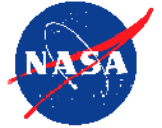
NASA Ames Research Center

<http://www.aviationsystems.arc.nasa.gov/atd-industry-day/>

ATD-3 Scope and Goal

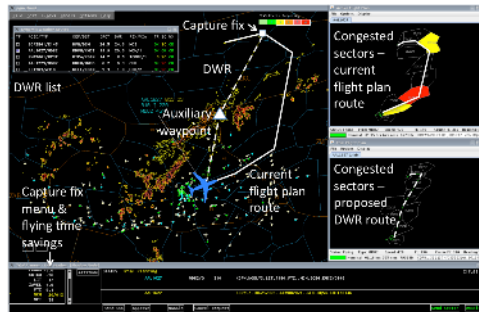


By 2020, ATD-3 will enable increased TFM efficiency and reduced delays, in domestic and oceanic airspace, by delivering advanced integrated air/ground technologies and procedures that use automation to facilitate the execution of strategic user-preferred routes, tactical route corrections, and enhanced airspace capacity.

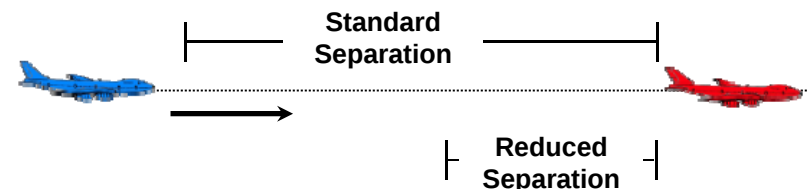
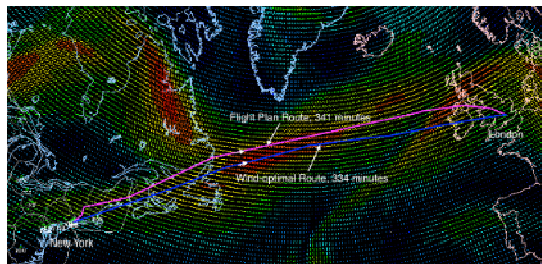


ATD-3 Objectives

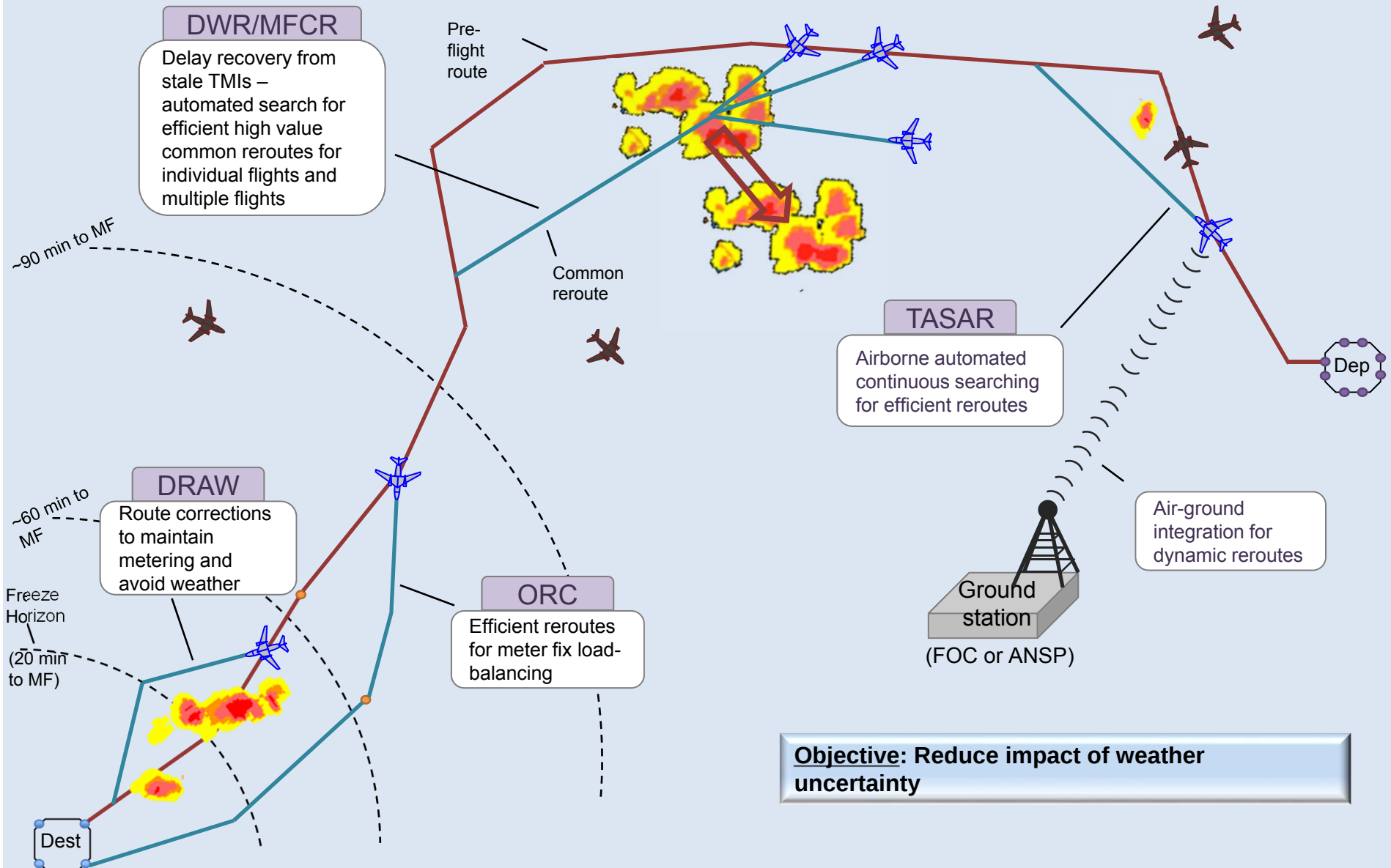
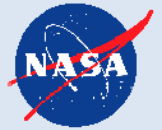
Domestic: Reduce impact of weather uncertainty in domestic airspace by developing integrated air/ground automation tools to continuously search for more efficient routes for individual flights and groups of flights, and the means for efficiently sharing route correction options between traffic managers, dispatchers, pilots, and controllers



Oceanic: Increase oceanic trajectory efficiency and capacity by integrating real-time cost-optimal trajectory search algorithms with air/ground tools to establish and maintain reduced separation minima to maximize the time aircraft fly on their preferred trajectories

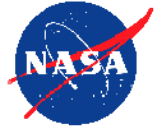


Domestic Integrated Concept



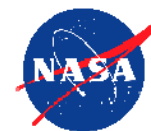
What's the Problem

Weather Avoidance in Domestic US Airspace



- Convective weather leading cause of delay in US airspace
- Static avoidance routes employ large buffers to forecast weather, not tailored to daily conditions, no automation to monitor or update as conditions change
- Time-based metering, which reduces delay during heavy arrival demand, not usable during weather events
- Even with known, workable, high-value route correction options, coordination workload for FAA traffic managers & controllers, airline dispatchers & pilots usually prohibitive
- Other than weather radar, pilots can't visualize weather and traffic on which dynamic route corrections are based

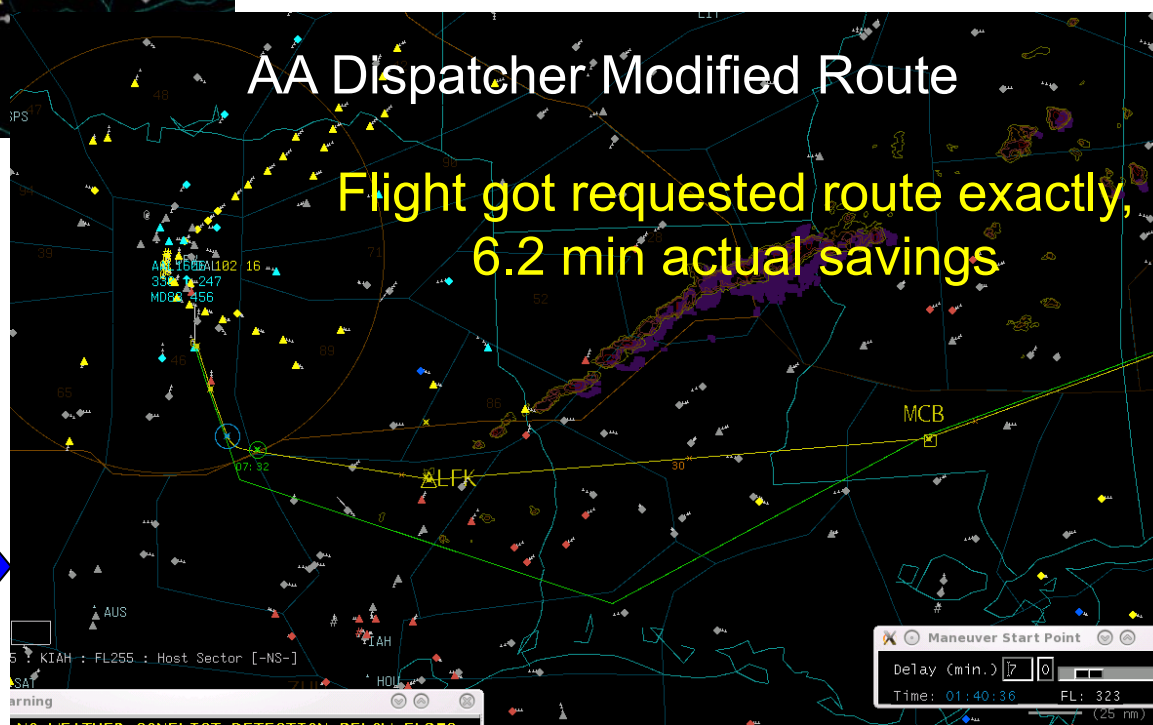
Route Correction Balances Potential Savings with Dispatcher/ATC Acceptability



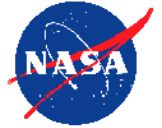
Balance potential savings with ATC factors for higher likelihood of success

11 min savings, but too close to weather, traffic conflicts, unfamiliar routing

Further from weather, ATC friendly, away from busy arrival stream



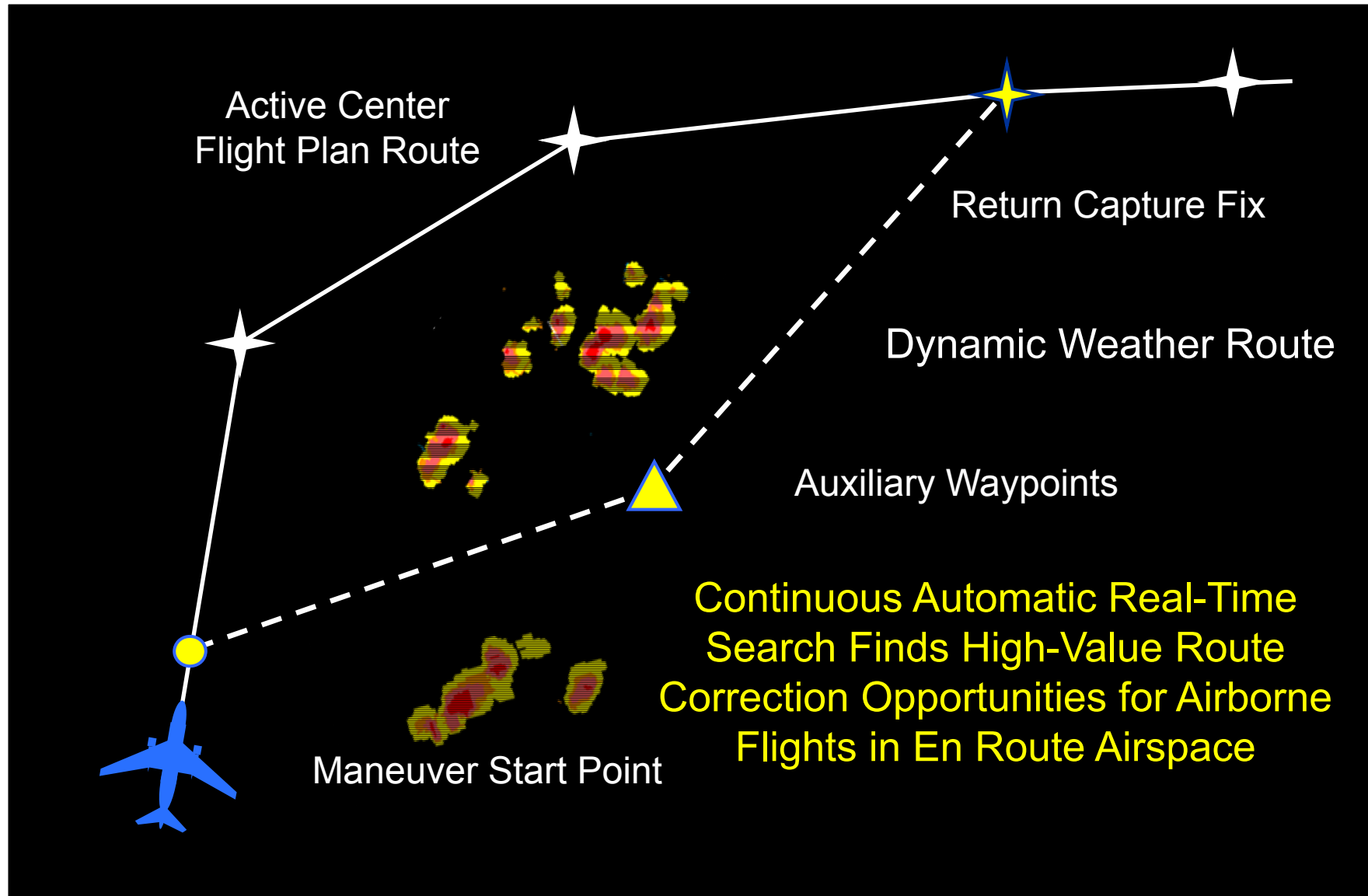
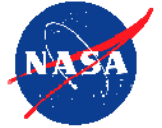
Research Objectives



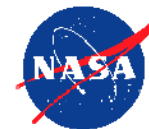
Weather Avoidance in Domestic US Airspace

- Multi Flight Common Route, ATC Acceptable High-Value Route Correction Automation
 - Balances delay reduction with ATC familiarity & acceptability
 - Finds common route corrections for multiple flights
 - Extends automation for merging arrivals, time-based metering, arrival fix balancing
 - Incorporates smarter integration of tactical route corrections with downstream congestion, metering constraints, conflict avoidance
 - Includes strategic advisories for heavy weather on course & improved weather models
- Evaluations with FAA Traffic Managers and Controllers
- Test with multiple airlines and FAA, secure web-based connectivity for low-workload alert, display, execute
- Airline/FAA test, Aircrew-Initiated Re-routes via Data Comm
- Expected Result: Demonstrate significantly more – 3 to 4 times more – actual savings for revenue flights

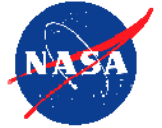
Dynamic Weather Routes (DWR) Concept



DWR User Interface



Multi-Flight Common Route

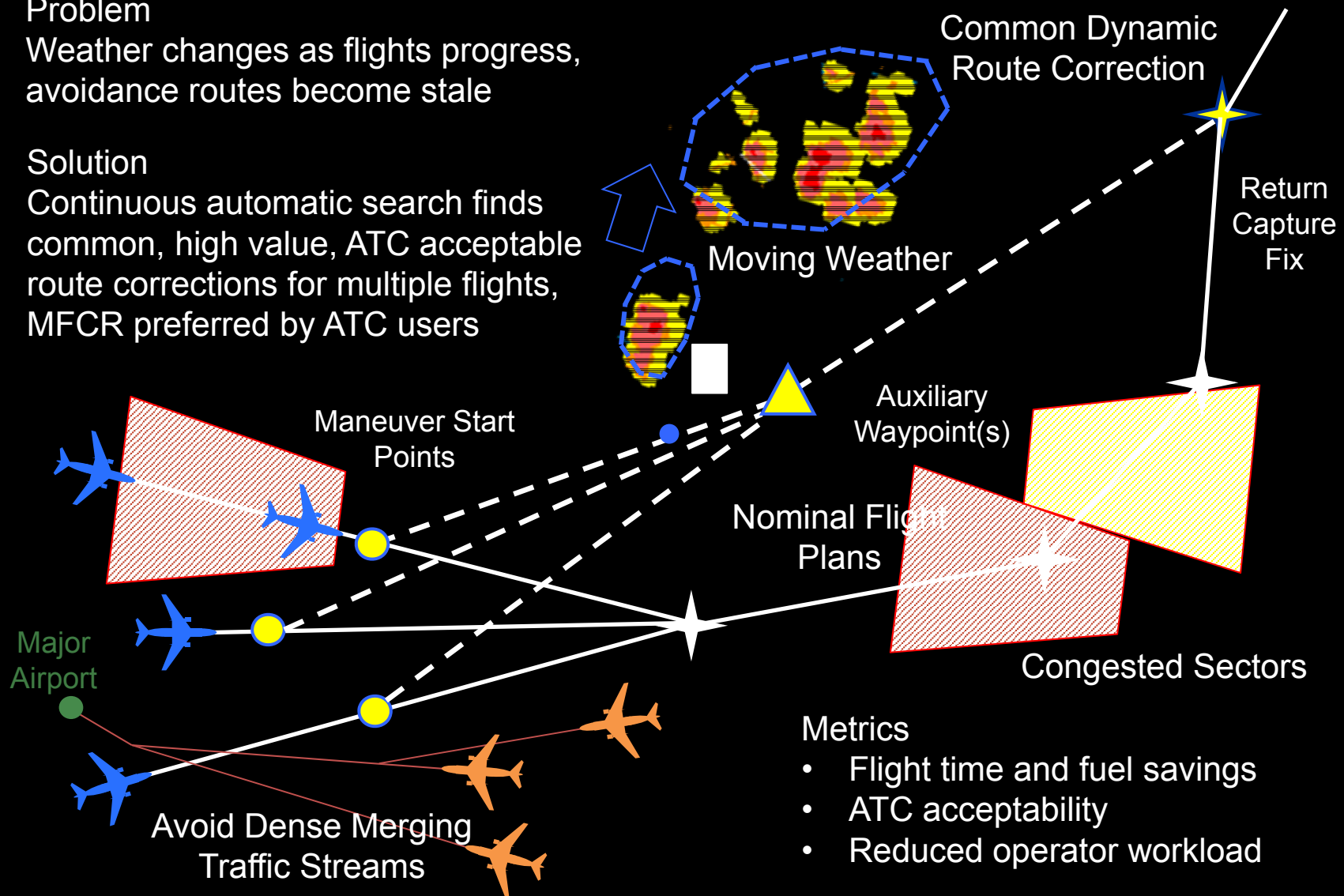


Problem

Weather changes as flights progress, avoidance routes become stale

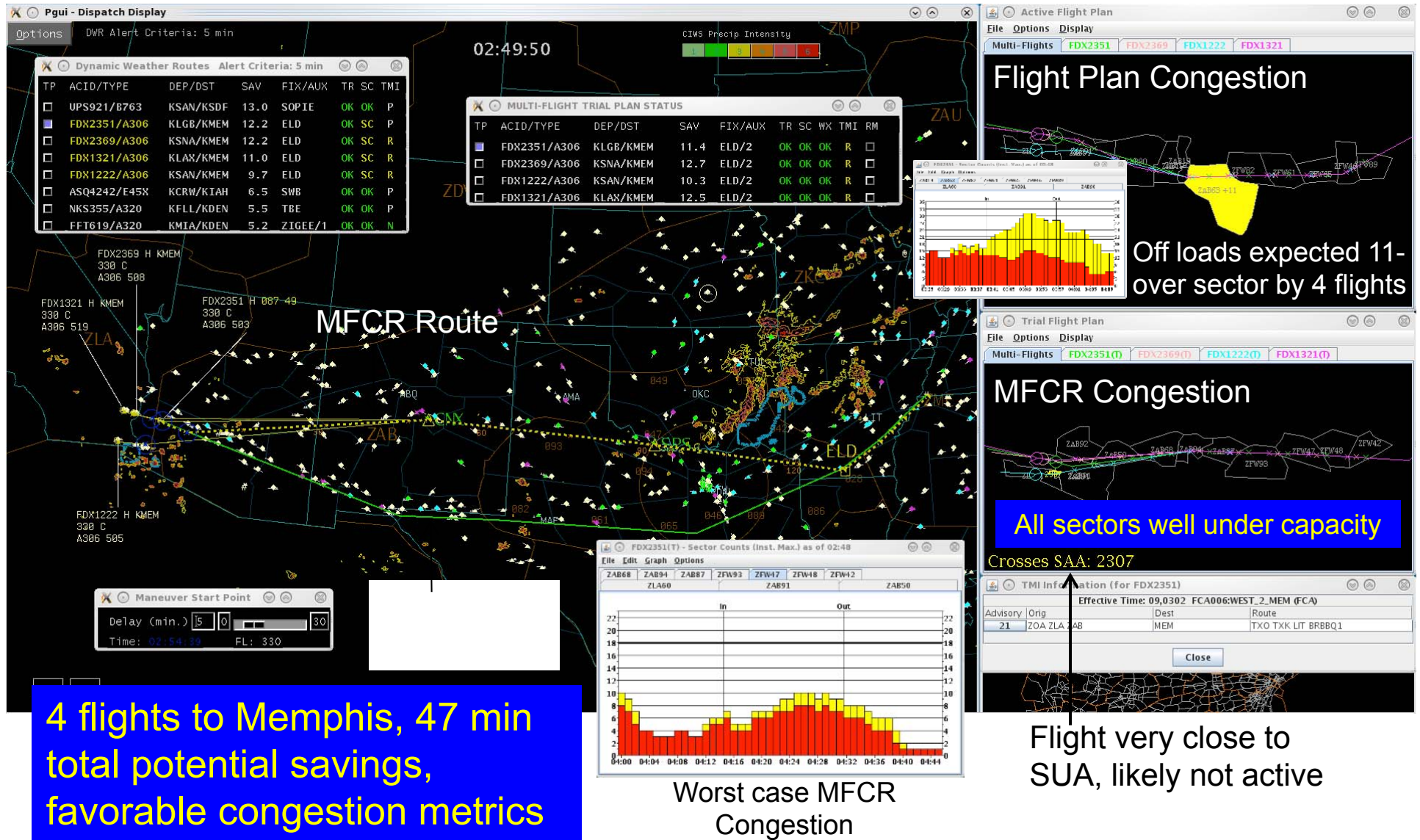
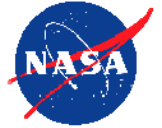
Solution

Continuous automatic search finds common, high value, ATC acceptable route corrections for multiple flights, MFCR preferred by ATC users

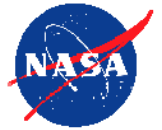


Multi-Flight Common Route

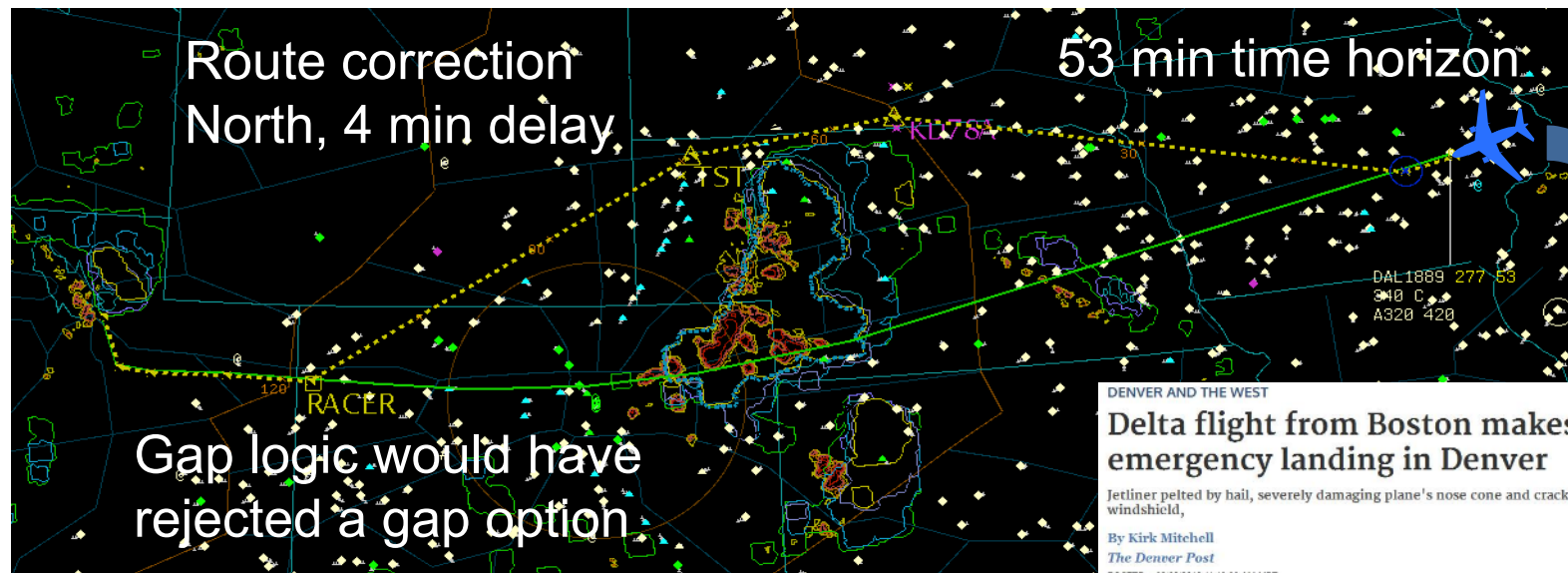
~~4 FedEx Flights to Memphis, 8 Sept 2015, 9:49 PM Central~~



Route Correction Alerts for Heavy Weather on Course



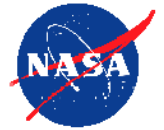
Leverage DWR to detect heavy weather on course, propose strategic minimum-delay solutions, might have prevented this 8/8/15 encounter



Smart route correction
could result in huge
savings and safety benefit



Alert, Display and Load



Small alert window on existing displays

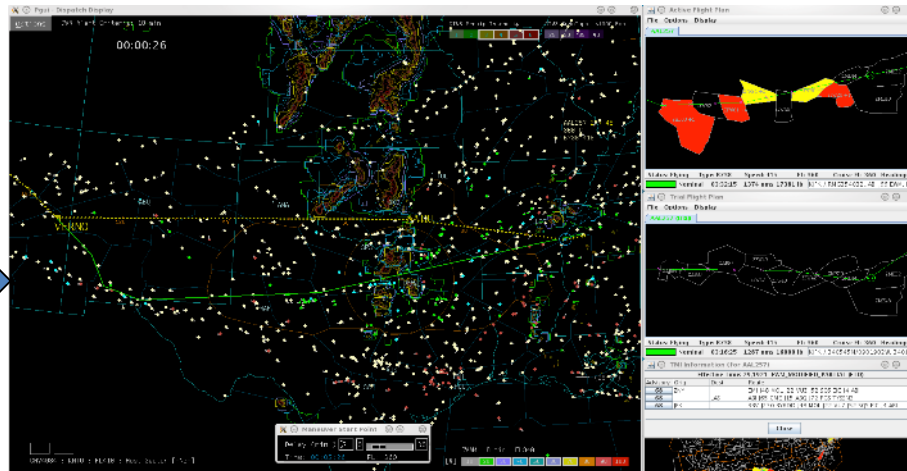
Show

257 JFK/LAS 16 min

Load

Dispatcher Work Station

Click alert window to toggle picture



Existing Dispatcher Display Systems

1. High value alert

2. Click for static picture

3. Send auto screen capture

4. Click to load route

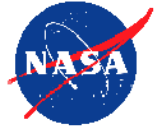
5. Send route string

6. Usage feedback (e.g., ACARS uplink msgs)

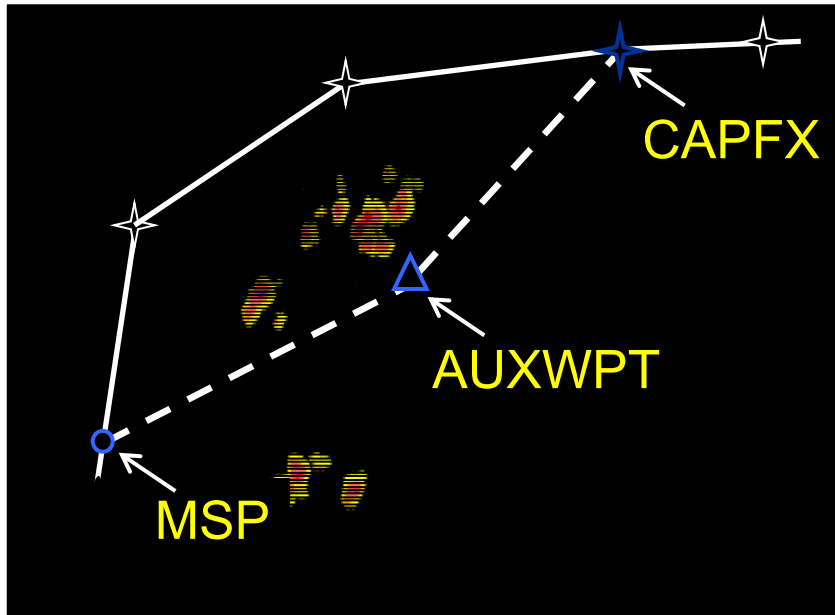
DWR++ System

Concept works for any NASA automation system and any user display

DWR Compatibility with Data Comm



DWR Automation



FANS-1/A CPDLC Equipped Aircraft
(747-400 Navigation Display)

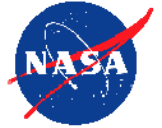


CPDLC Route Clearance (UM79)
CLEARED TO [FIX] VIA [ROUTE CLEARANCE]
CLEARED TO [CAPFX] VIA [MSP..AUXWPT]

Today's Existing FANS-1/A Controller Pilot Datalink Communication (CPDLC)

Press buttons to load, communicate, visualize, execute

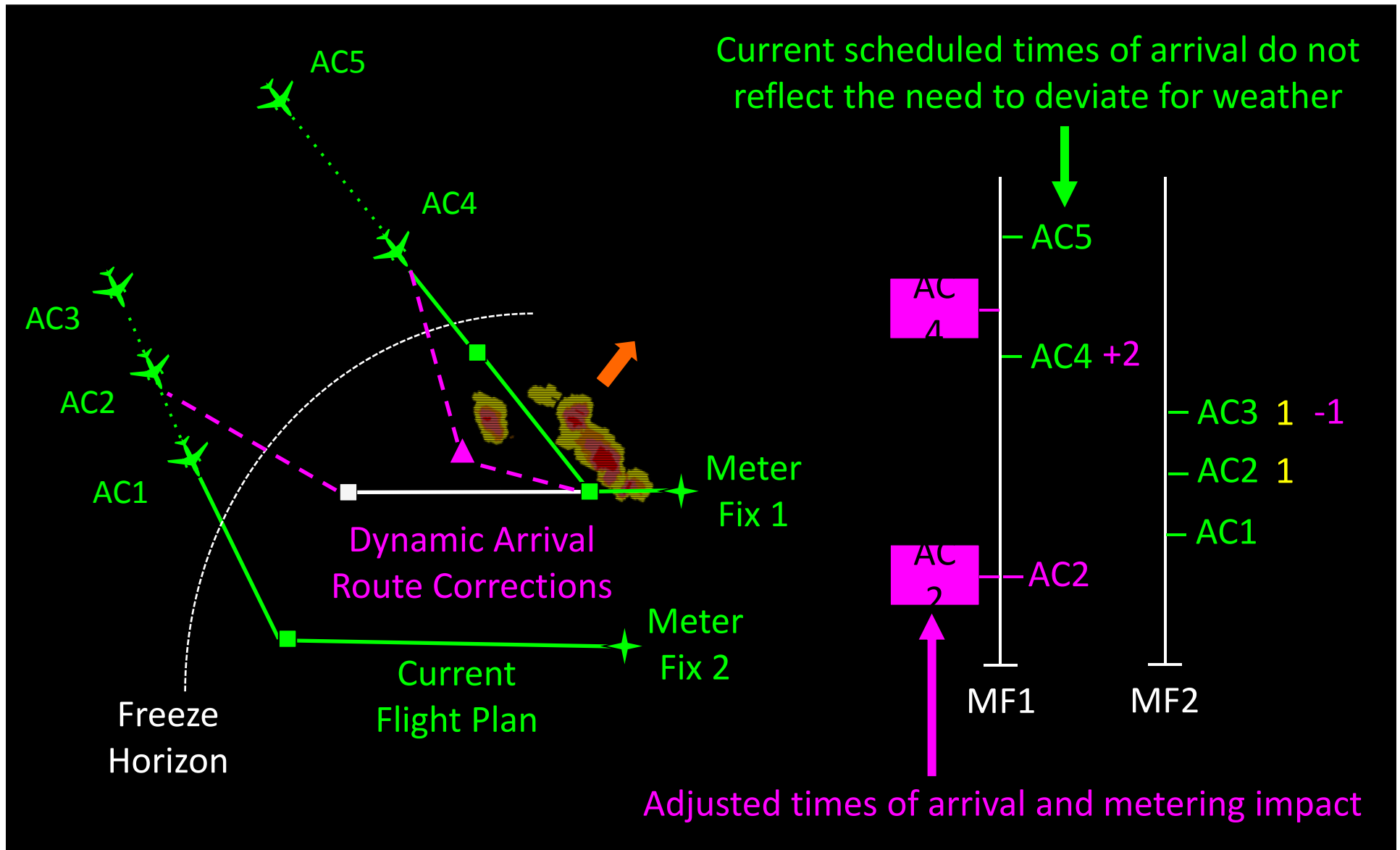
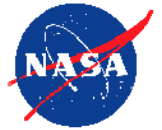
Dynamic Reroutes for Arrivals with Weather



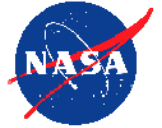
What's the Problem?

- Weather is one of the primary reasons for time-based metering to be discontinued
- Current operational system **cannot** adjust its scheduled times of arrival for aircraft that need to deviate around weather
- Traffic Managers and Controllers revert to less efficient methods of managing arrival traffic flow
 - Implement conservative alternate routes hours in advance
 - Miles-in-trail (MIT)

Improving Arrival Traffic Flow



DRAW Time Savings Analysis

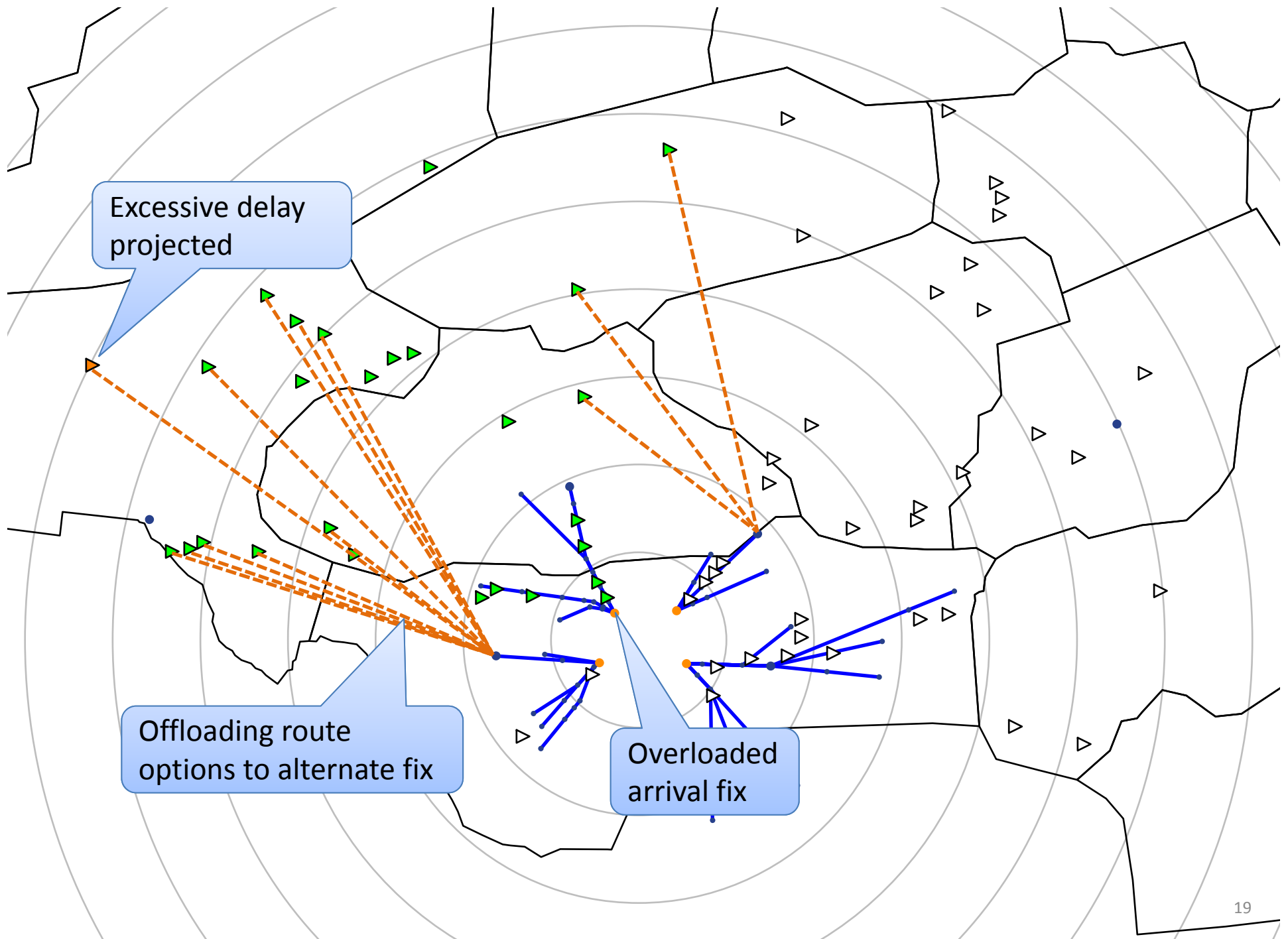


- Analysis of Fort Worth Center (ZFW) – live traffic data for 12 “average” weather-impacted days, totaling 93 hours
- Evaluated flights potentially benefiting from an arrival route change in a two-phase process
 - Phase I: Efficiency improvement
 - Phase II: Weather avoidance
- Phase I
 - Evaluated flight routes 60 minutes prior to meter fix
 - Net of 234 flights identified for reroute
 - Reroutes averaged 12 minutes of time savings per flight
- Phase II
 - Evaluated flight routes 30 minutes prior to meter fix
 - 642 flights required adjusted arrival times due to weather

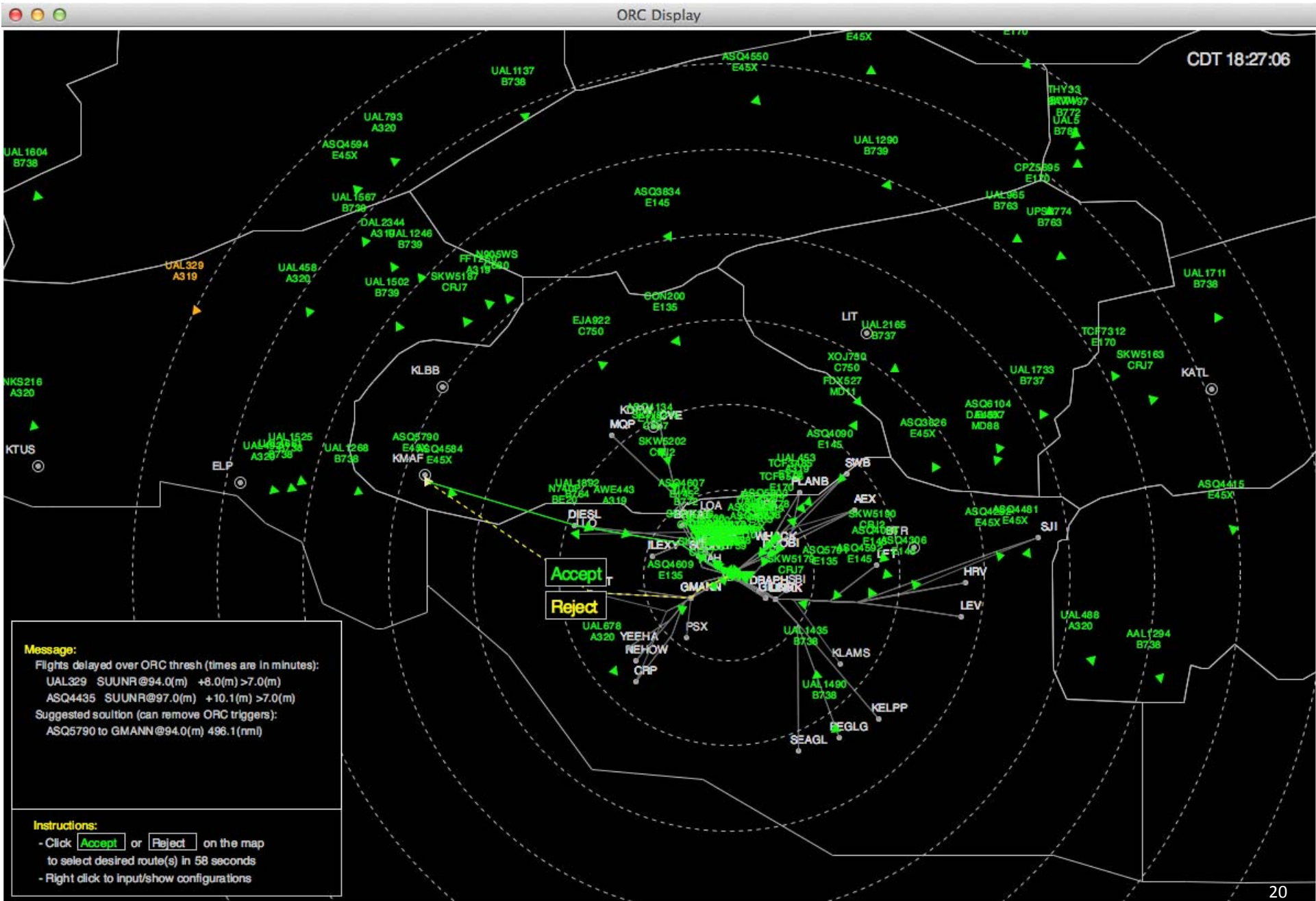
- Intelligent off-loading of over-loaded meter fixes
- Data-driven processes to predict when capacity limits will be exceeded
- Ability to identify optimal path routing options to balance capacity

- Improving overall system efficiency by utilizing data-driven traffic flow management decisions to optimize route configurations
- Reducing delay and fuel consumption by minimizing the need for holding and tactical maneuvering (i.e., vectoring)
- Enhanced utilization of Performance-Based Navigation (PBN) routing and other NextGen capabilities
- Augments today's metering capabilities

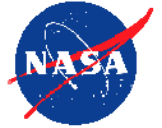
- 18



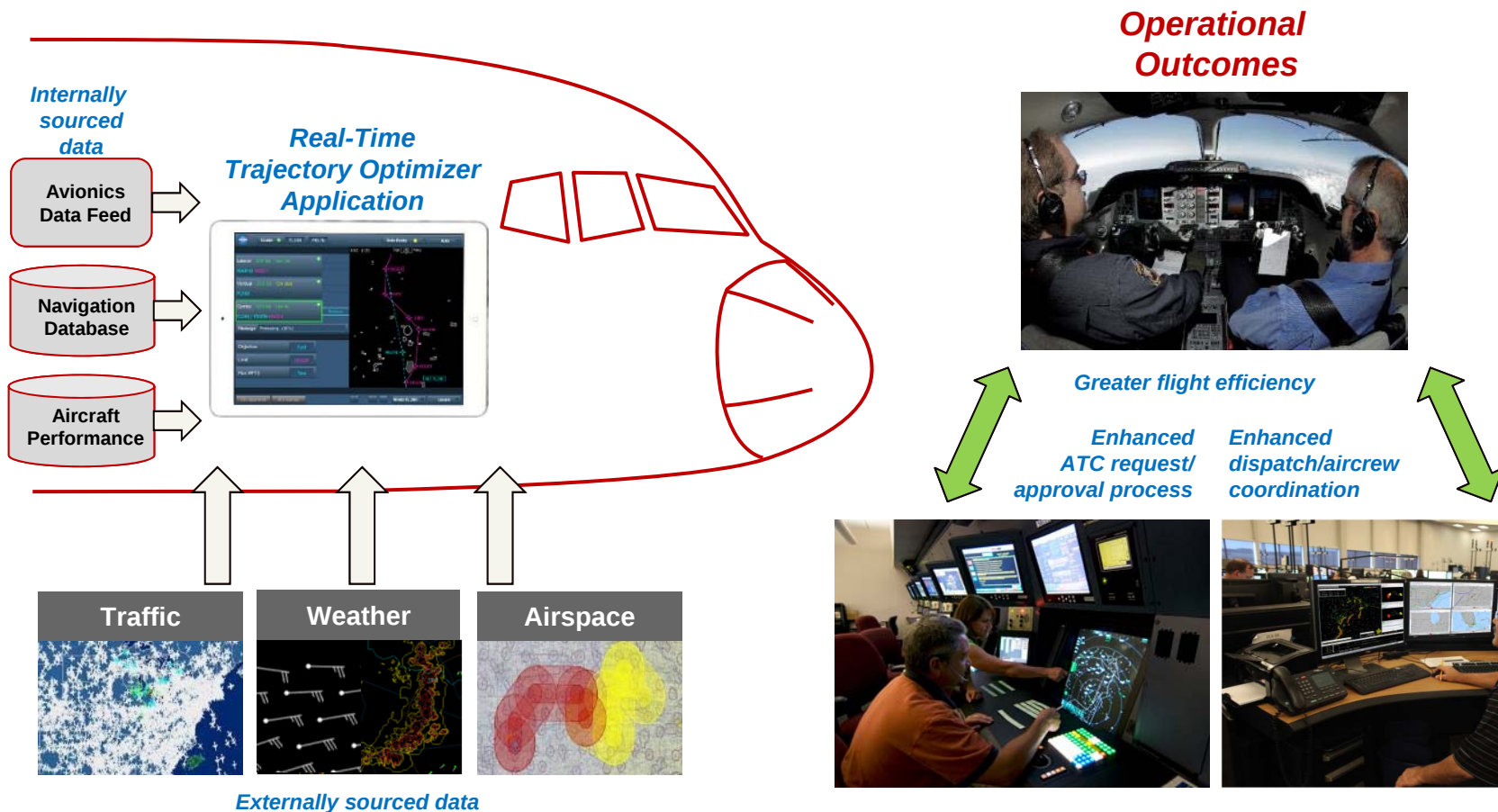
Mock display of recommended route option presented to Traffic Management Coordinator



Traffic Aware Strategic Aircrew Requests



Cockpit Automation for optimizing an aircraft's trajectory en route that leverages **Networked Connectivity** to real-time operational data to produce a greatly **Enhanced User Request Process** for users and service providers



Traffic Aware Planner (TAP) Software Application



Consumer of Cockpit Connectivity

Connects to avionics via standard interfaces

Ownship flight data, ADS-B traffic data

Optional connectivity to external data sources

Latest winds, weather, airspace status, etc.

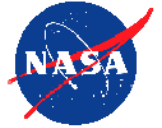
Computes real-time route optimizations

- Integrates optimization with conflict avoidance (traffic,
- Produces lateral, vertical, and combo solutions
 - o *Powerful pattern-based genetic algorithm*
 - o *Processes 400-800 candidates every minute*
- Computes time/fuel outcomes
- Displays solutions and outcomes to the pilots for selection

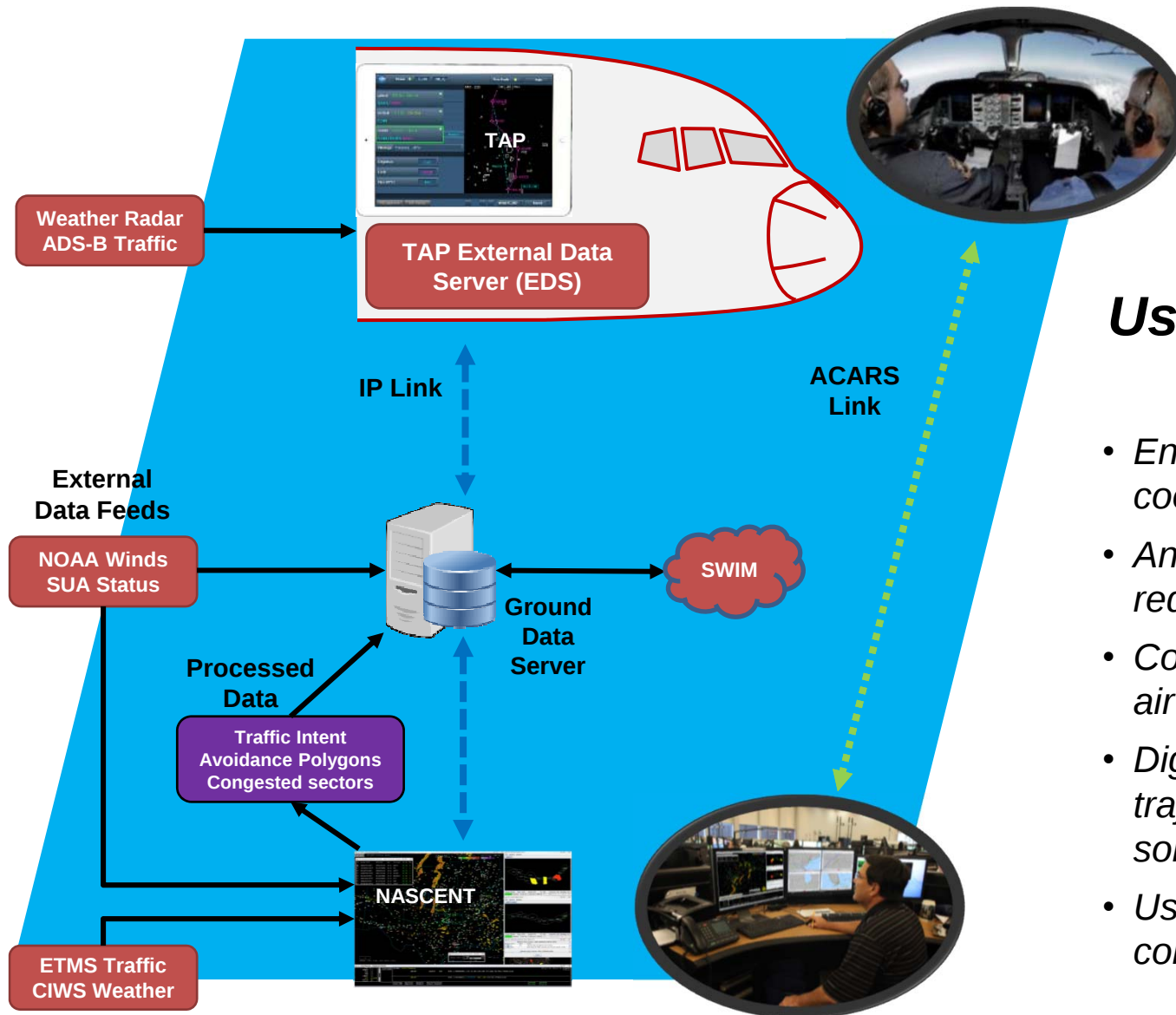
Analyzes pilot-entered route changes

- Touch-screen interface for easy entry
- Displays time/fuel outcomes
- Indicates conflicts with traffic, weather, airspace





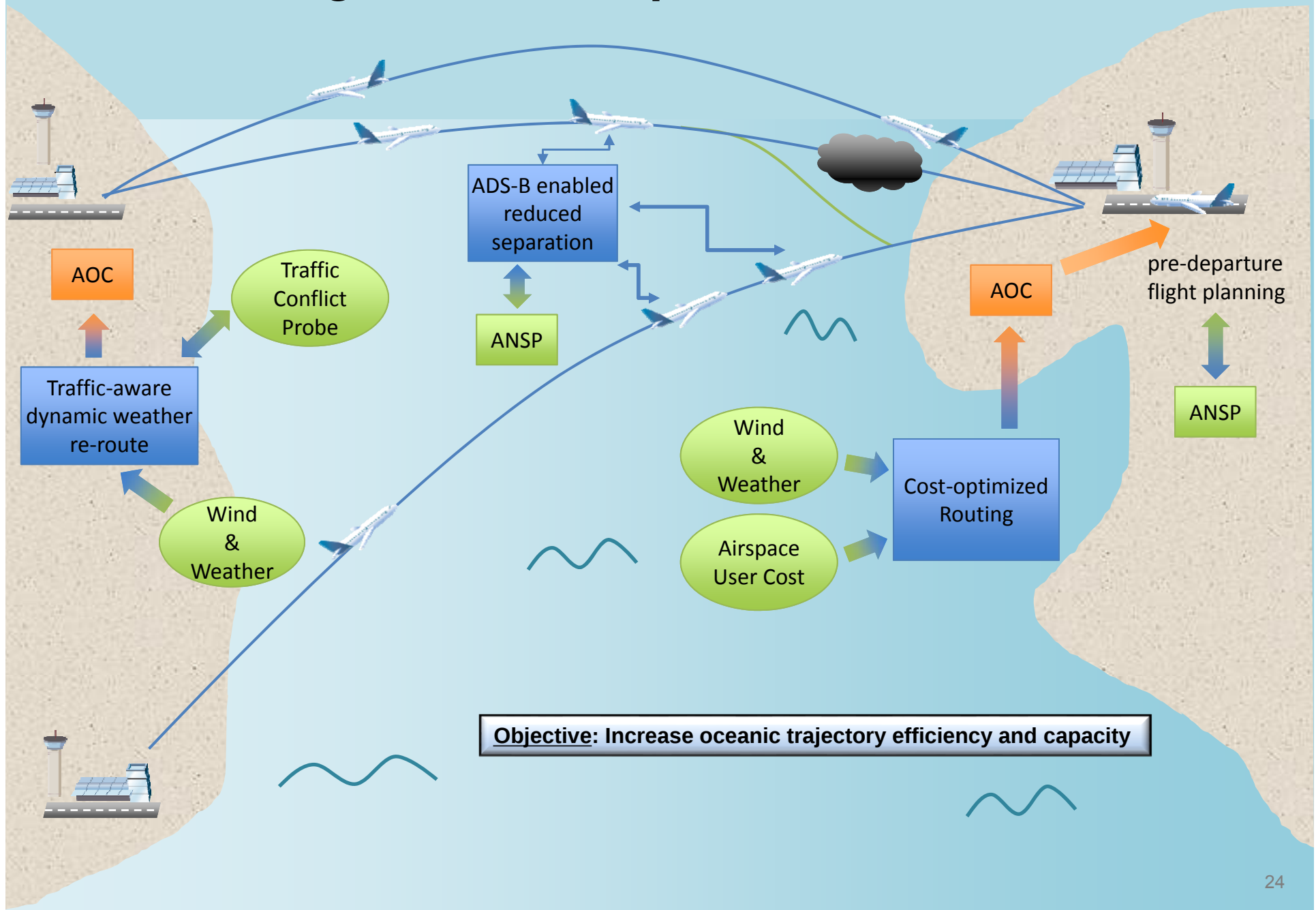
ATD-3 Air/Ground User Integration



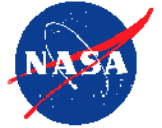
User Integration Benefits

- Enhanced pilot/dispatch coordination
- Annunciations of required coordination
- Common data inputs to air & ground automation
- Digital exchanges of trajectory change solutions
- User operational constraints incorporation

Oceanic Integrated Concept



Dynamic Cost-Optimal Routes

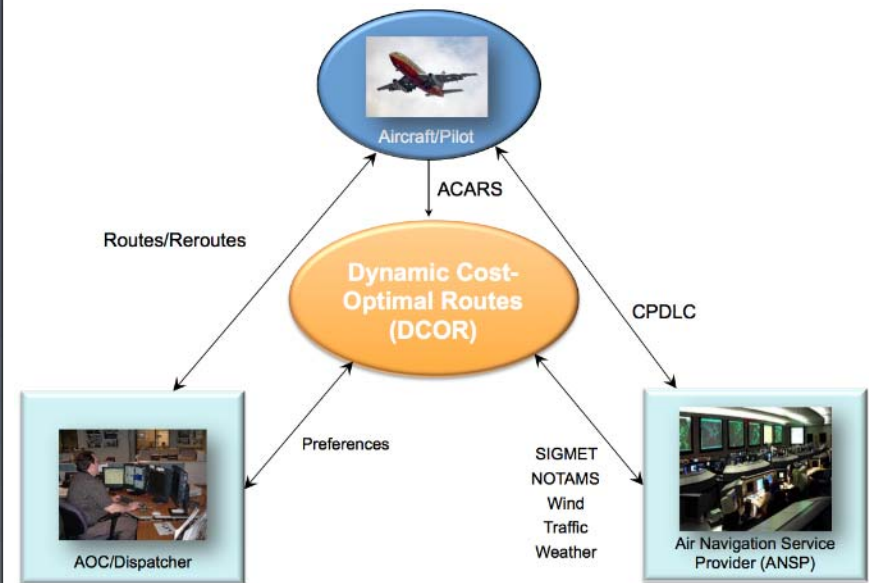


- **Capability**

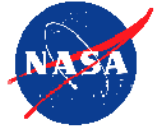
- Pre-Departure Planning of Routes (PDPR)
Cost-optimal routes minimizing fuel, time and airspace costs and comparative analysis of fuel savings
- Dynamic Planning of Re-routes (DPR)
Continuous automated monitoring of en route flights against changes in wind, weather and congestion, provides reroute advisories

- **Benefits**

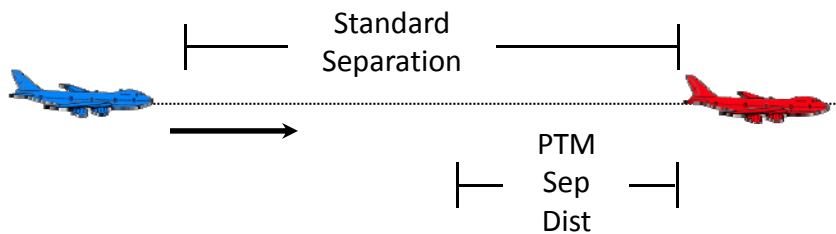
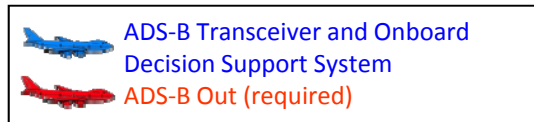
- Flexible, more efficient, automated route planning and benefits information, with situation awareness, for AOC
- Automated dynamic searches for efficient re-routes based on most current en route information
- Average savings of 4%, varying from 2% to 6% depending on city-pairs and seasons
- Actual savings from 1300 lb to 3000 lb of fuel depending on type of aircraft and city-pair



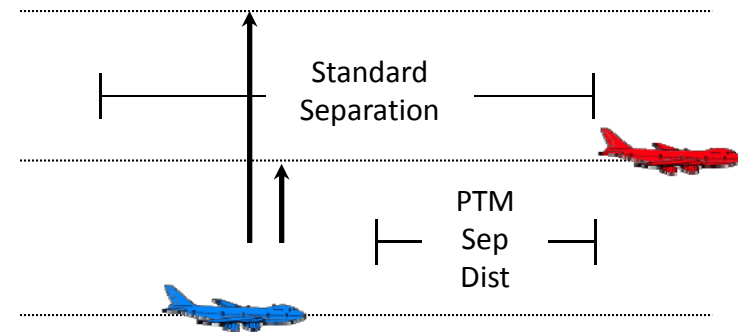
Pairwise Trajectory Management (PTM)



PTM Oceanic Operations – Sample Scenarios



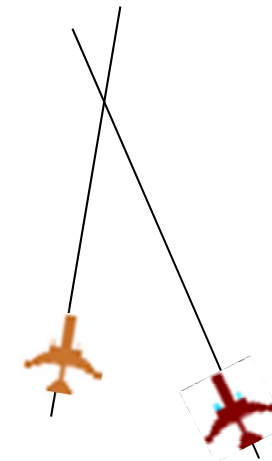
Same Route Co-Altitude



Same Route, Altitude Change

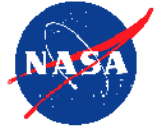


Same-Track Loading, Multiple Aircraft Interactions (Track Loading)

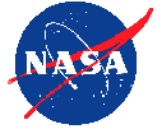


Intersecting Routes, Same Altitude (constrained geometry)

PTM Advantages



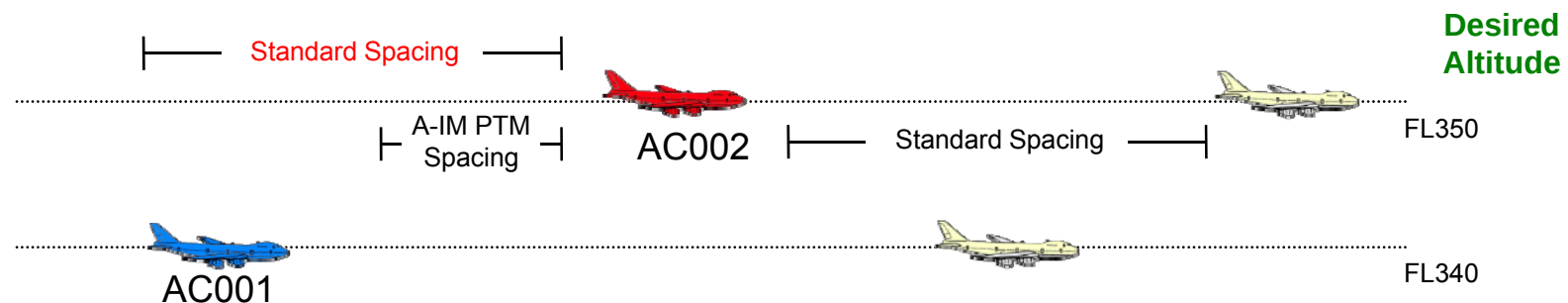
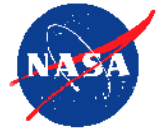
- Separation standards approaching those of domestic airspace
- Increased capacity where desired
- Immediate full benefit as soon as an aircraft is equipped
- No communication upgrades needed
- No recurring costs (one time investment)
- No additional controllers needed; however, additional workload expected
- PTM Requirements
 - Datacom (e.g., CPDLC) and therefore likely FANS 1/A
 - ADS-B In equipage
 - o Similar to FIM equipment (traffic processor, CDTI, forward display)
 - o Bundles with other ADS-B in applications to aide business case



PTM Concept Overview

- PTM enables a new separation standard for ATC
 - Uses ADS-B In Surveillance
 - Delegated airborne separation application
- Flight crews do not request a PTM operation. Rather, ATC issues a PTM clearance to resolve potential conflicts
- Crews are given speed guidance and situation awareness necessary to manage their spacing relative to proximate aircraft
- When conventional separation is available, the controller can terminate the PTM operation and reassumes separation responsibility
- Equipage requirements
 - Traffic Processor
 - Speed guidance and traffic awareness (CDTI) displays
 - DataComm (CPDLC)
- Concept does not require ATC monitoring for intervention under normal operation

PTM Concept Overview – Same Track



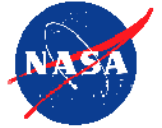
Controller/Automation

- Step 2: Identifies traffic conflict @ FL350
 - ☒ A-IM PTM aircraft involved
 - ☒ Aircraft are within nominal ADS-B range
- Step 3: Send A-IM PTM clearance to AC001
- Step 6: Conflict is resolved by pilot accepting IM PTM clearance; controller issues climb clearance

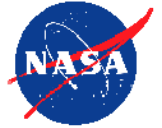
Flight Crew/Avionics

- Step 1: Flight crew makes climb request to FL350
- Step 4: A-IM PTM clearance received
 - ☒ Avionics detects designated aircraft
 - ☒ Avionics provides pending speed guidance that allows aircraft to manage spacing relative to designated aircraft
- Step 5: Accept A-IM PTM clearance; engage A-IM PTM avionics
- Step 7: A-IM PTM aircraft climbs and follows A-IM PTM guidance

Industry Engagement Opportunities

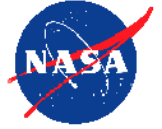


- **Licensing and commercialization**
 - Adapt NASA technology to new user customers
 - Integrate with your COTS products and services
 - Insert your value-added capabilities
- **NASA partnering on air/ground integration**
 - **Airlines:** hosting ATD3 tools in both aircraft and dispatch for evaluation
 - **Airframers:** aircraft adaptation process
 - **Avionics:** supporting partner airlines w/ hardware & adaptation
 - **Information services:** data products to NASA tools
 - **Operations management:** integration of user systems with NASA tools
 - **Operations analysis:** evaluating and improving system performance



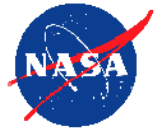
Partnership Opportunities

- Support benefits/cost analysis
- Participate in ConOps development
- Help develop ground automation requirements
- Support (HITL) experiments
 - Supply subject pilots
 - Supply controller subjects
- Support large scale integrated simulations
- Support flight demonstration



Backup Material

Sample of Stakeholder Responders



 THE OHIO STATE UNIVERSITY



Rockwell
Collins



Alaska



American Airlines



PURDUE
UNIVERSITY®



Honeywell



GE Aviation

PASSUR.
AEROSPACE

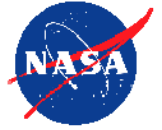
KNOW NOW™

Slide 33

KMR(1

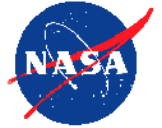
Should we add United Airlines since we are now in touch? L&M liked the fact that we are now talking to them. Sounds like no United was a ding. They have not completed the survey, though.

KOCH, MICHAEL R. (LARC-D318), 5/18/2015

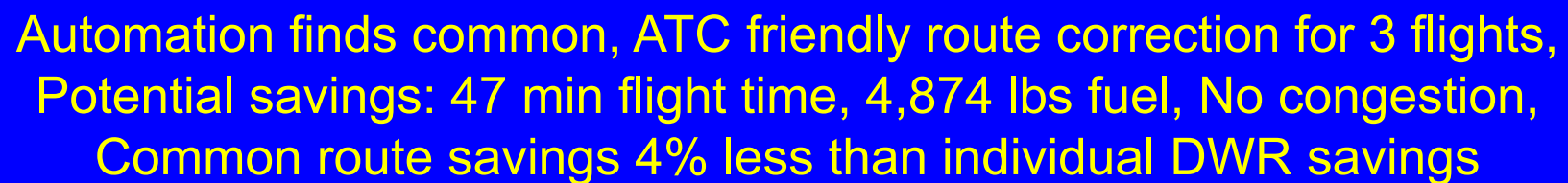


DWR Backup

DWR Test Results

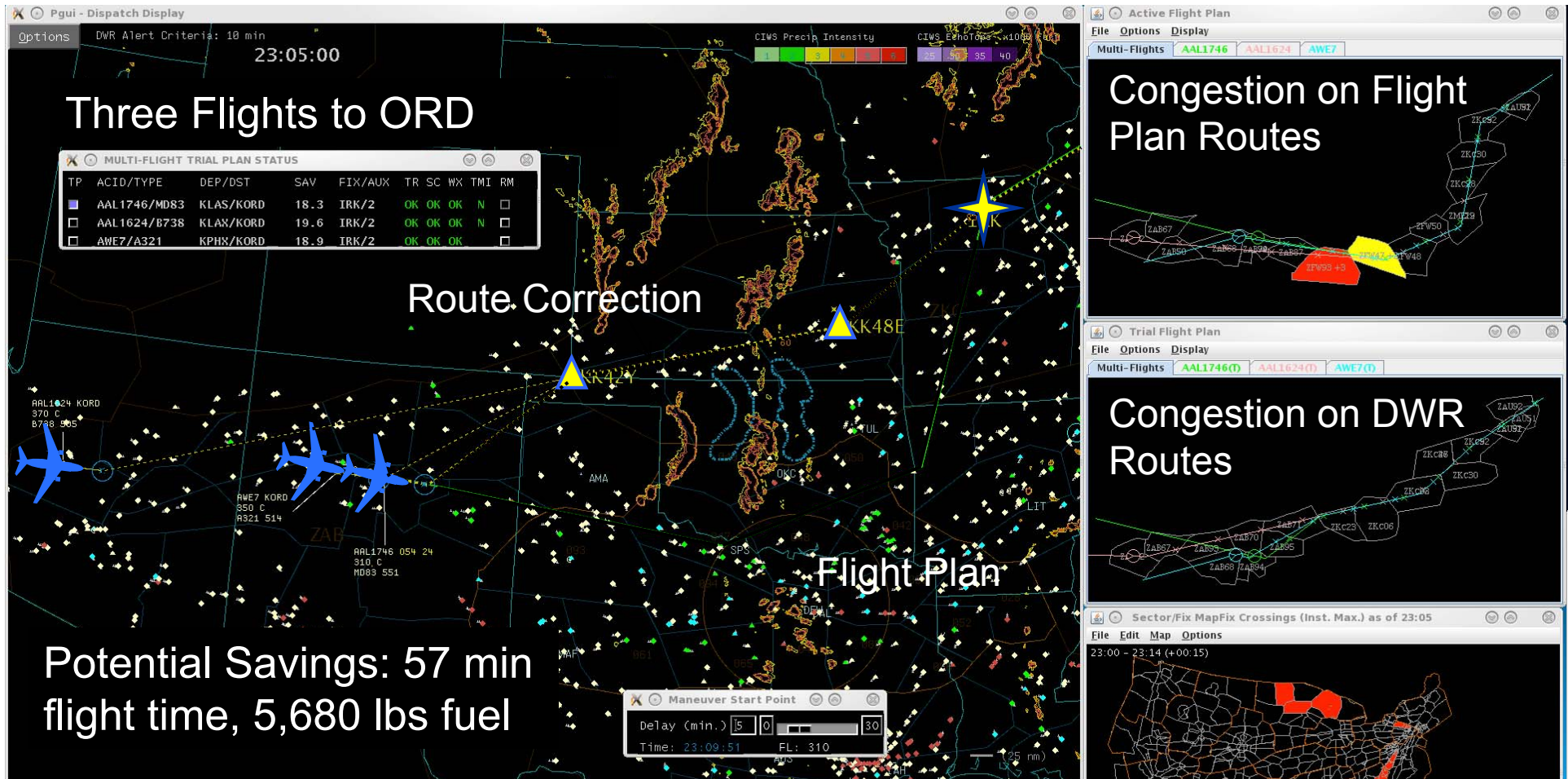
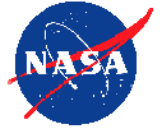


- DWR testing at American Airlines (2012-2014) has clearly established benefit of continuous, real-time automation to identify/advise high-value route correction opportunities
- FAA has noticed. "Opportunities for delay reduction" now a core element of FAA's Collaborative Air Traffic Management Technologies (CATMT) Work Package 5, Strategic Flow Management Application (SFMA)
- Early operational testing with airlines has proven an effective, impactful means for timely proof of concept, and proof of airline benefit



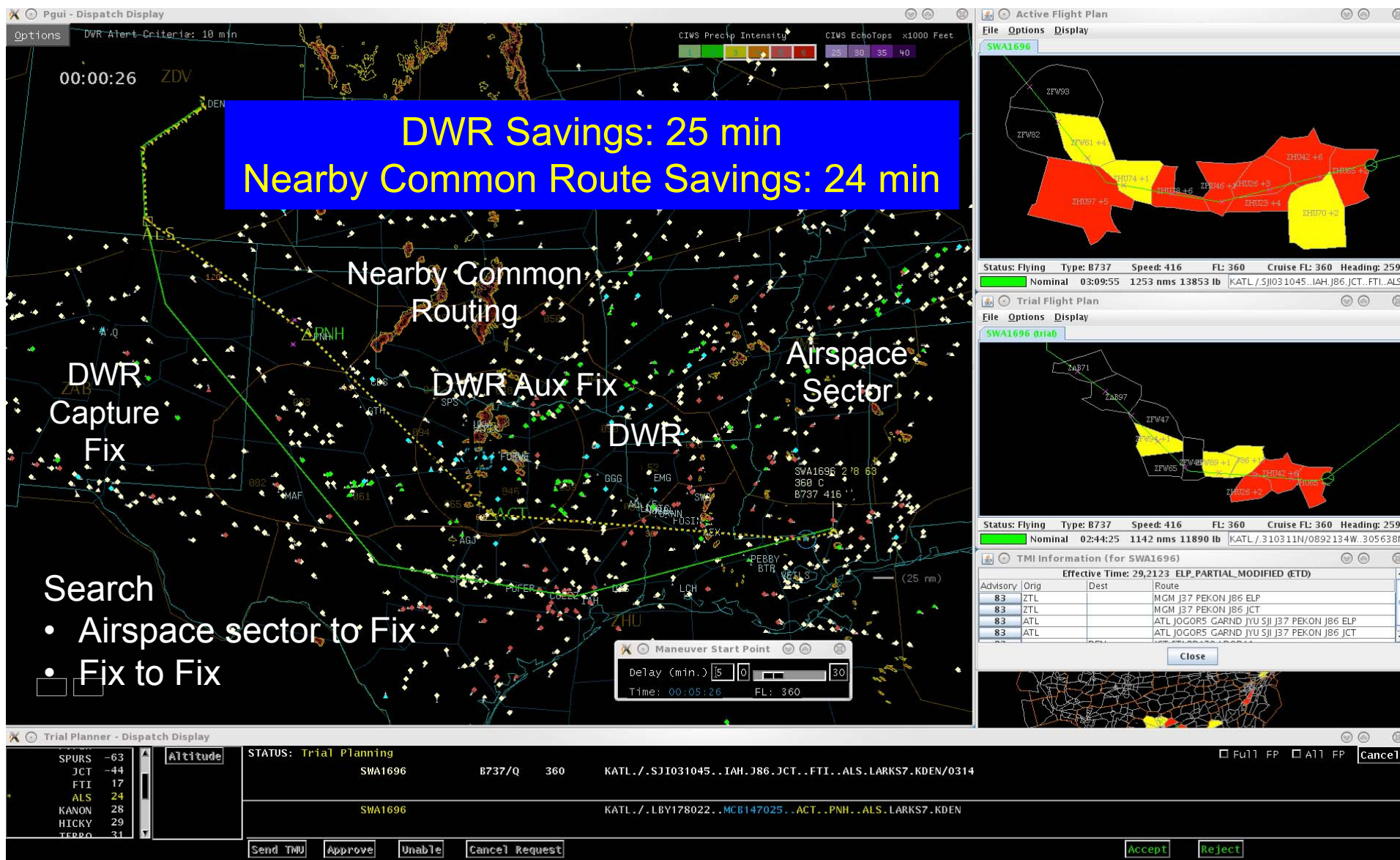
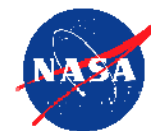
Multi-Flight Common Route

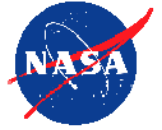
Leverages DWR Software



Automation finds common, ATC friendly route correction for 3 flights, Potential savings: 57 min flight time, 5,680 lbs fuel, Reduces congestion

Data Mining for Common Routings

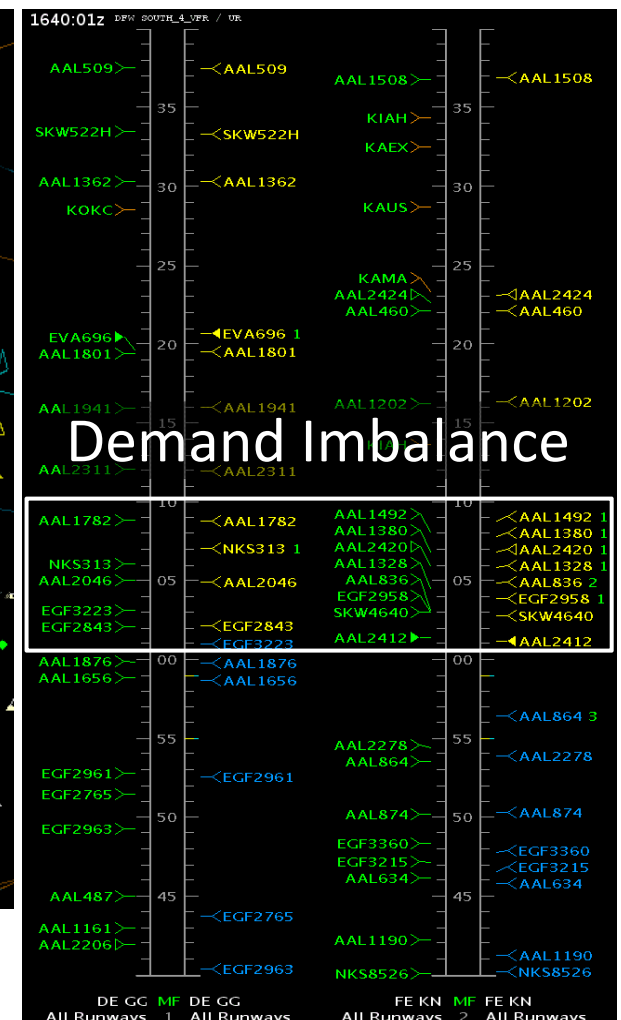
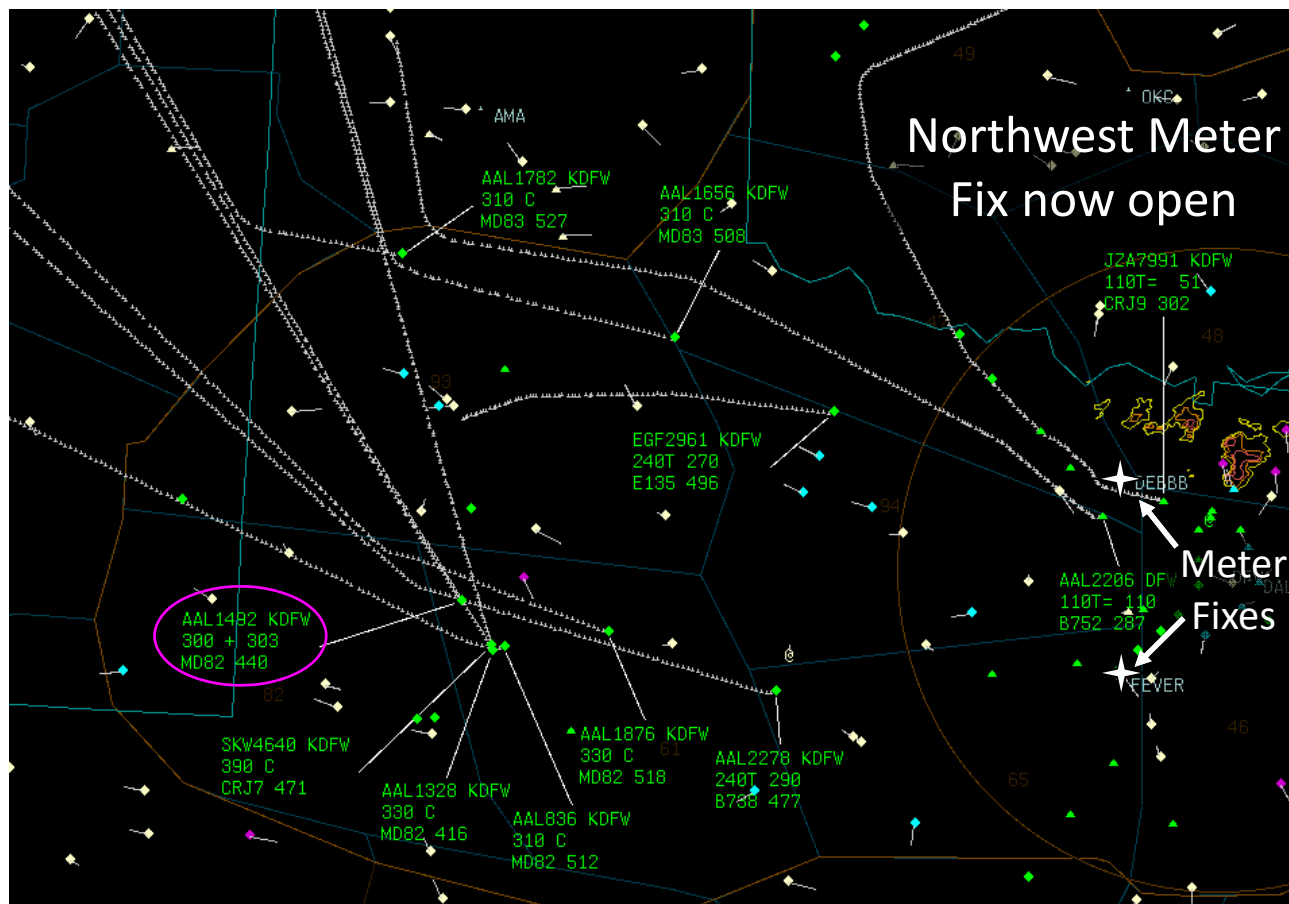
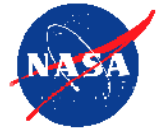




DRAW Backup

Actual Example of Inefficient Arrival Routing

Fort Worth Center (ZFW), March 23, 2013 – 1640z

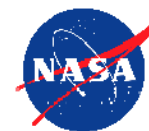


6 flights originating from airports northwest of ZFW on routes to less efficient, more loaded southwest meter fix

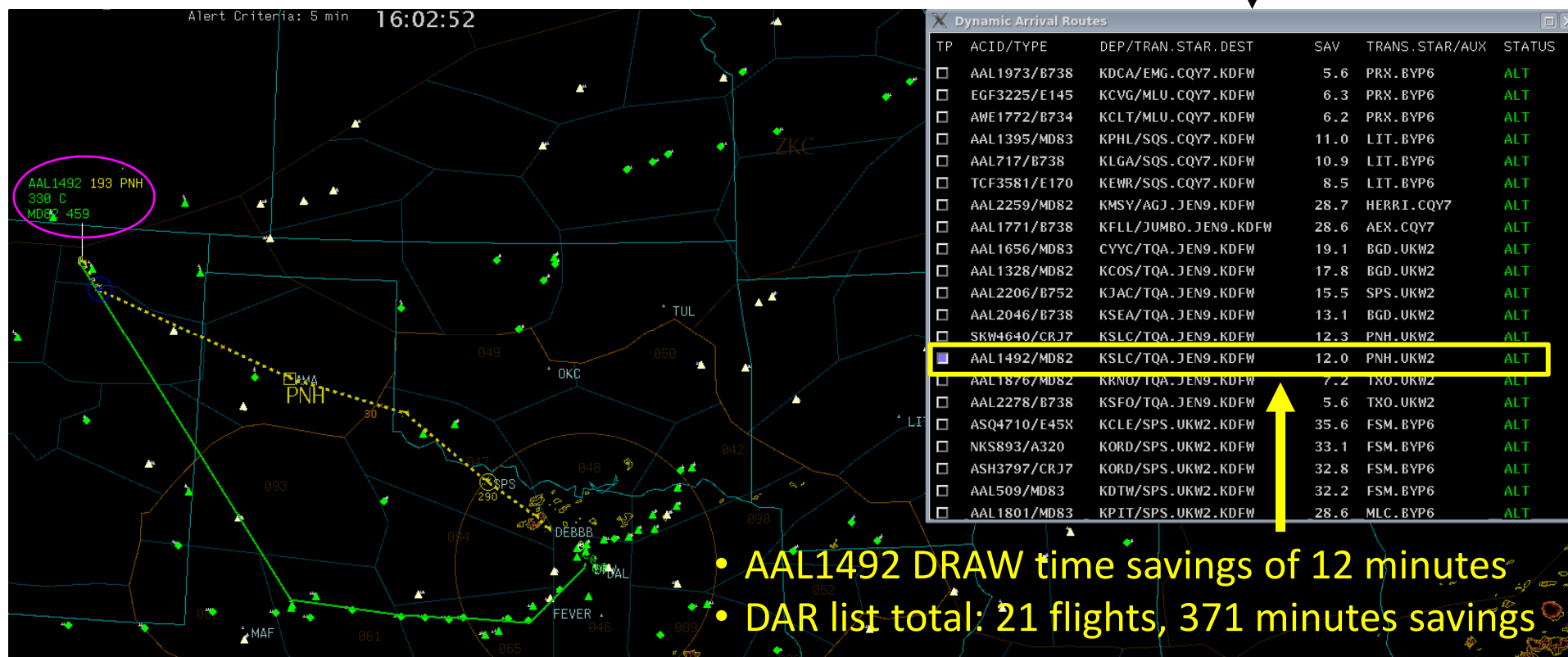
NW Meter Fix
(DEBBB)

SW Meter Fix
(FEVER)

Example of DRAW Time Saving Reroute to Alternate STAR

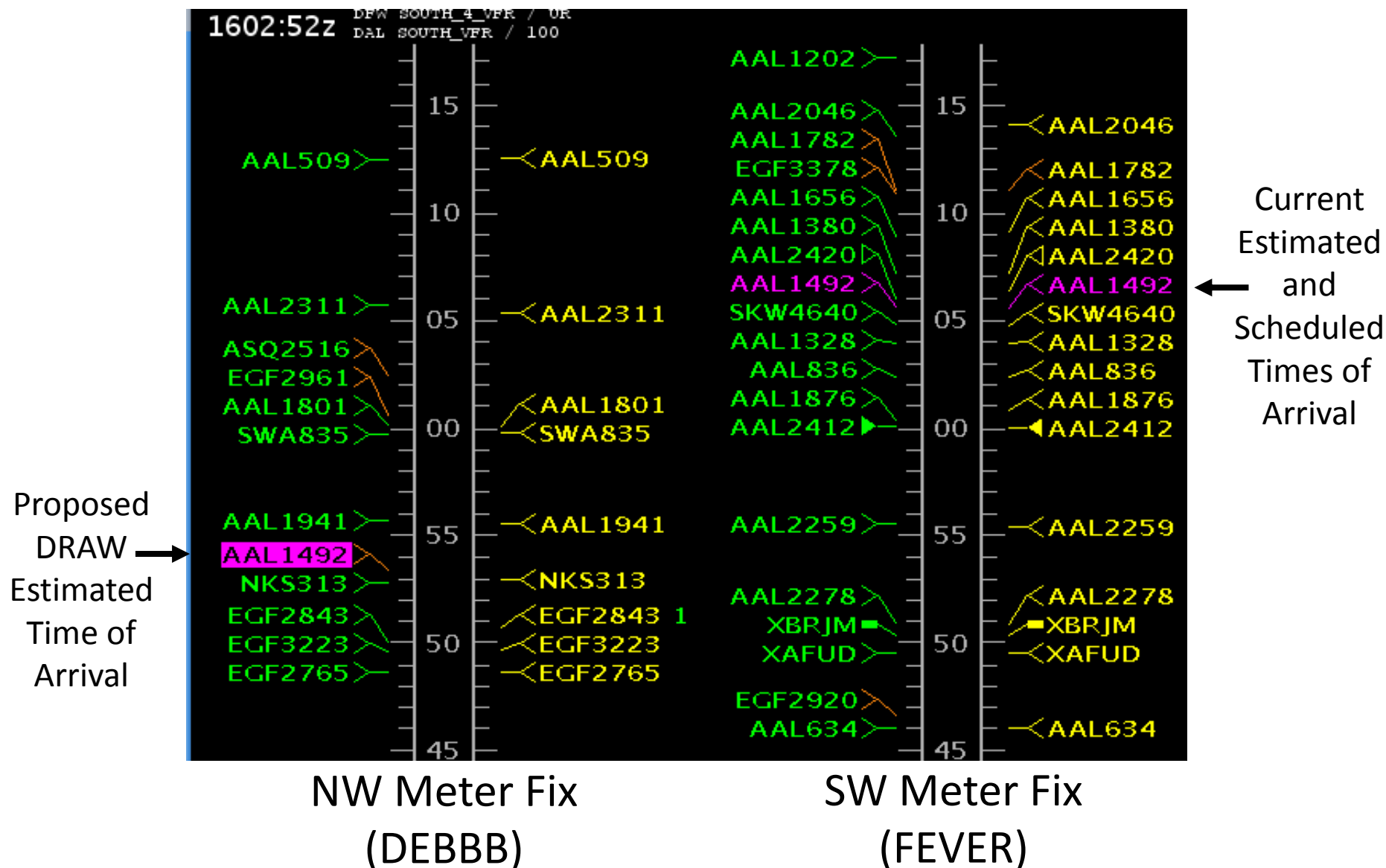
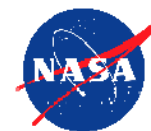


DAR List

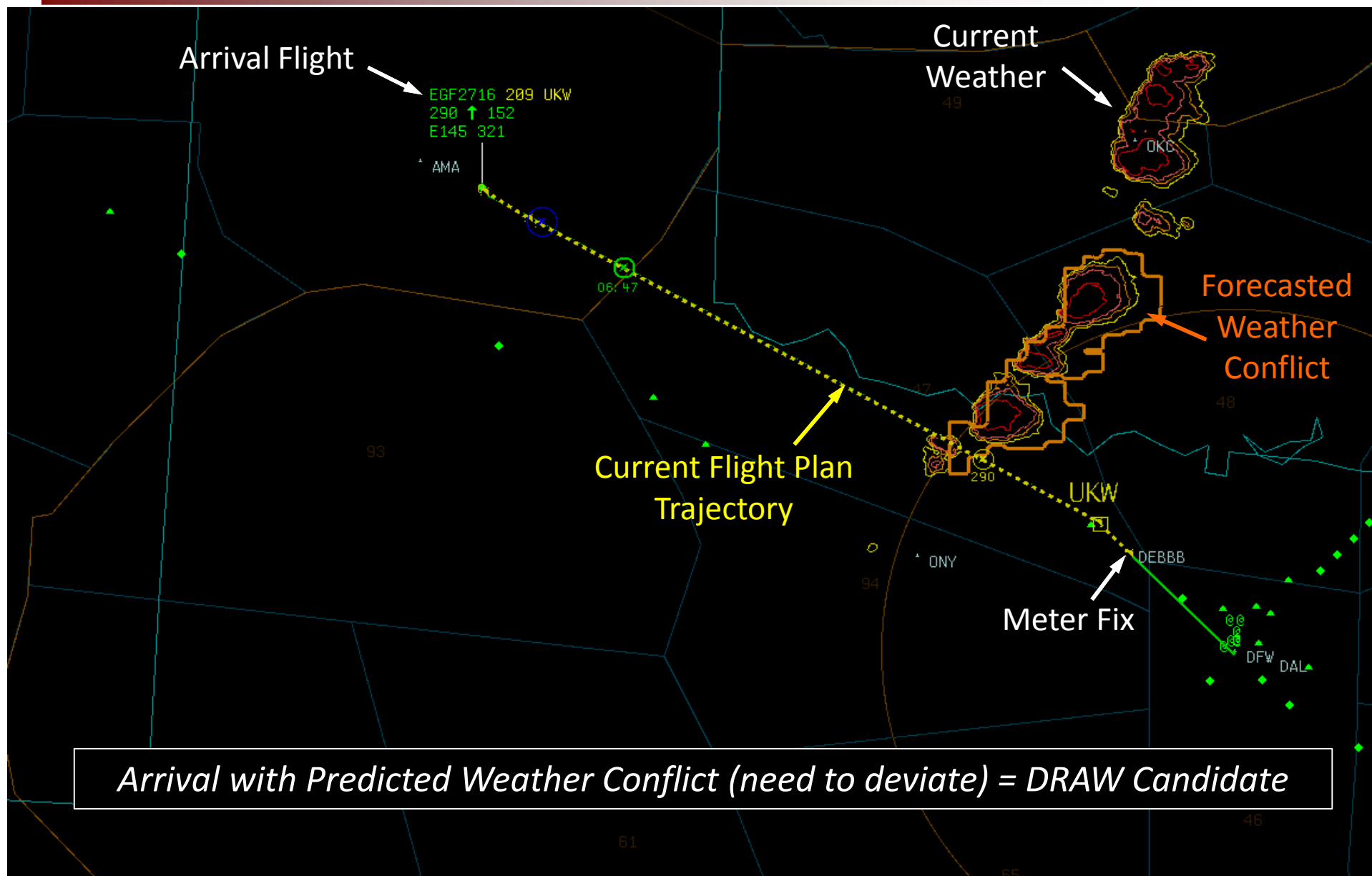
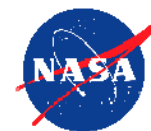


- AAL1492 DRAW time savings of 12 minutes
- DAR list total: 21 flights, 371 minutes savings

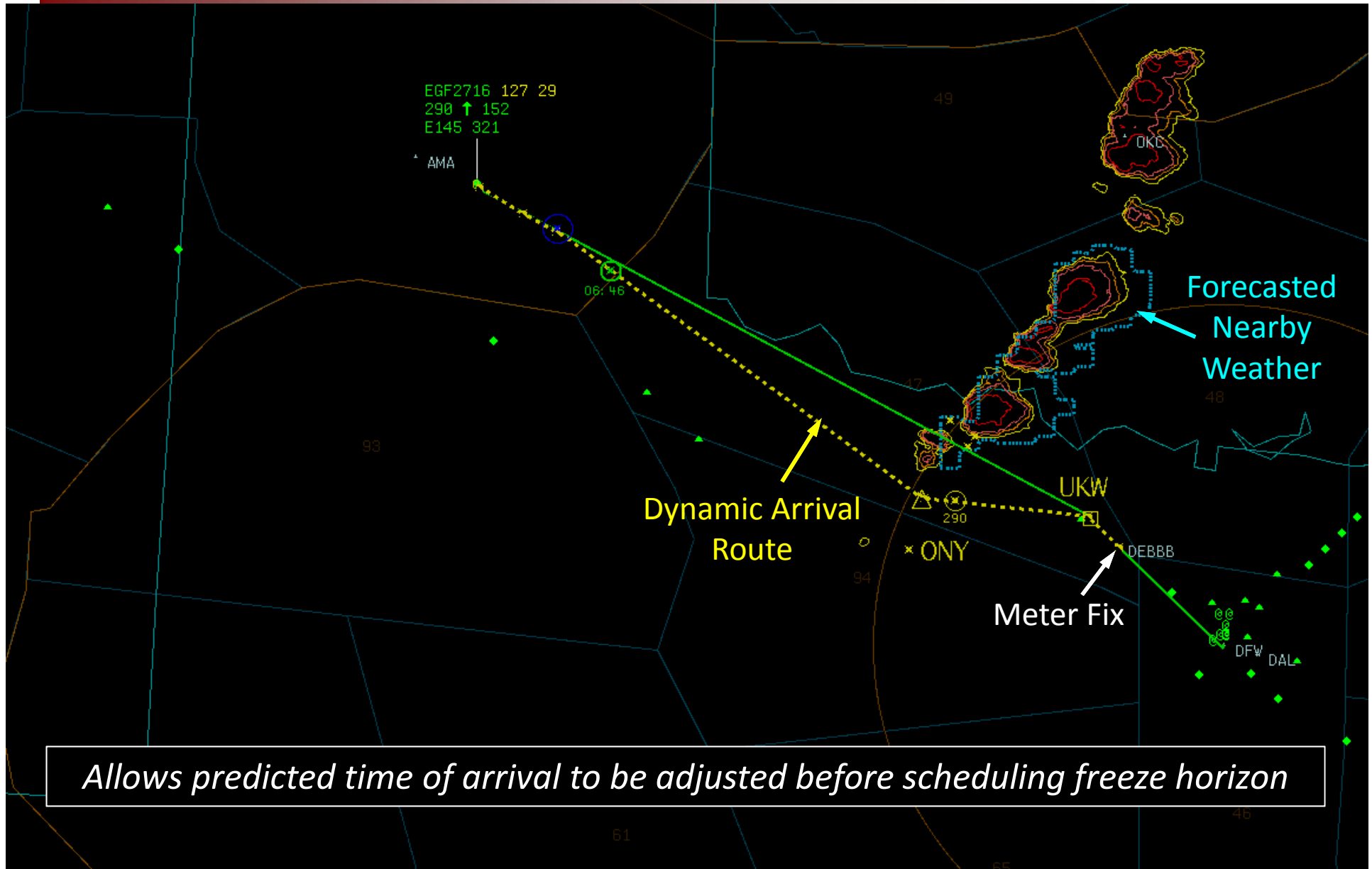
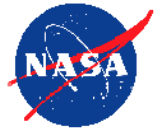
DRAW Integrated with Arrival Scheduling



Predicting the Need to Deviate

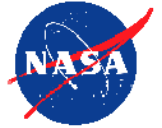


Weather Adjusted Arrival Route

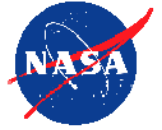


Allows predicted time of arrival to be adjusted before scheduling freeze horizon

ORC - Text

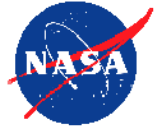


- The Optimized Routing Capability is TFM decision support for arrival fix offloading
 - Proactively alert ATM personnel when demand is projected to exceed capacity (e.g. 30-90 minutes from arrival fix)
 - Identify arrival fix overloading from a time-based scheduling perspective (i.e. excessive projected delay)
 - Analyze route options to alternate meter fixes and associated flight costs (e.g. extra time or distance) and uncertainties
 - Identify minimal cost route options to mitigate projected delay
- Anticipated benefits
 - Enable more efficient routing decisions to be made and implemented earlier
 - Increase arrival throughput by utilizing available capacity at alternate meter fixes
 - Reduce delay and fuel consumption by minimizing the need for holding and vectoring
 - Augment today's metering capability and utilization of PBN routing and Optimal Profile Descents by creating synergy between en-route and terminal TFM

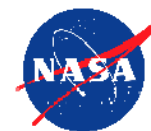


TASAR Backup

An Early Adopter Application



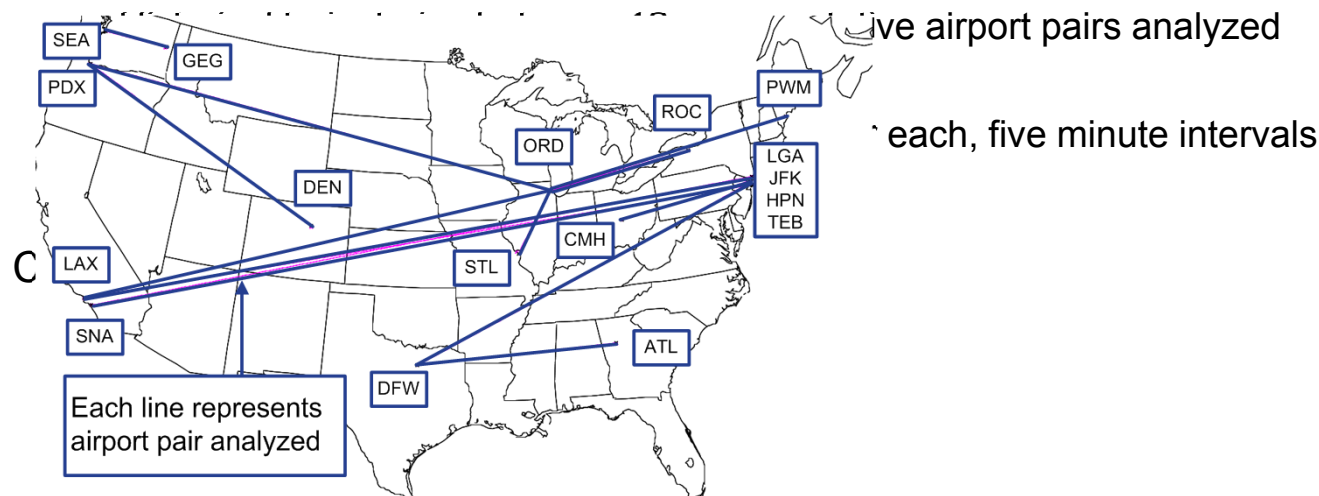
TASAR Attributes	Benefits
Consistent with current operations <i>Requires no changes to existing FAA systems, policies, roles, training</i>	Near term
Low threshold for FAA approval <i>Non-safety-critical intended function</i>	Low Cost
Per-aircraft capability <i>Allows gradual implementation with immediate benefits</i>	Immediate Savings
Leverages aircrew availability / low workload en route <i>Provides more opportunities to accrue benefits</i>	Accelerated ROI
Platform for future innovations in cockpit automation <i>Integrate with avionics, dispatch, data sources, data communications</i>	Growth Potential



Preliminary TASAR Benefits Estimate

All Airspace User Classes are Projected to Benefit

Fast-time simulation study (2012)



- No requests within 200 nmi of destination

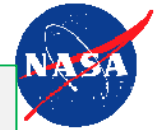
Mean savings per flight

Benefit per operation analyzed for different flight objectives

Class of Airspace User	Time Objective		Fuel Objective		Time/Fuel 50/50 Objective	
	TS	FS	TS	FS	TS	FS
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

TS: Time savings (minutes) FS: Fuel savings (pounds)

TASAR Safety, Certification, and Operational Approval



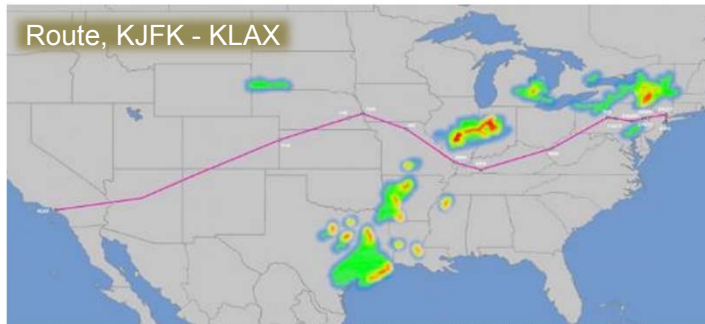
As currently defined, TASAR has a low threshold for FAA certification & operational approval

- **Analyses by Rockwell Collins under contract to NASA**
 - Analysis documented in NASA-CR/2015-218708
- **Operational hazards / safety requirements**
 - Applied two industry-accepted methods of safety analysis to TASAR
 - Method 1: Traditional system safety process based on SAE ARP 4761
 - Method 2: Operational Safety Assessment per ED78A/RTCA DO-264 (abbreviated)
 - **FEC determination likely to be “Minor” or “No Effect” for workload, “No Effect” for loss of function**
- **Certification and operational approval**
 - Reviewed 17 regulations, standards, and guideline documents
 - Class 2 EFB – no special requirements beyond hardware and installation approval
 - Type B application – lightweight compared to other Type B apps
 - **Dry run review by Rockwell Collins DERs, with no cert/approval concerns identified**
- **FAA AIR-130 and AFS-430 officials briefed on TASAR (July 2013)**
 - Safety, certification, operational approval conclusions were confirmed
 - TASAR declared not an “ADS-B In Application”
 - o Rather, it’s a performance/planning app w/ optional ADS-B input
 - No need for an industry “TASAR Standard”
 - **Existing policies allow for TASAR operations now, via POI approval**

DER: Designated Engineering Representative
FEC: Failure Effects Classification
POI: Principal Operations Inspector

TASAR Simulation Experiments

Aug 2013, Oct-Nov 2014



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



ATC Station



U.I. Operator Performance Lab 777 Simulator

Photo by M. Cover



EFB Mounted in Simulator

Photo by M. Cover

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

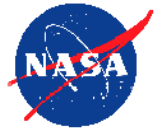
Results

1. No additional workload on the pilots 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

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

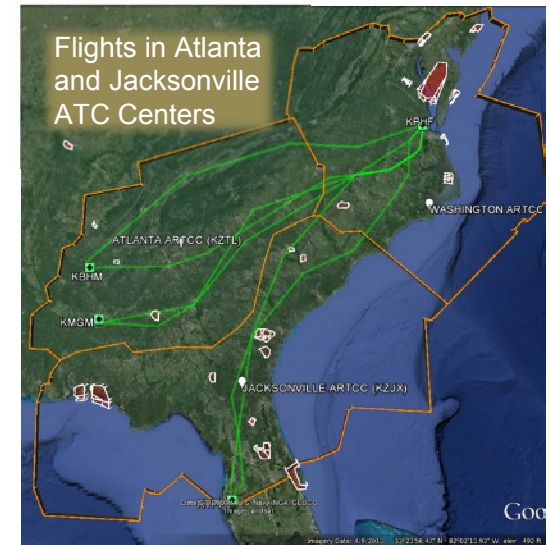
- 54 hours, 21 flights, 17 evaluation pilots
- DC, NY, Boston, Atlanta, Jax Centers
- ATC observations, 50 interviews w/ ATC
- 2 EFBs, UTAS AID, ACSS TCAS 3000SP
- Broadband connection to NOAA winds, FAA SUA status, WSI convection data



iPad AIR



ATC Observations



Flights in Atlanta and Jacksonville ATC Centers

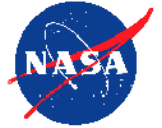
Objectives

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 usability high, workload low
3. ATC provided extensive feedback on user request acceptability factors
4. 2013: 9 of 12 TASAR requests approved

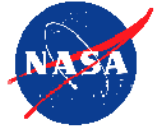
Detailed analysis of 2015 flight trial in progress



For More Information on TASAR

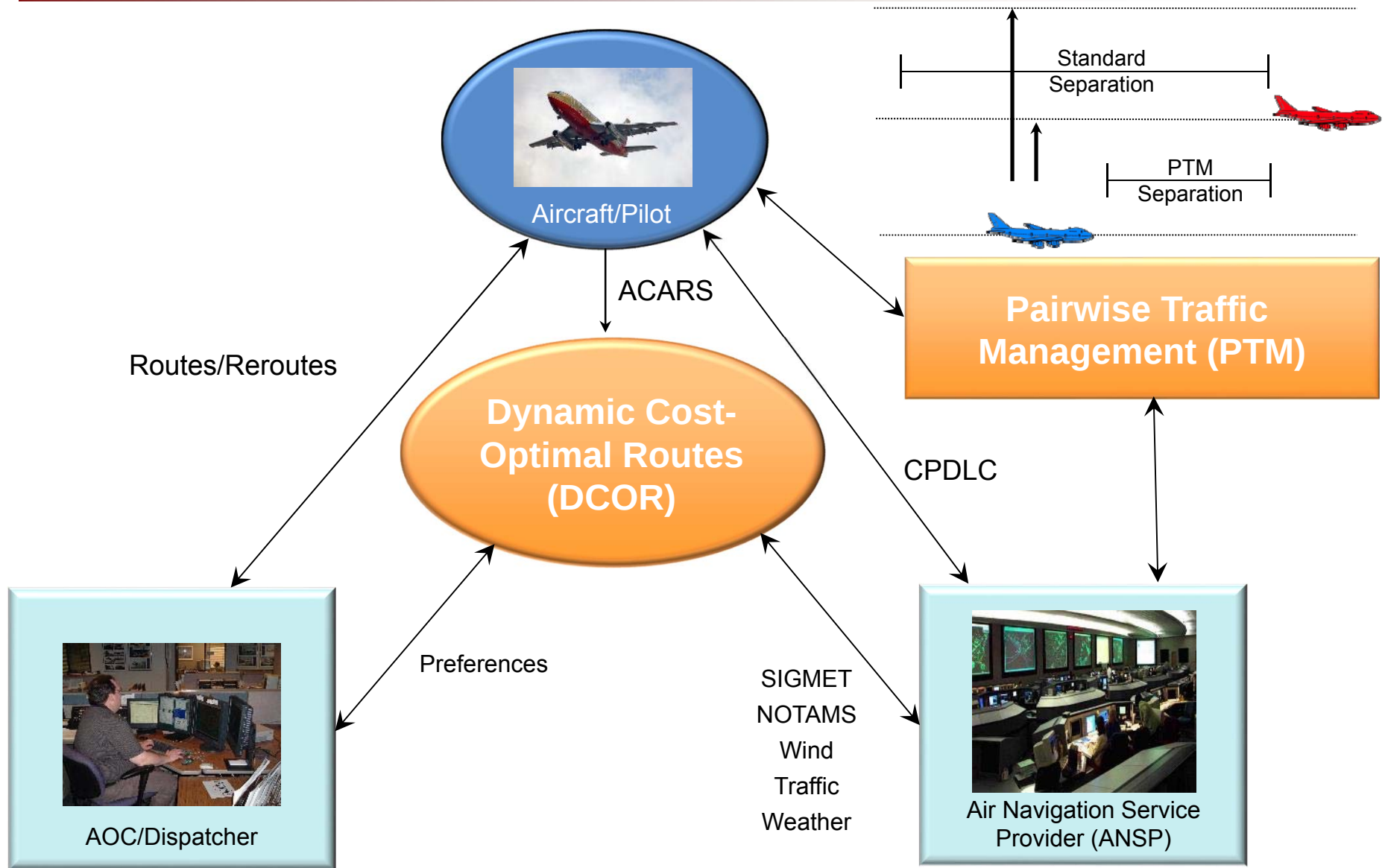
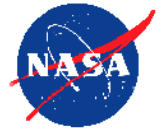
Available at ntrs.nasa.gov

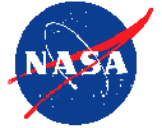
- **Project summary & status**
 - AIAA-2015-3400, AIAA-2013-4231
- **Concept description**
 - NASA/CR-2013-218001, AIAA-2012-5623
- **TAP software application description**
 - AIAA-2013-4967, AIAA-2013-4968
- **User benefits**
 - AIAA-2012-5684, NASA/CR-2015-218786, NASA/CR-2015-218787
- **Safety and operational hazards**
 - NASA/CR-2013-218002, DASC.2013.6712530
- **Certification and operational approval**
 - NASA/CR-2015-218708, DASC.2013.6712530
- **HITL simulation experiments (2013, 2014)**
 - Pending NASA TM (HITL-1, 2)
- **Flight Trials (2013, 2015)**
 - AIAA-2014-2166, NASA-CR-2015-218673 (FT1), Pending NASA TP (FT2)



Oceanic Backup

Oceanic Integrated Air/Ground Architecture

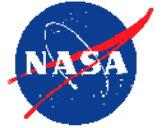




PTM in a Nutshell

- **Goal:** Improve efficiency of oceanic operations
- **Barrier:** Limited communication and surveillance
 - Large separation standards
 - Limits Capacity
 - Prevents aircraft from flying optimal altitude and speed
- **Operational Objectives**
 - Leverage ADS-B In technology to improve surveillance and reduce separation standards on a pair-wise basis
 - Provide capacity where it is needed
- **Benefits**
 - Reduced fuel burn
 - Reduced delay
 - Reduced CO2 emissions

PTM in a Nutshell



NEED



CHALLENGE

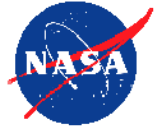
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OPPORTUNITIES

→ Flights desire an optimal altitude for efficiency or ride quality

→ The combination of locally dense traffic and large spacing minima limits number of aircraft per altitude

→ Use PTM to enable more aircraft to operate at desired altitudes

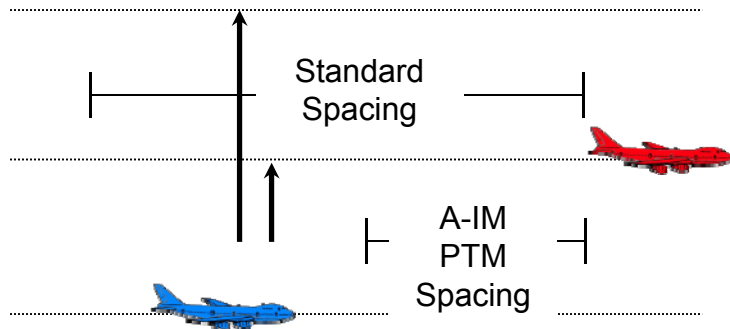


PTM Concept Overview

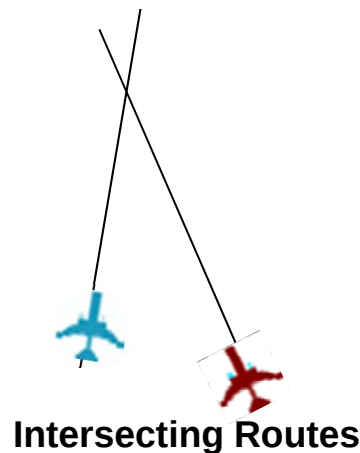
- **Operational Objective:** Use airborne surveillance and tools to manage reduced “at or greater than” inter-aircraft spacing of ATC assigned aircraft pairs that results in reduced fuel burns and delays
- **Mechanism:** Advanced Interval Management (A-IM) PTM equipment and procedures enable reduced oceanic spacing distances which will allow more aircraft to fly at their preferred altitudes for greater periods of time; providing additional capacity where aircraft desire to operate



■ Sample scenarios



Same Route, Altitude Change



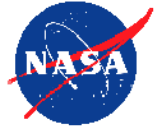
Intersecting Routes

Characteristics

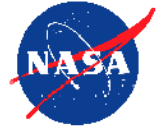
- **Significant air/ground coordination**
- **Unique enabling capabilities include:**
 - Coincident & non-coincident routes
 - Up to 8 targets which can be ahead or behind the PTM aircraft and can be at a different altitudes
- **Significant operational flexibility**

A-IM Pairwise Trajectory Management (A-IM PTM)

Other efforts to reduce oceanic separation distances



- Spaced-Based ADSB
 - Targeting 15 NM Longitudinal Separation
 - Requires significant investment with high usage cost to support that investment
 - Requires some aircraft investment if FANS 1/A is not a part of the aircraft's current equipage
- FANS 1/A and RNP-4 equipage
 - Targeting 30/30 separation
 - Requires some aircraft investment if FANS 1/A is not a part of the aircraft's current equipage

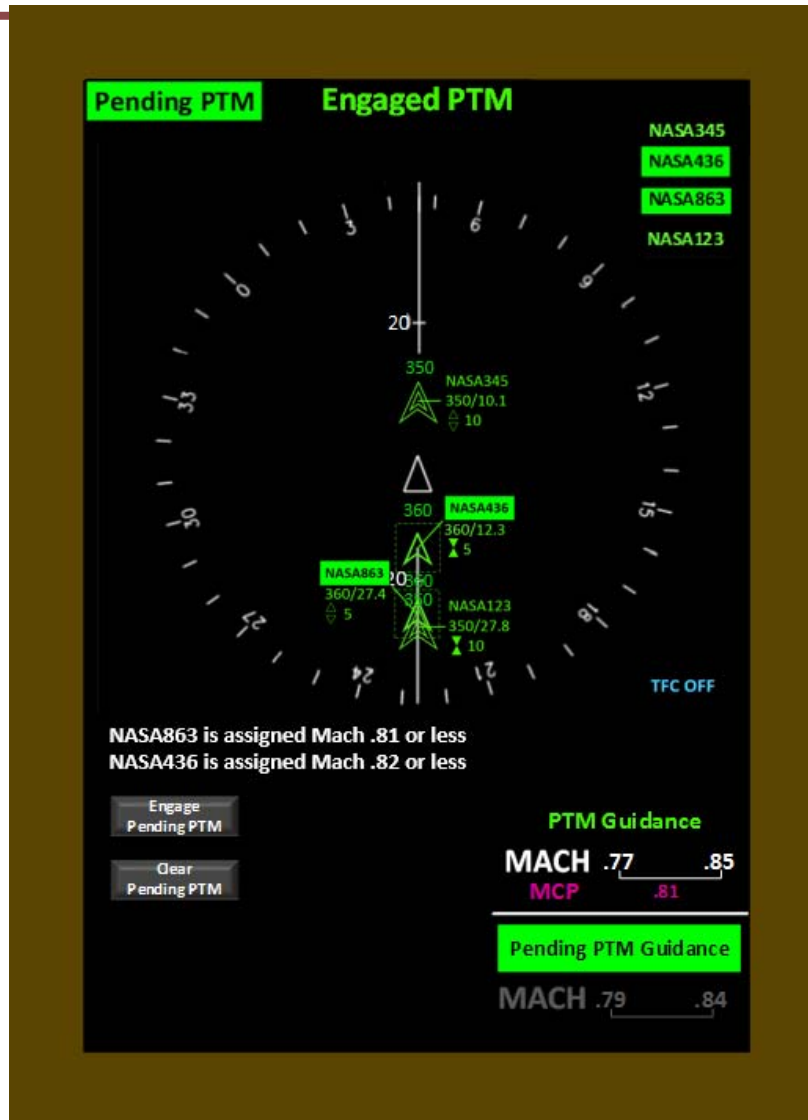
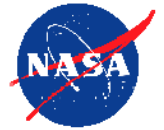


Oceanic Capacity Constraints

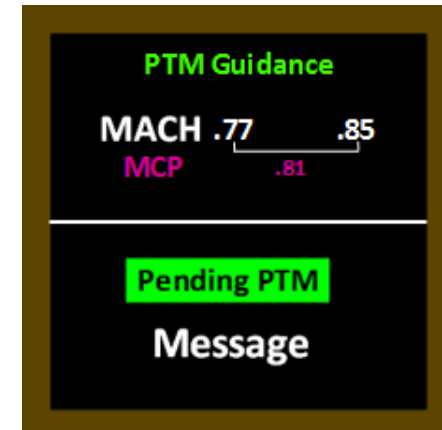
- Large separation standards in oceanic airspace (currently 30-120 NM) limit an aircraft's ability to fly optimal trajectories (altitude and speed) resulting in increased fuel burn
 - Unable to climb due to conflicting traffic
 - Suboptimal speeds due to same route, co-altitude traffic
- Separation standards determined by Communication, Navigation, and Surveillance
 - Better equipped aircraft enable smaller separation requirements
 - Assigned separation between two aircraft is determined by the least equipped
- Wide equipage variance: Example – 2012 Central East Pacific data: 90% get 80 NM, 6% get 50 NM, 3% get 30 NM

FANS 1/A	RNP10	RNP4
23%	99%	17%

Brief Introduction to the PTM HMI

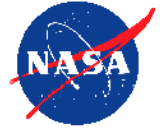


Side-Mounted Display
with touchscreen interface



Configurable Graphics
Display (CGD)

Safety Assessment



- Initial Safety Assessment Complete
- Four Hazards identified
 - PTM-1. Designated or PTM aircraft encounters wake turbulence during a climb or descent maneuver
 - PTM-2. Designated or PTM aircraft encounters wake turbulence while conducting PTM operations at the same flight level
 - PTM-3. Flight crew accepts a clearance with an aircraft for which no PTM spacing exists
 - PTM-4. Flight crew unable to maintain PTM spacing from designated aircraft
- Conducted an allocation of safety objectives and requirements
 - Fault trees
 - Event trees
 - Risk assessment

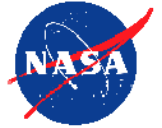
Severity \ Likelihood	Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A					
Probable B					
Remote C			PTM-1		
Extremely Remote D		PTM-2, PTM-4b			
Extremely Improbable E				PTM-3 PTM-4a PTM-4d	PTM-4c

High

5
Medium

2
Low

* Unacceptable with single point and/or common cause failures

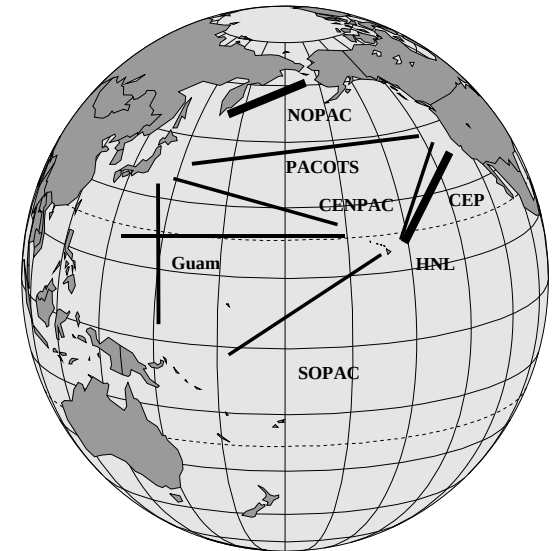
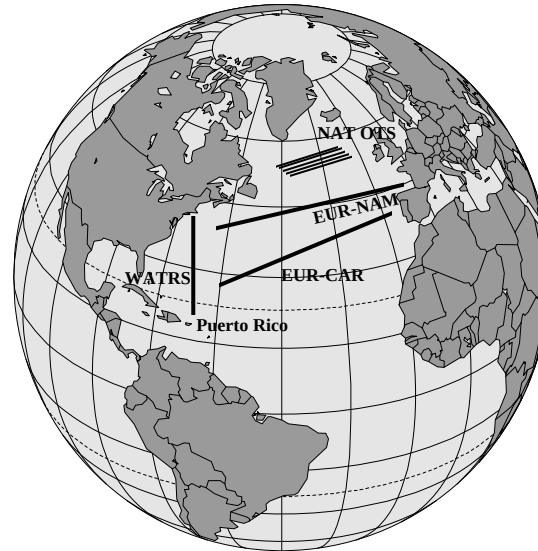


Precedural Airspace

Oceanic Regions and Route Structures

- **Fixed Routes (e.g., CEP)**

- Fixed routes similar to domestic airway structure
- Do not account for changing wind or weather conditions
- Reduce complexity for ATC, but are not always most efficient for airline fuel usage and payload capacity



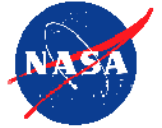
- **Organized Track Systems (e.g., NATOTS, PACOTS)**

- Flexible track system established by ATSP's, utilizing forecasted weather conditions to produce the most time/fuel efficient routes for a representative city pair (established daily)

- **User Preferred Routes (UPRs) (e.g., SOPAC)**

- Optimized routes generated by individual operators based on aircraft type, aircraft loading, weather and flight plan requirements
- Advantages include optimum cruise trajectories (altitudes, routes), improved fuel efficiency, increased predictability on fuel usage and payload capacity

Reduced Oceanic Separation Technologies



- FANS-1/A
 - Employs more frequent ADS-C reports, higher navigation performance, and tighter detection thresholds
 - Parameters requirements (20/20, 15/15)
 - o Numbers are based on collision risk estimations and not on safety assessments.
 - o Bandwidth may not be able to support ADS-C at 4 minute update rates
 - o Mixed equipage operation is a concern
 - o Questionable whether separations will meet SMS objectives w/o additional mitigations
- Space-based ADS-B
 - High cost and it is unclear who is paying for it
 - Recurring subscription costs
 - o Subscription cost does not guarantee benefit
 - o Communication subscription cost required (CPDLC is not good enough to support 15 NM)
 - Significant technical hurdles are not resolved (not a done deal)
 - Government mandate likely
 - More controllers needed
- PTM
 - Separation standards approaching those of domestic airspace
 - Increased capacity where desired
 - Immediate full benefit as soon as an aircraft is equipped
 - Bundles with other ADS-B in applications reducing the cost to equip
 - No communication upgrades needed, no recurring costs (one time investment)
 - No additional controllers needed