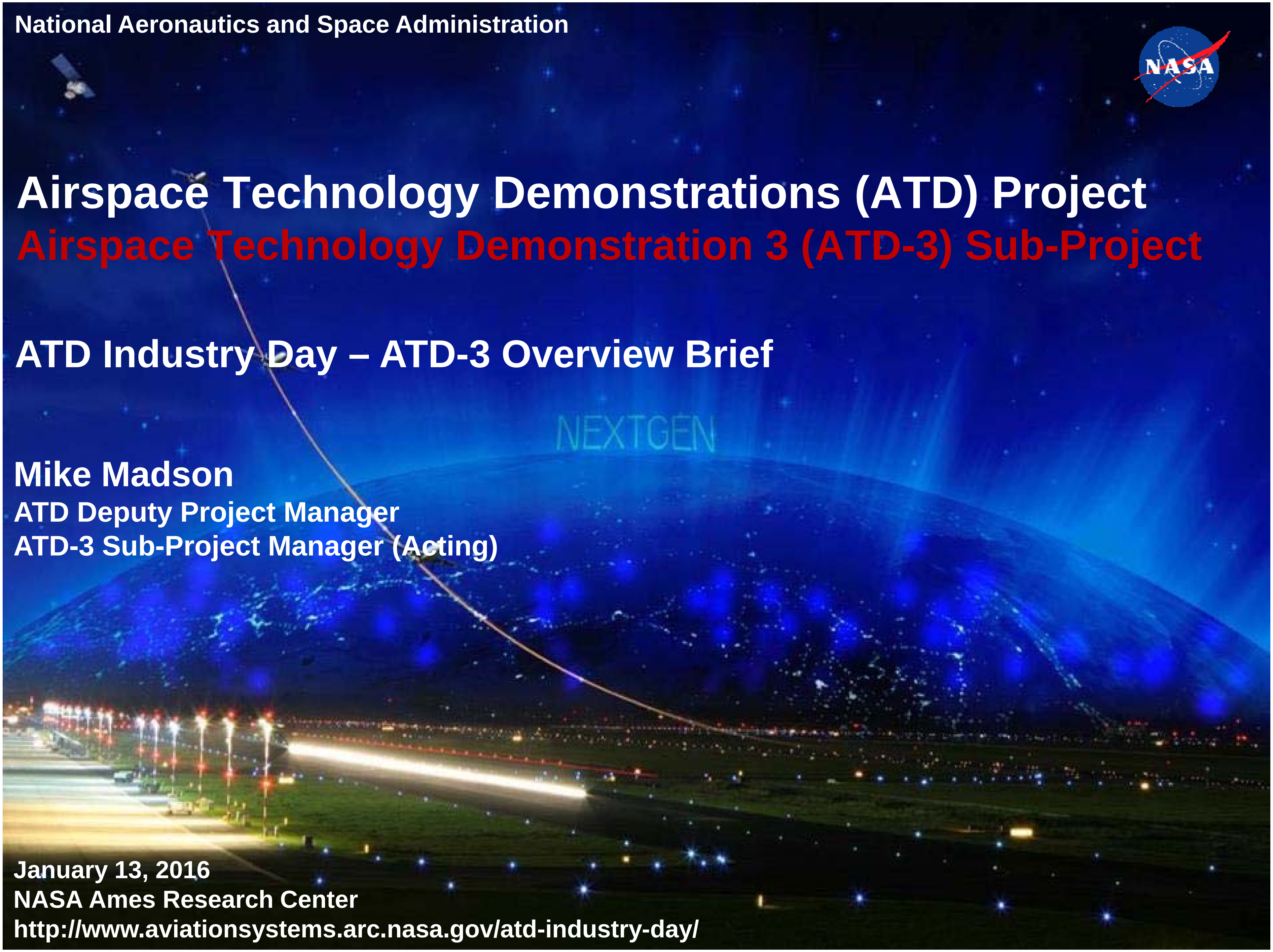
National Aeronautics and Space Administration



Airspace Technology Demonstrations (ATD) Project

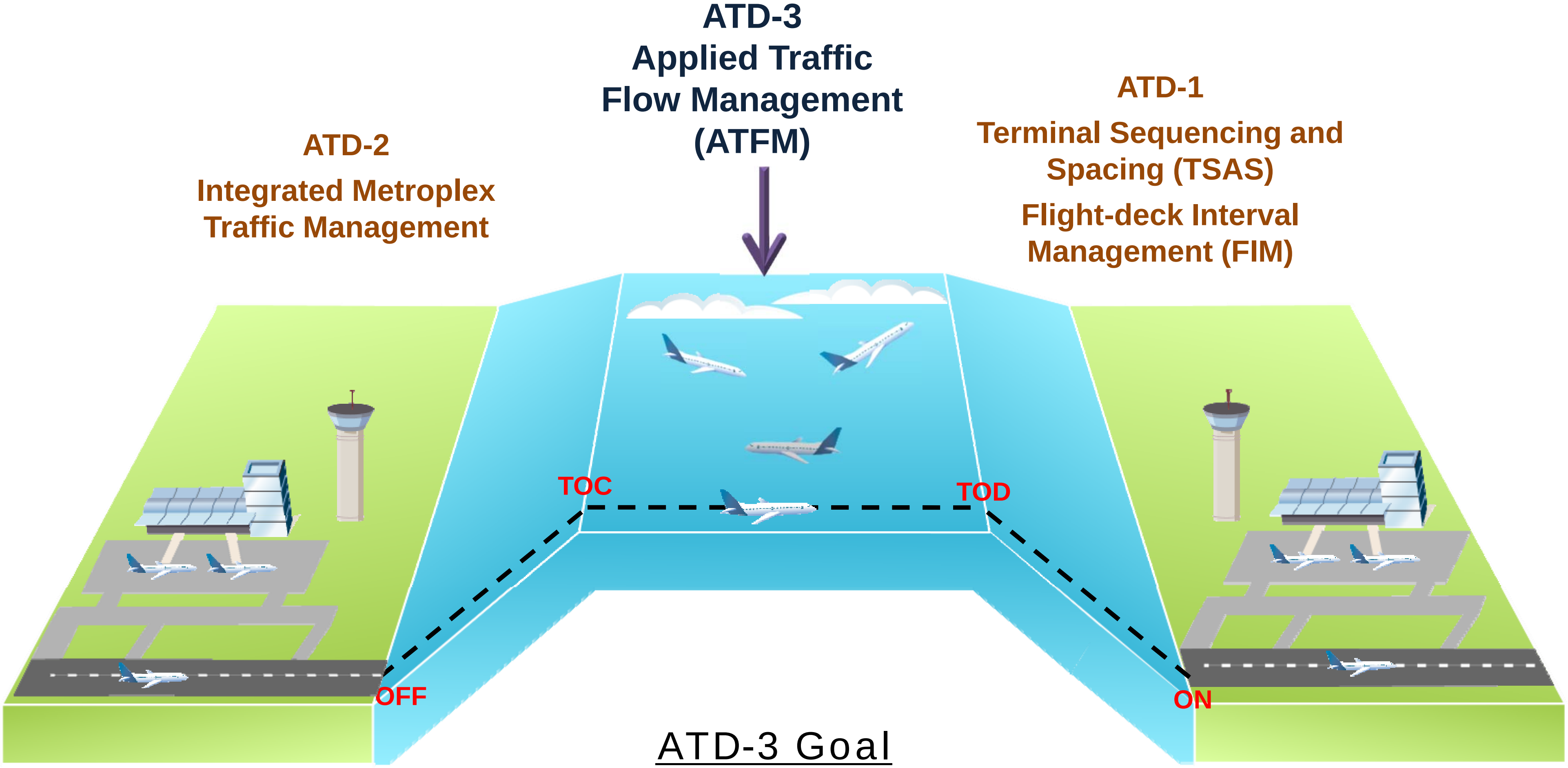
Airspace Technology Demonstration 3 (ATD-3) Sub-Project

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

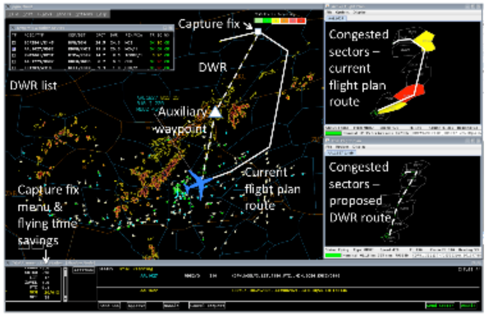


ATD-3 Goal

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

<u>Domestic</u>: 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

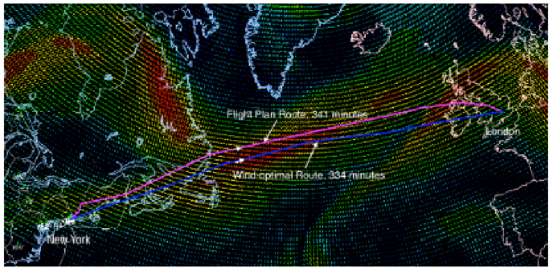


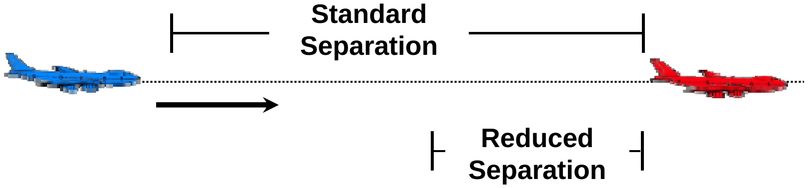
Optimize For Fuel

Optimize To WPT NEXTE

Max Off-Route WPTs Two

<u>Oceanic</u>: 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

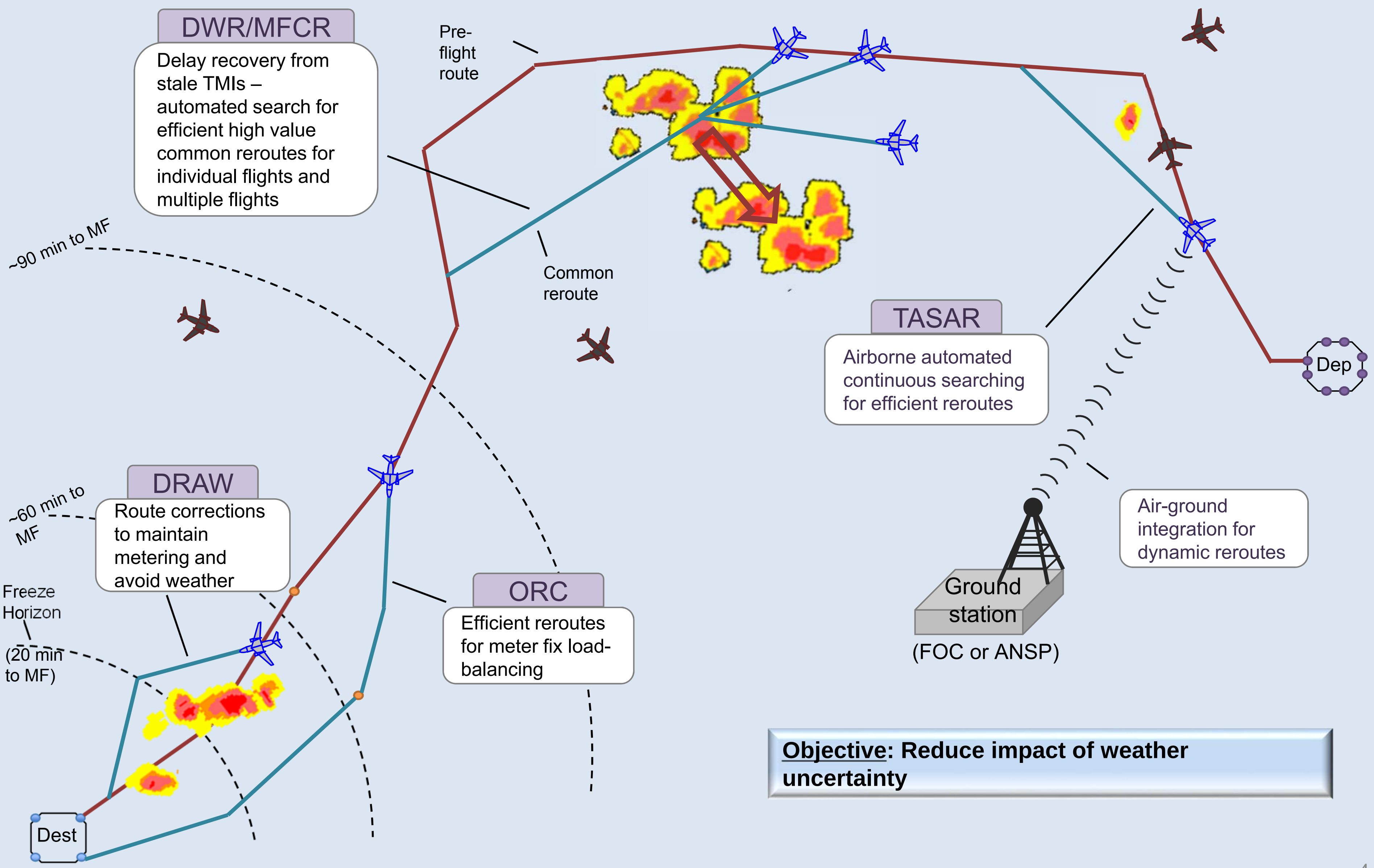




Standard Separation

Reduced Separation

Domestic Integrated Concept



DWR/MFCR

Delay recovery from stale TMIs – automated search for efficient high value common reroutes for individual flights and multiple flights

TASAR

Airborne automated continuous searching for efficient reroutes

DRAW

Route corrections to maintain metering and avoid weather

ORC

Efficient reroutes for meter fix load-balancing

Air-ground integration for dynamic reroutes

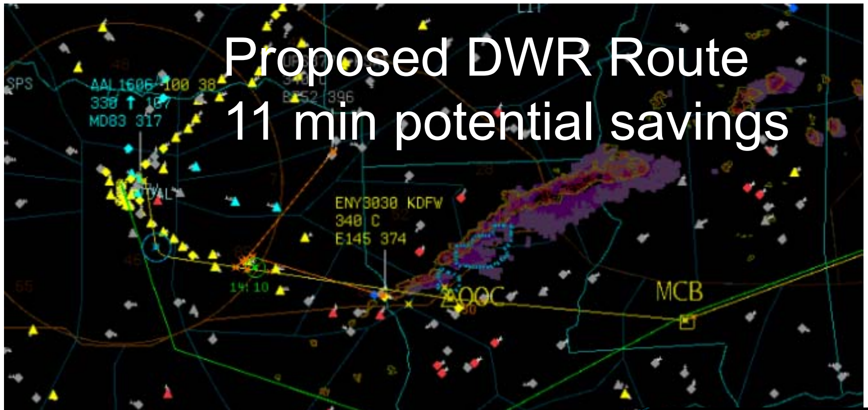
Objective: Reduce impact of weather uncertainty

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



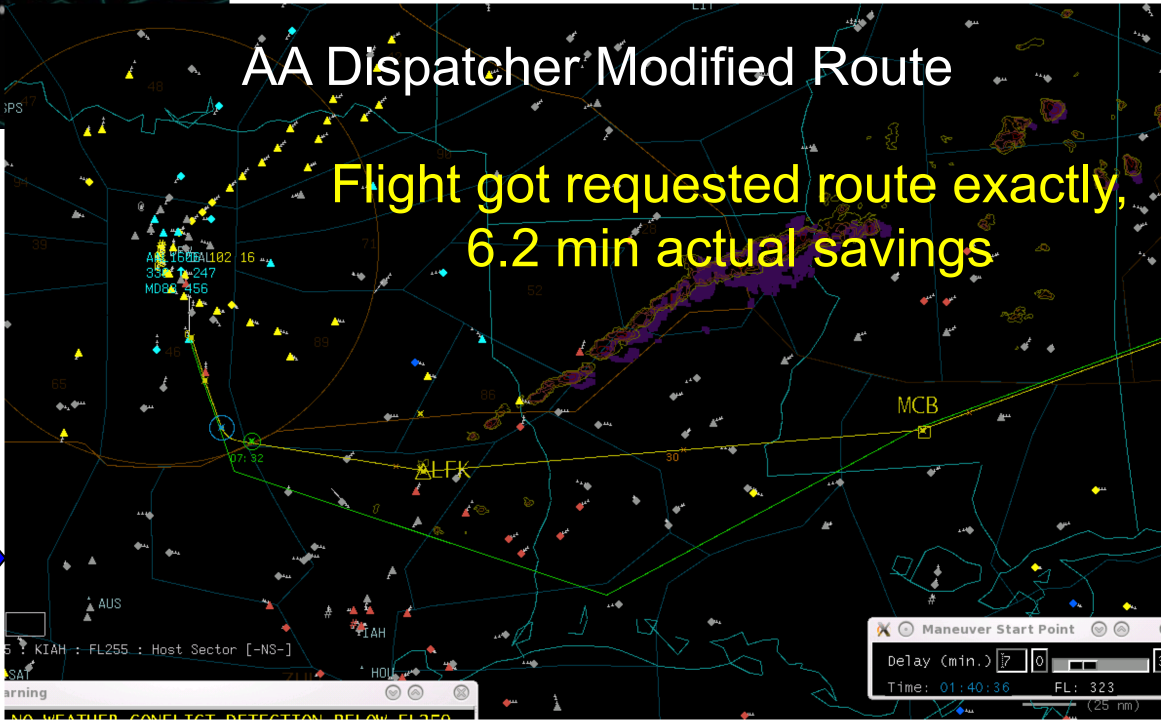
Proposed DWR Route
11 min potential savings

MD83 DFW/RDU

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



AA Dispatcher Modified Route

Flight got requested route exactly, 6.2 min actual savings

KIAH : FL255 : Host Sector [-NS-]

Maneuver Start Point

Delay (min.) 7 0

Time: 01:40:36 FL: 323

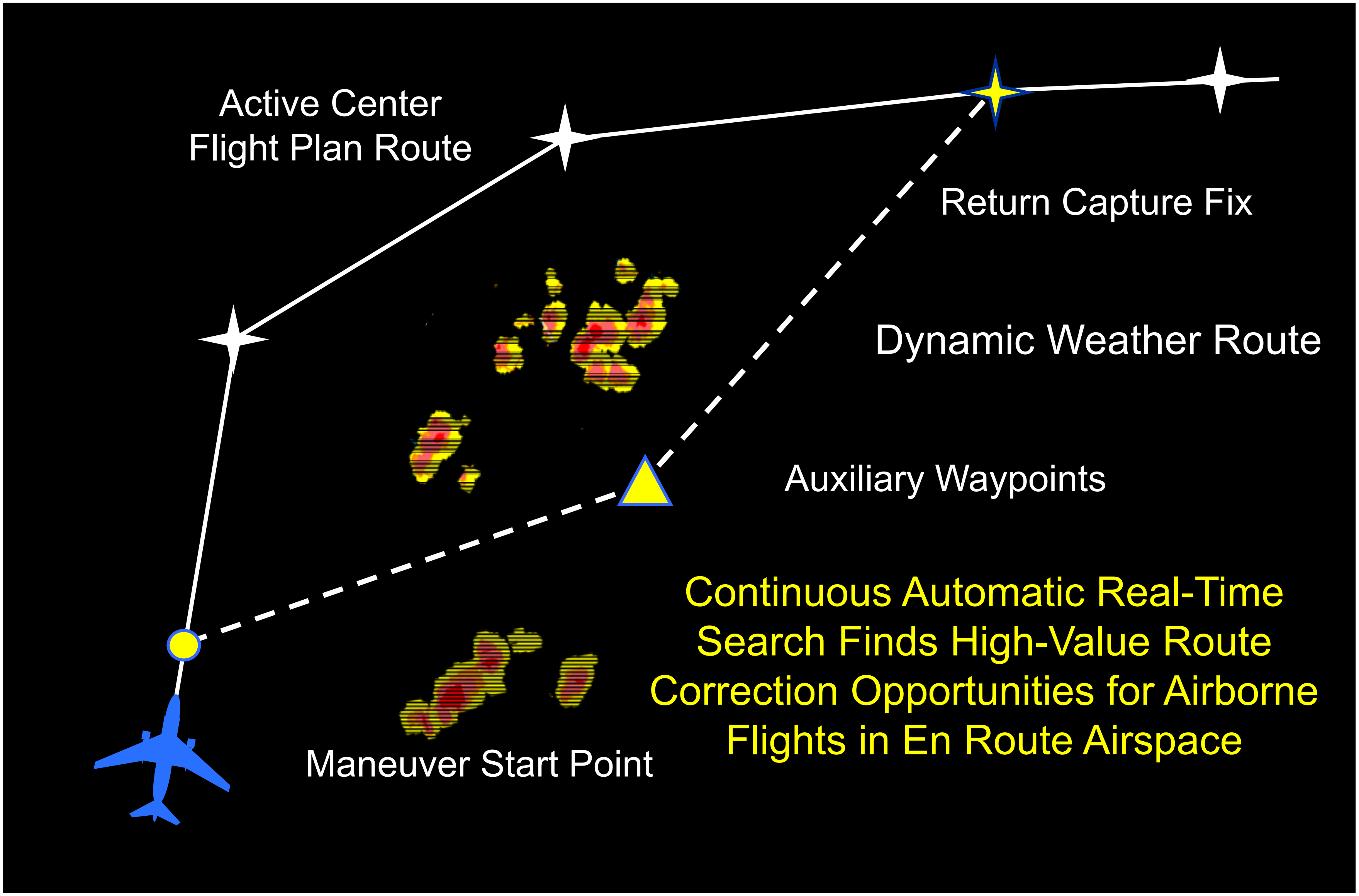
NO WEATHER CONFLICT DETECTION BELOW FL250

Research Objectives

Weather Avoidance in Domestic US Airspace

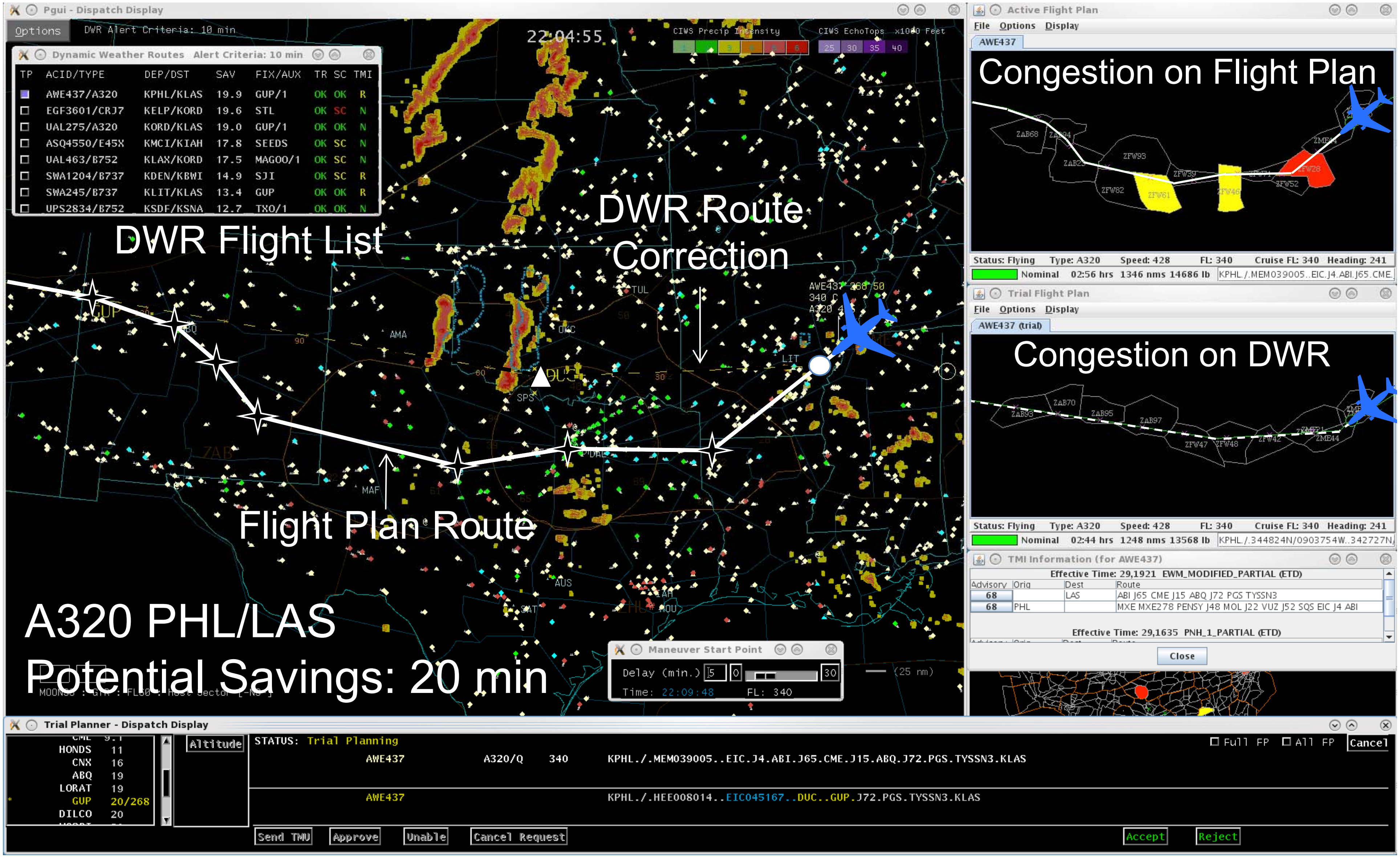
- Multi Flight Common Route, ATC Acceptable High-Value Route Correction Automation
  - Balances delay reduction with ATC familiarity & acceptability
  - Finds common route corrections for multiple flights
  - Extends automation for merging arrivals, time-based metering, arrival fix balancing
  - Incorporates 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



Continuous Automatic Real-Time Search Finds High-Value Route Correction Opportunities for Airborne Flights in En Route Airspace

DWR User Interface



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

DWR Flight List

DWR Route Correction

Flight Plan Route

A320 PHL/LAS
Potential Savings: 20 min

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/

Effective Time: 29,1921 EWM_MODIFIED_PARTIAL (ETD)

Advisory	Orig	Dest	Route
68		LAS	ABI J65 CME J15 ABQ J72 PGS TYSSN3
68	PHL		MXE MXE278 PENSY J48 MOL J22 VUZ J52 SQS EIC J4 ABI

Effective Time: 29,1635 PNH_1_PARTIAL (ETD)

Delay (min.) 5 0 30
Time: 22:09:48 FL: 340

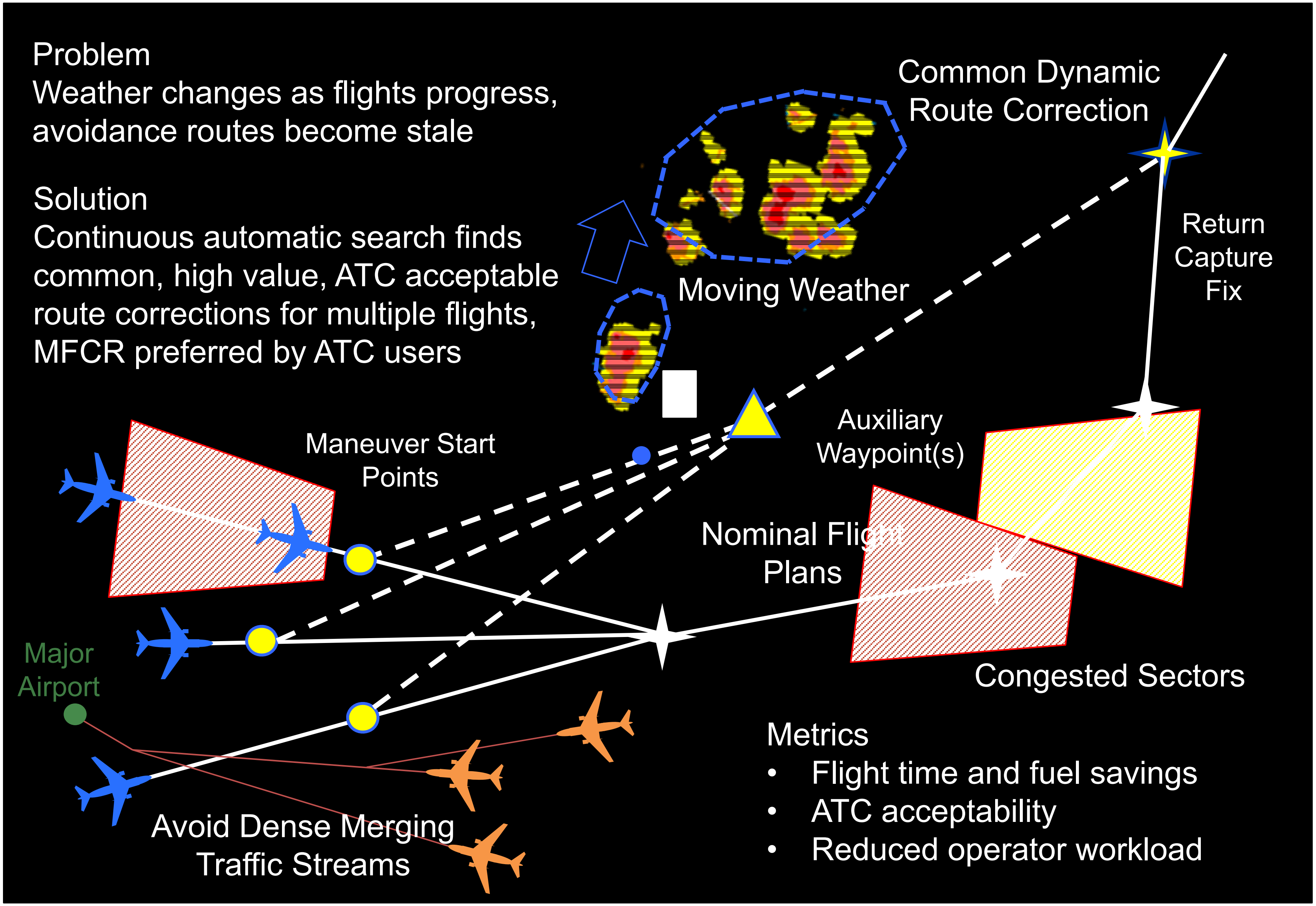
```
HONDS    11
  CNX    16
  ABQ    19
LORAT    19
* GUP    20/268
DILCO    20
```

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
```

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

Common Dynamic Route Correction

Moving Weather

Return Capture Fix

Auxiliary Waypoint(s)

Maneuver Start Points

Nominal Flight Plans

Major Airport

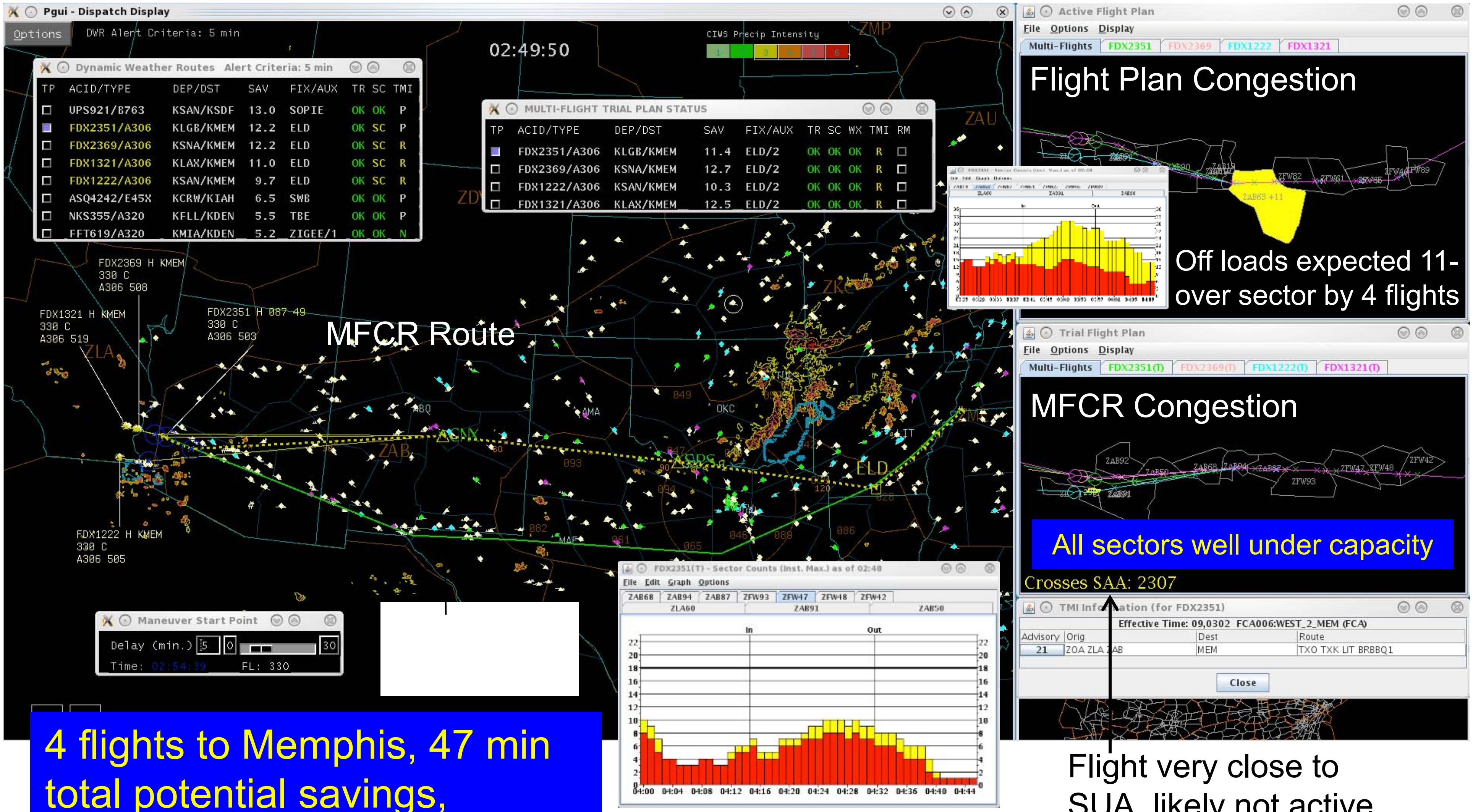
Congested Sectors

Avoid Dense Merging Traffic Streams

Metrics
- Flight time and fuel savings
- ATC acceptability
- Reduced operator workload

Multi-Flight Common Route

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



DWR Alert Criteria: 5 min

Dynamic Weather Routes   Alert Criteria: 5 min

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
☐	UPS921/B763	KSAN/KSDF	13.0	SOPIE	OK	OK	P
■	FDX2351/A306	KLGB/KMEM	12.2	ELD	OK	SC	P
☐	FDX2369/A306	KSNA/KMEM	12.2	ELD	OK	SC	R
☐	FDX1321/A306	KLAX/KMEM	11.0	ELD	OK	SC	R
☐	FDX1222/A306	KSAN/KMEM	9.7	ELD	OK	SC	R
☐	ASQ4242/E45X	KCRW/KIAH	6.5	SWB	OK	OK	P
☐	NKS355/A320	KFLL/KDEN	5.5	TBE	OK	OK	P
☐	FFT619/A320	KMIA/KDEN	5.2	ZIGEE/1	OK	OK	N

MULTI-FLIGHT TRIAL PLAN STATUS

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	WX	TMI	RM
■	FDX2351/A306	KLGB/KMEM	11.4	ELD/2	OK	OK	OK	R	☐
☐	FDX2369/A306	KSNA/KMEM	12.7	ELD/2	OK	OK	OK	R	☐
☐	FDX1222/A306	KSAN/KMEM	10.3	ELD/2	OK	OK	OK	R	☐
☐	FDX1321/A306	KLAX/KMEM	12.5	ELD/2	OK	OK	OK	R	☐

Maneuver Start Point

Delay (min.) 5   0   30

Time: 02:54:39   FL: 330

MFCR Route

Flight Plan Congestion

Off loads expected 11-over sector by 4 flights

MFCR Congestion

All sectors well under capacity

Crosses SAA: 2307

TMI Information (for FDX2351)

Effective Time: 09,0302 FCA006:WEST_2_MEM (FCA)

Advisory	Orig	Dest	Route
21	ZOA ZLA ZAB	MEM	TXO TXK LIT BRBBQ1

Close

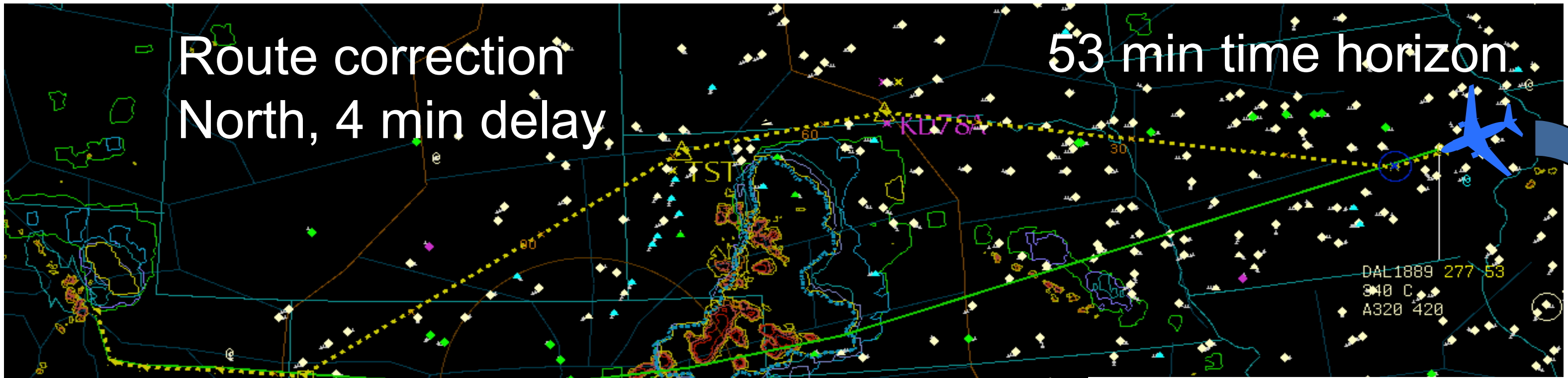
4 flights to Memphis, 47 min total potential savings, favorable congestion metrics

Worst case MFCR Congestion

Flight very close to SUA, likely not active

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



Route correction North, 4 min delay

53 min time horizon

Gap logic would have rejected a gap option

DENVER AND THE WEST

Delta flight from Boston makes emergency landing in Denver

Jetliner pelted by hail, severely damaging plane's nose cone and cracking its windshield,

By Kirk Mitchell

The Denver Post

POSTED: 08/08/2015 11:49:00 AM MDT

UPDATED: 08/08/2015 10:13:42 PM MDT

30 COMM

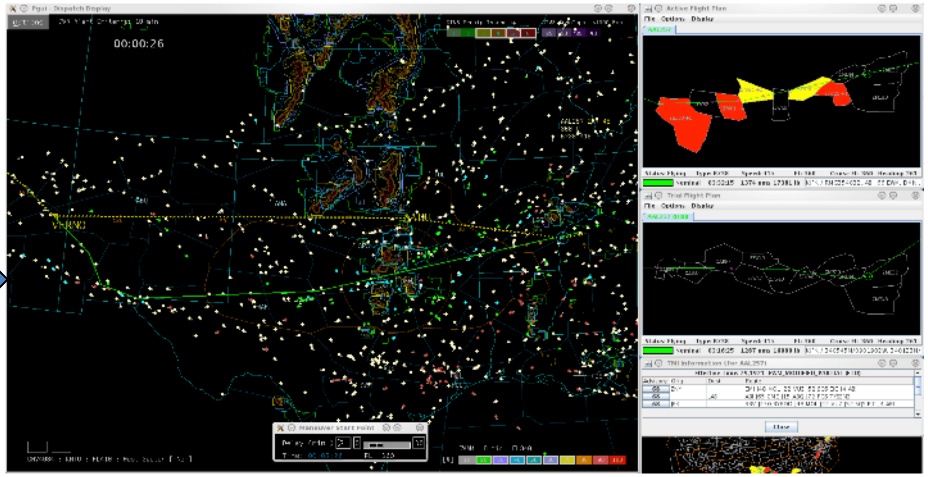
Smart route correction could result in huge savings and safety benefit

Alert, Display and Load

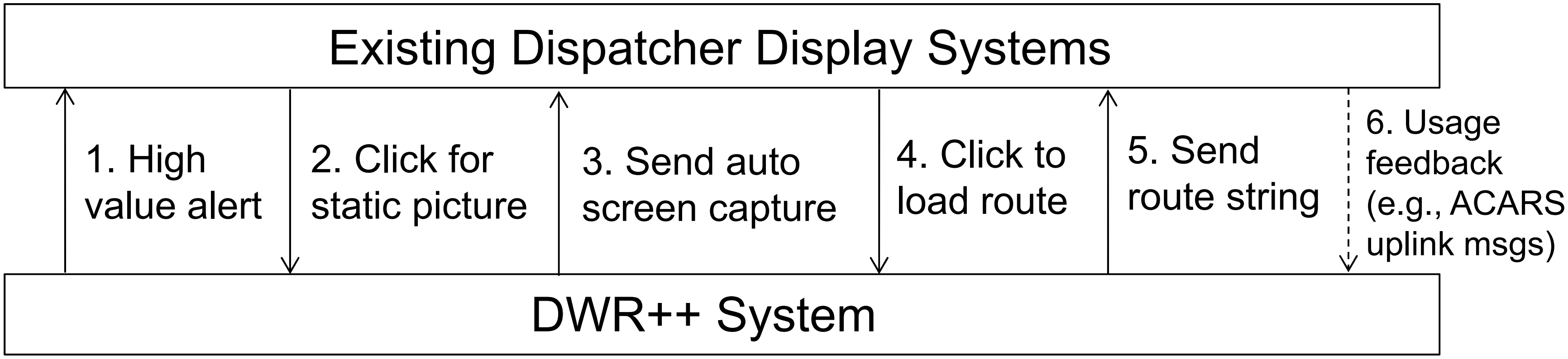
Small alert window on existing displays

Show 257 JFK/LAS 16 min Load

Click alert window to toggle picture



Dispatcher Work Station



Existing Dispatcher Display Systems

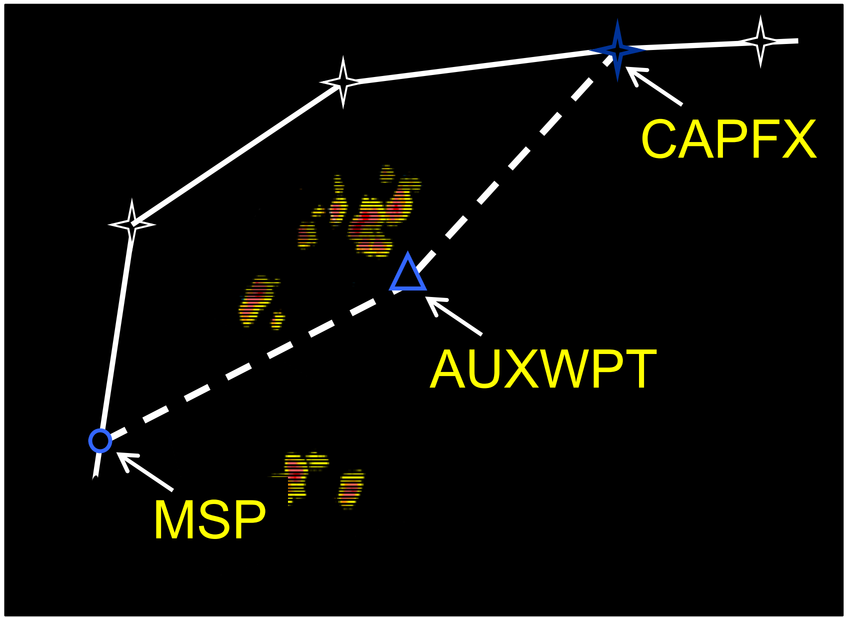
1. High value alert
2. Click for static picture
3. Send auto screen capture
4. Click to load route
5. Send route string
6. Usage feedback (e.g., ACARS uplink msgs)

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)

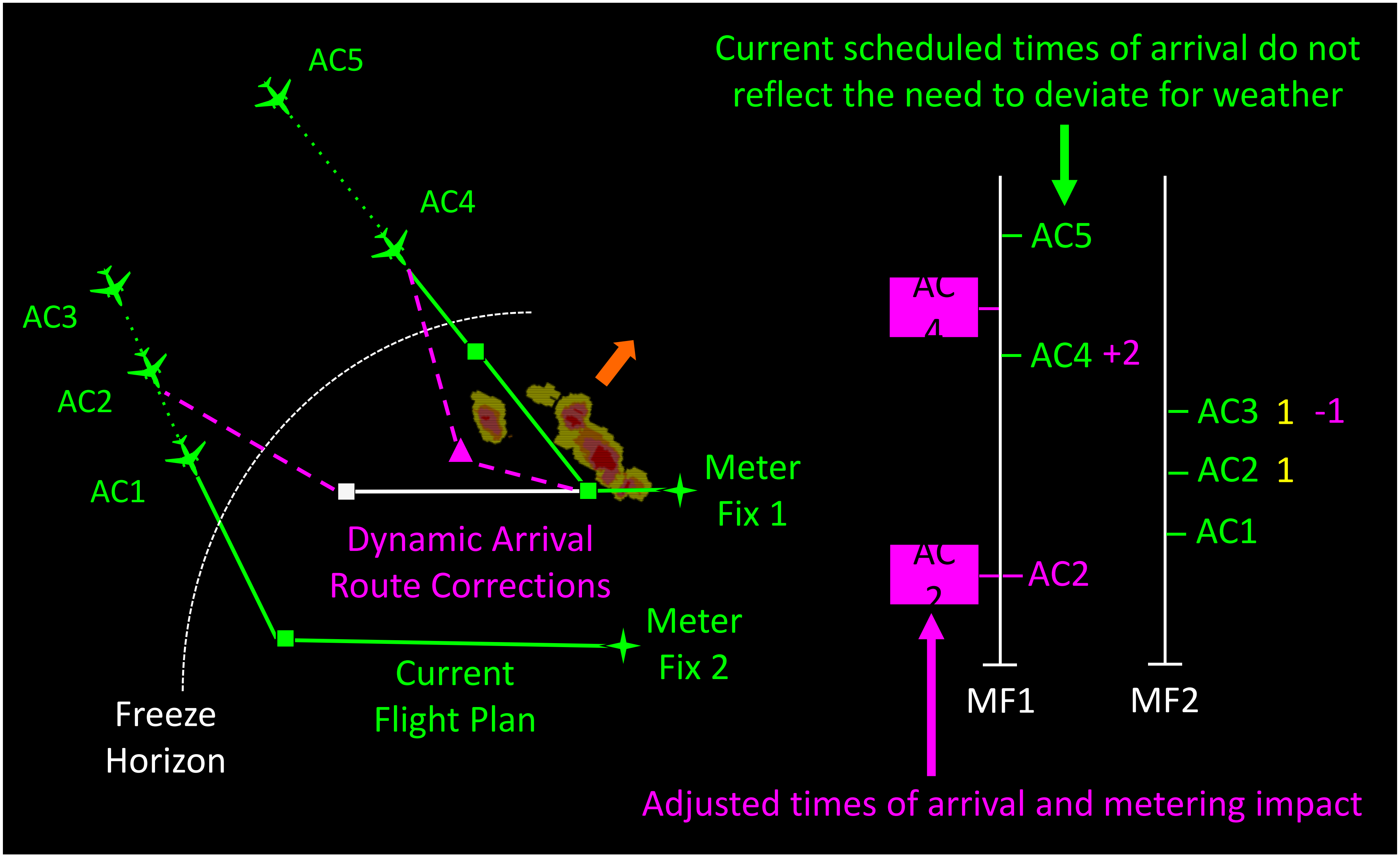
Press buttons to load, communicate, visualize, execute

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



Current scheduled times of arrival do not reflect the need to deviate for weather

Dynamic Arrival Route Corrections

Current Flight Plan

Adjusted times of arrival and metering impact

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

Optimized Route Capability (ORC)

- **Capability**
  - 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
- **Benefits**
  - 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

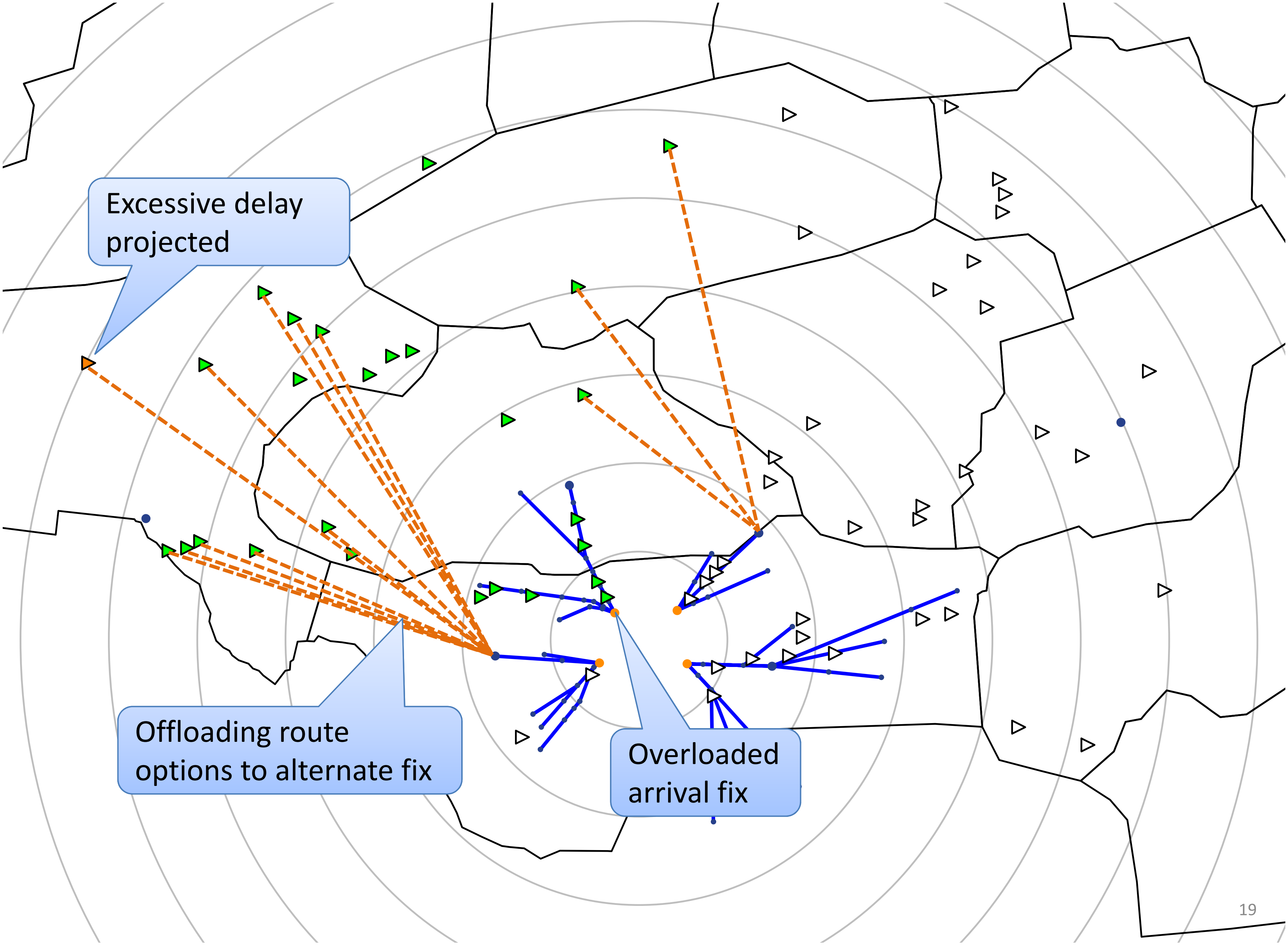
Without intervention, demand exceeds capacity at NW arrival gate and results in holding

1. ORC identifies excess demand

2. ORC alerts TMC/STMC

3. ORC identifies candidate reroute

4. TMC/STMC accepts solution

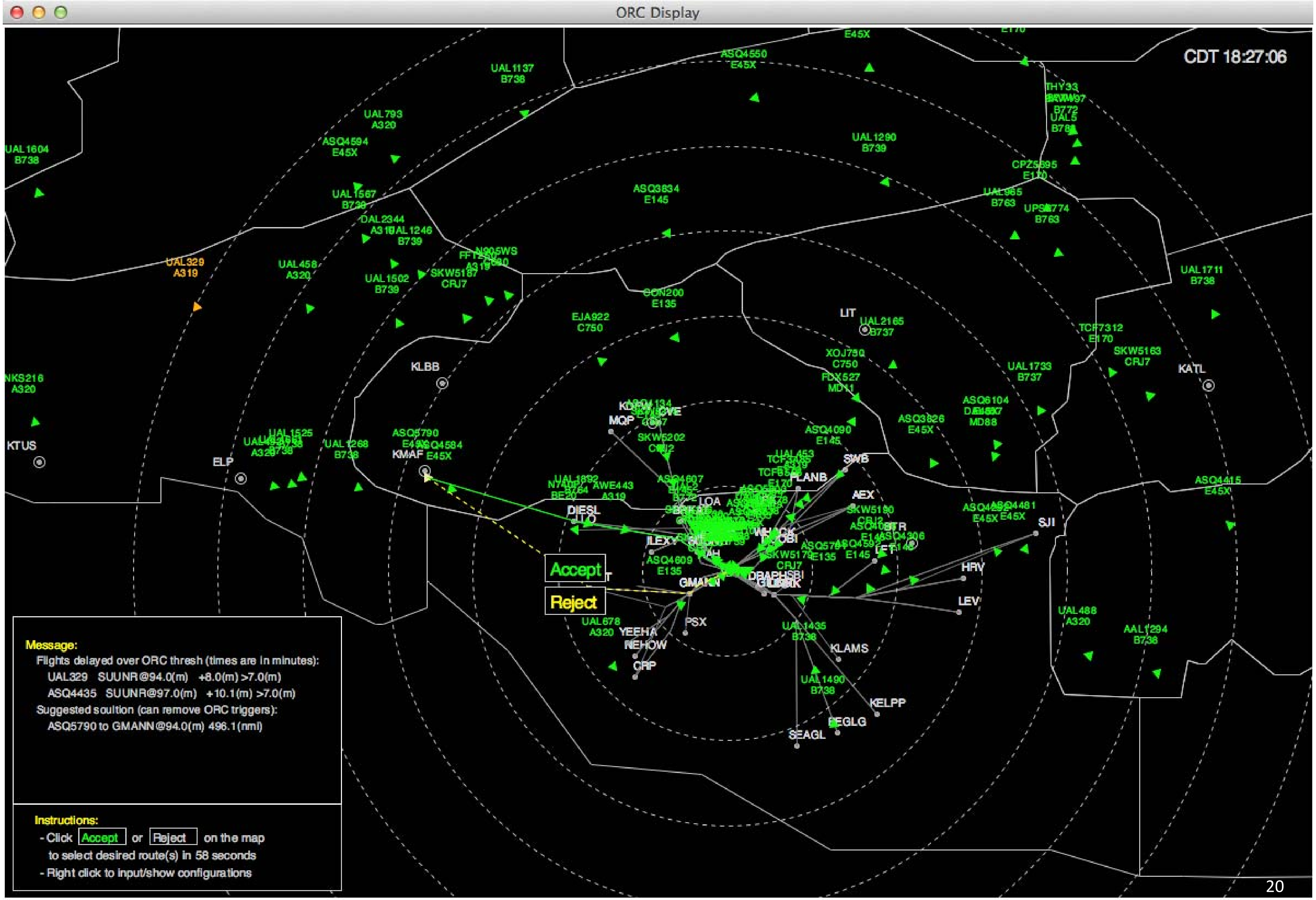


Excessive delay projected

Offloading route options to alternate fix

Overloaded arrival fix

Mock display of recommended route option presented to Traffic Management Coordinator



Message:

Flights delayed over ORC thresh (times are in minutes):

UAL329 SUUNR@94.0(m) +8.0(m) >7.0(m)

ASQ4435 SUUNR@97.0(m) +10.1(m) >7.0(m)

Suggested soultion (can remove ORC triggers):

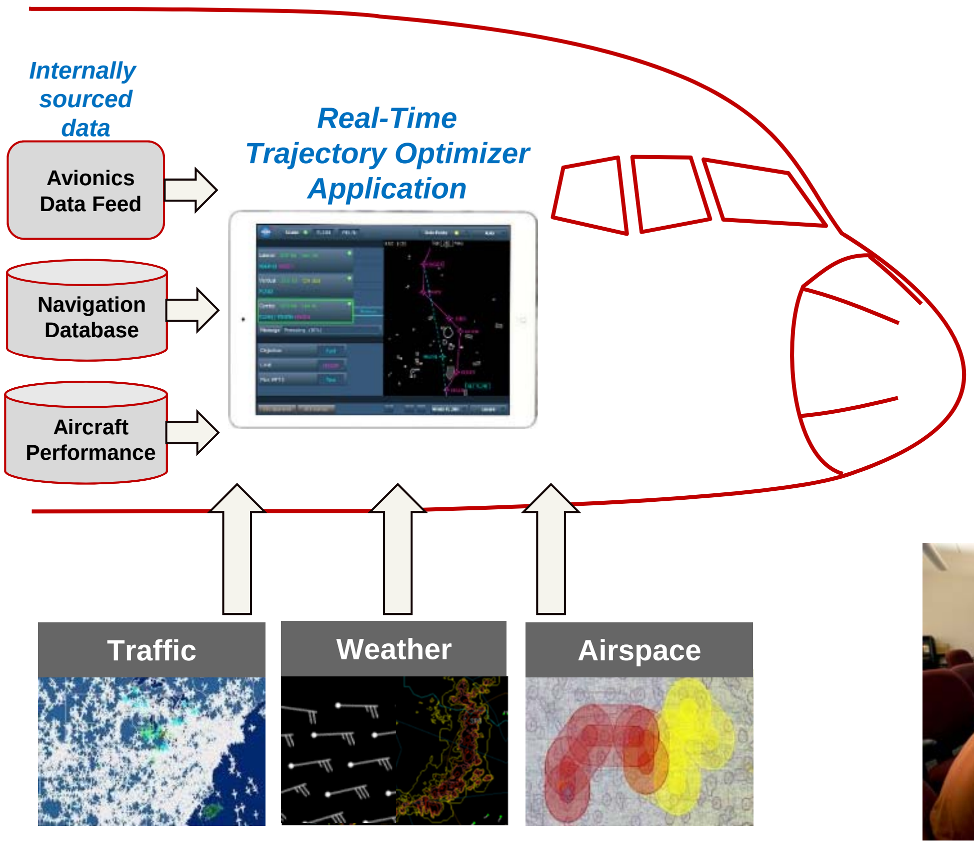
ASQ5790 to GMANN@94.0(m) 496.1(nmi)

Instructions:

- Click Accept or Reject on the map to select desired route(s) in 58 seconds
- Right click to input/show configurations

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



Internally sourced data

Avionics Data Feed

Navigation Database

Aircraft Performance

Real-Time Trajectory Optimizer Application

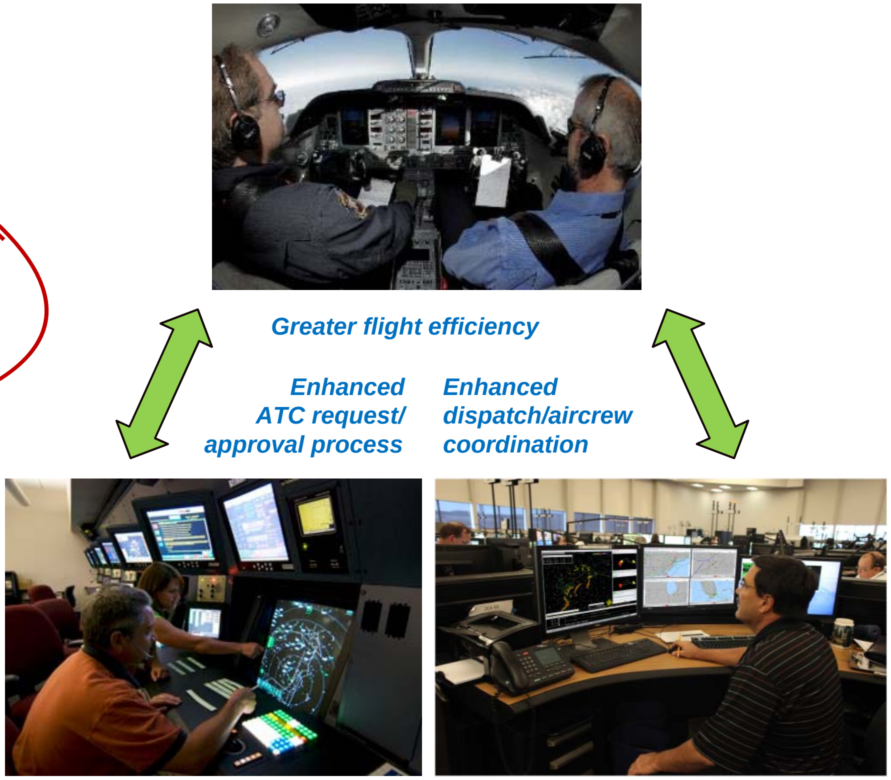
Traffic

Weather

Airspace

Externally sourced data

Operational Outcomes



Greater flight efficiency

Enhanced ATC request/ approval process

Enhanced dispatch/aircrew coordination

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

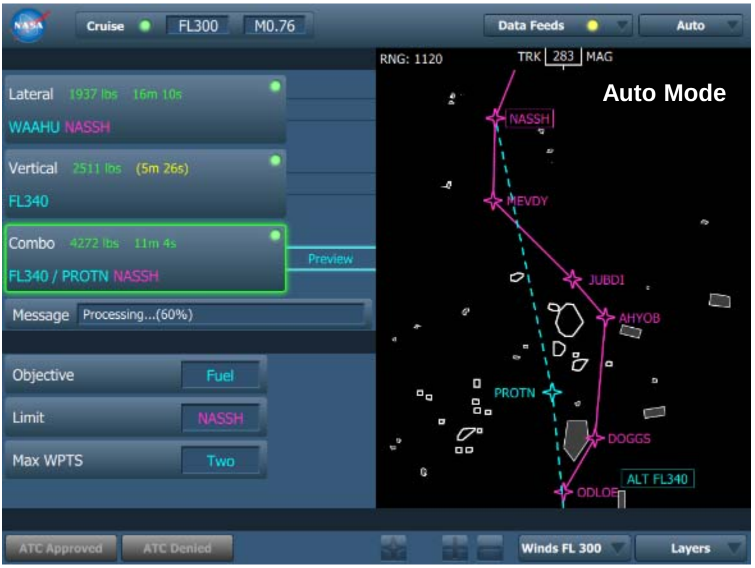
Latest winds, weather, airspace status, etc.

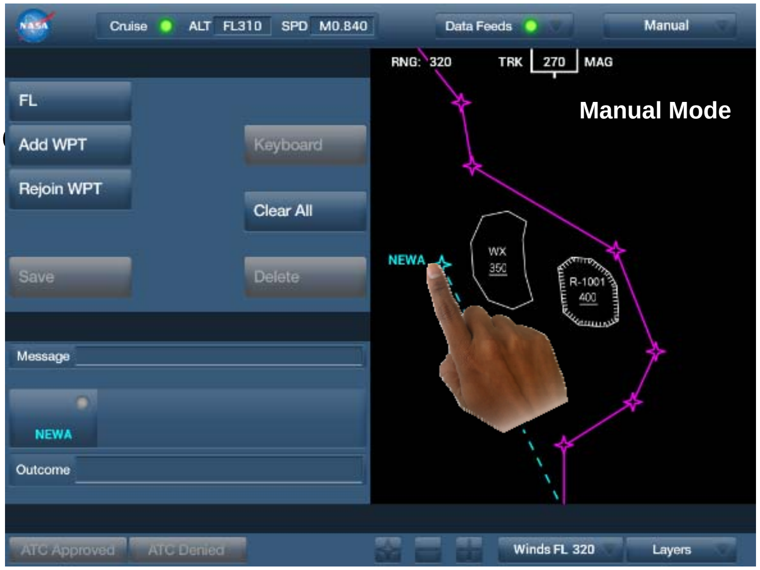
Computes real-time route optimizations

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

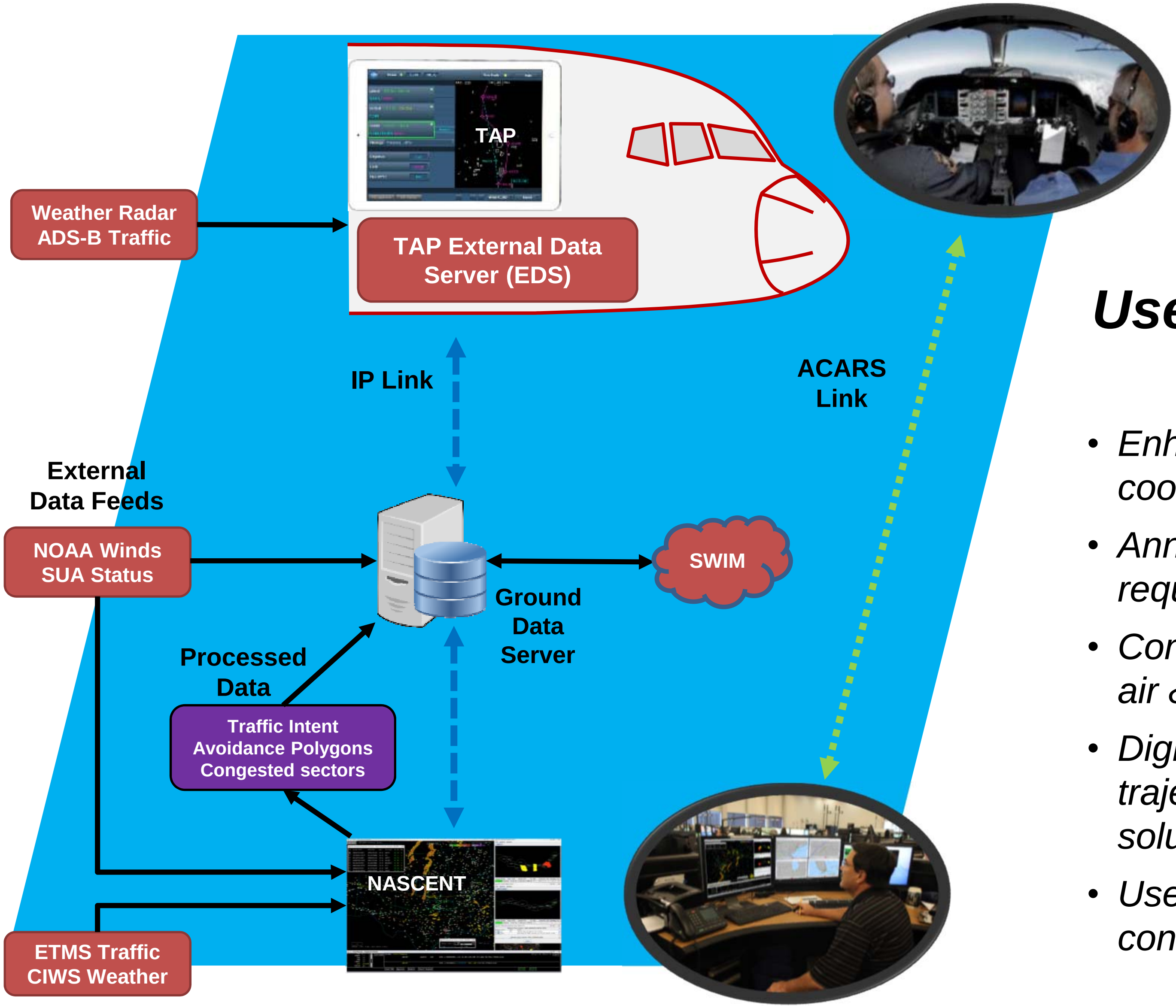
Analyzes pilot-entered route changes

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


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
FL340 / PROTN NASSH
Message Processing...(60%)
Objective Fuel
Limit NASSH
Max WPTS Two


Cruise ALT FL310 SPD M0.840
Data Feeds Manual
RNG: 320 TRK 270 MAG
Message
NEWA
Outcome

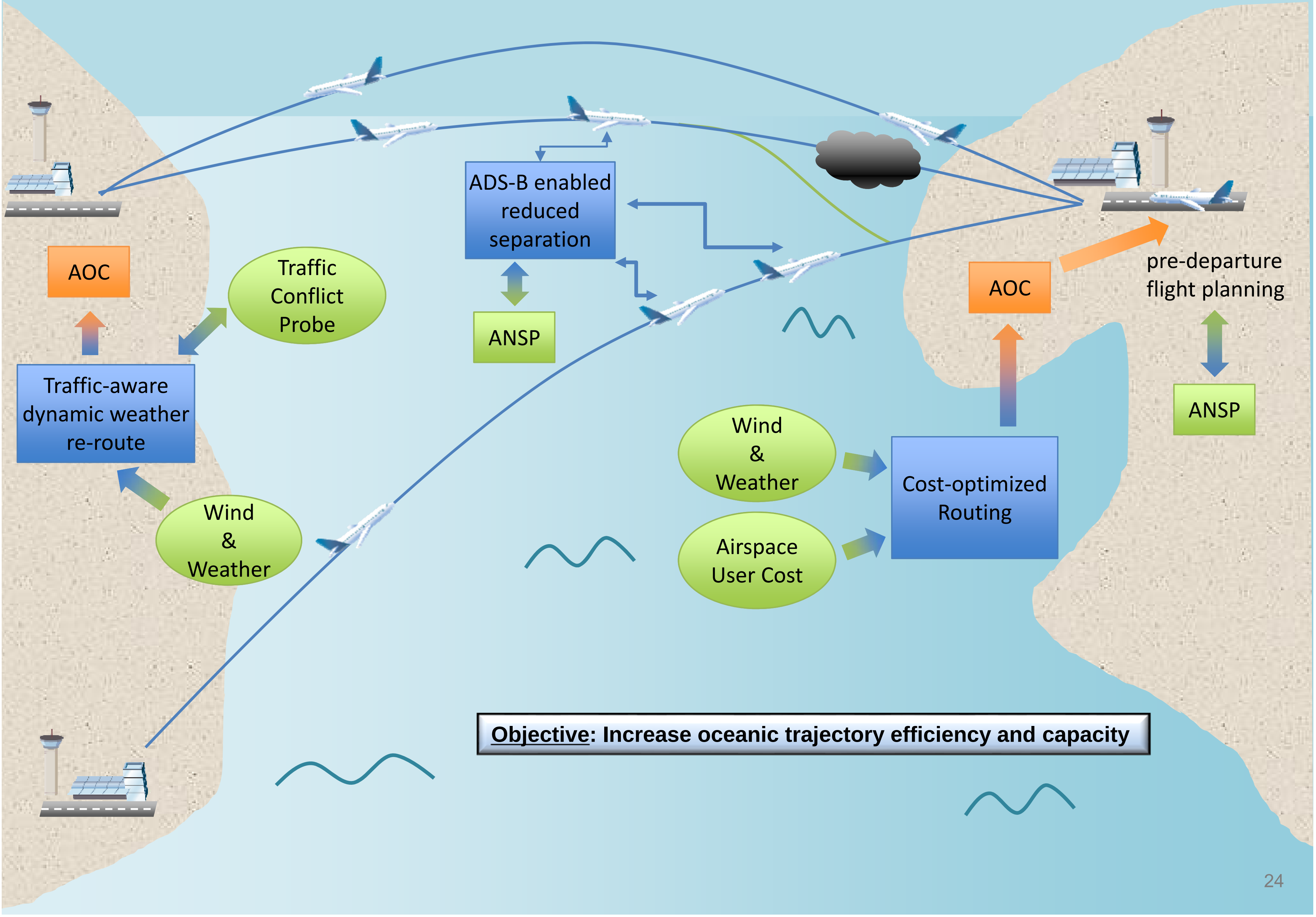
ATD-3 Air/Ground User Integration



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



ADS-B enabled reduced separation

ANSP

Traffic Conflict Probe

AOC

Traffic-aware dynamic weather re-route

Wind & Weather

AOC

pre-departure flight planning

ANSP

Wind & Weather

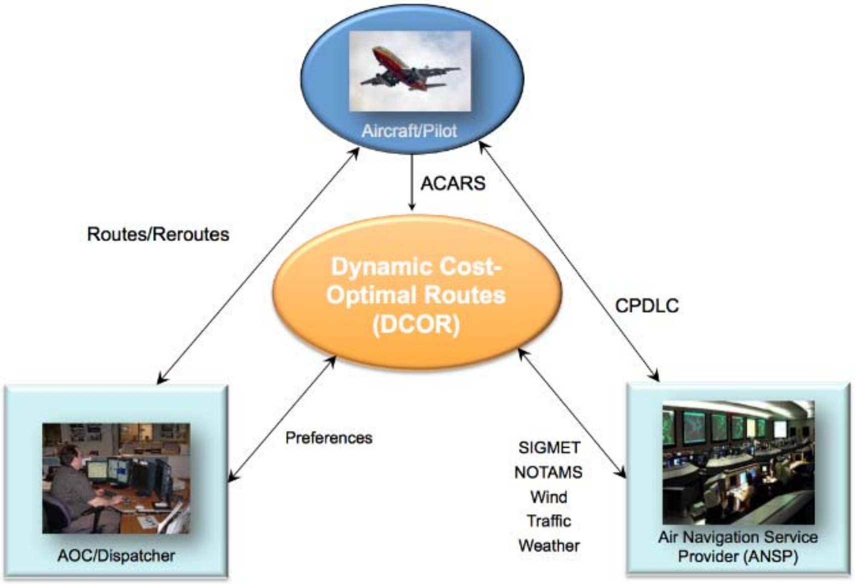
Airspace User Cost

Cost-optimized Routing

Objective: Increase oceanic trajectory efficiency and capacity

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

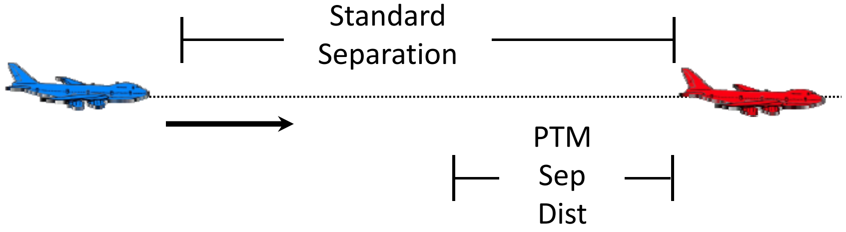


Pairwise Trajectory Management (PTM)

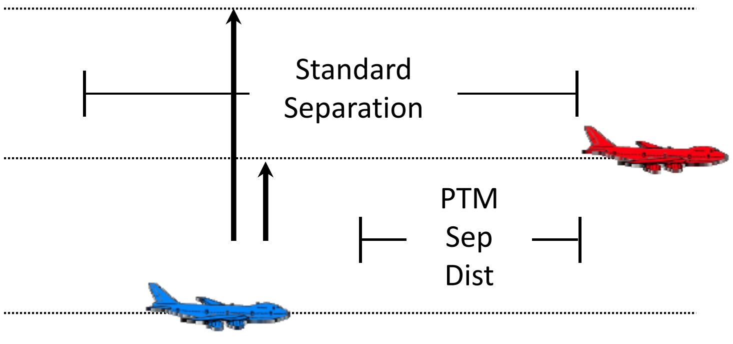
PTM Oceanic Operations – Sample Scenarios

ADS-B Transceiver and Onboard Decision Support System

ADS-B Out (required)

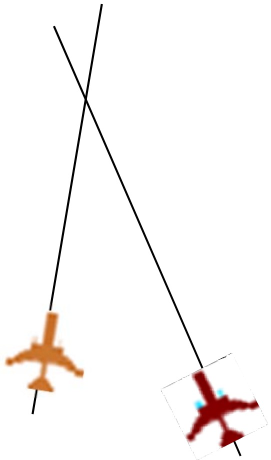


Same Route Co-Altitude



Same Route, Altitude Change

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



Intersecting Routes, Same Altitude (constrained geometry)

PTM Advantages

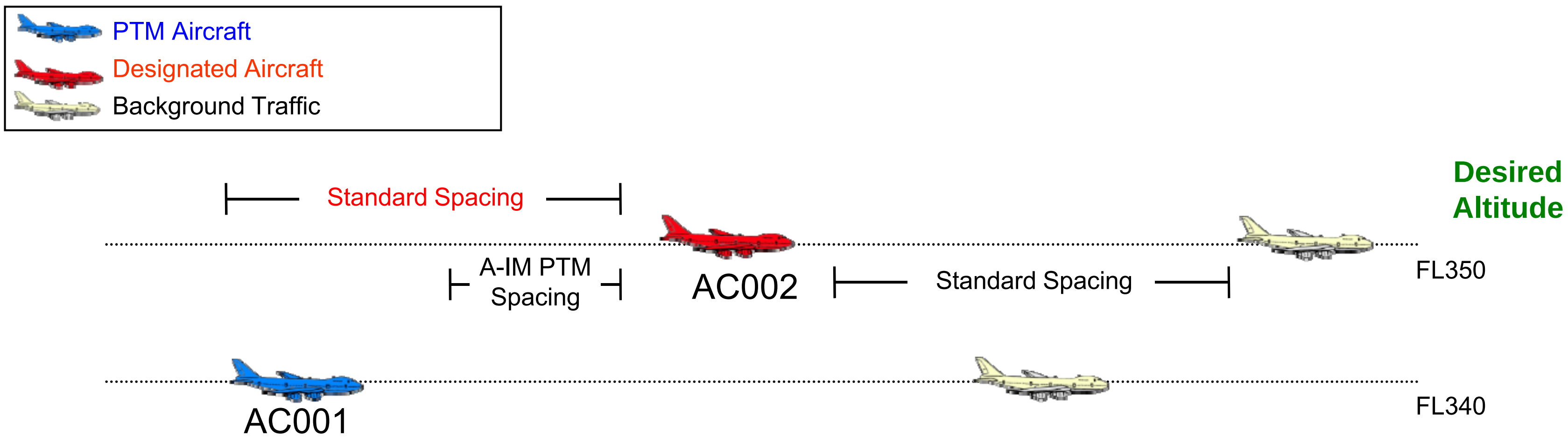
- Separation standards approaching those of domestic airspace
- Increased capacity where desired
- Immediate full benefit as soon as an aircraft is equipped
- No communication upgrades needed
- No recurring costs (one time investment)
- No additional controllers needed; however, additional workload expected

- PTM Requirements
  - Datacom (e.g., CPDLC) and therefore likely FANS 1/A
  - ADS-B In equipage
    - Similar to FIM equipment (traffic processor, CDTI, forward display)
    - 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

KMR(1

Sample of Stakeholder Responders

NASA

The Ohio State University

Federal Aviation Administration

Boeing

NBAA

Virgin america

Metron Aviation
The science of harmonizing air traffic

AvMet

Rockwell Collins

Alaska

SAAB Sensis

American Airlines

CCI

DELTA

ups

Purdue University

ACSS
An L-3 Communications & Thales Company

Mosaic ATM

FedEx

Honeywell

GE Aviation

PASSUR Aerospace

KNOW NOW

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

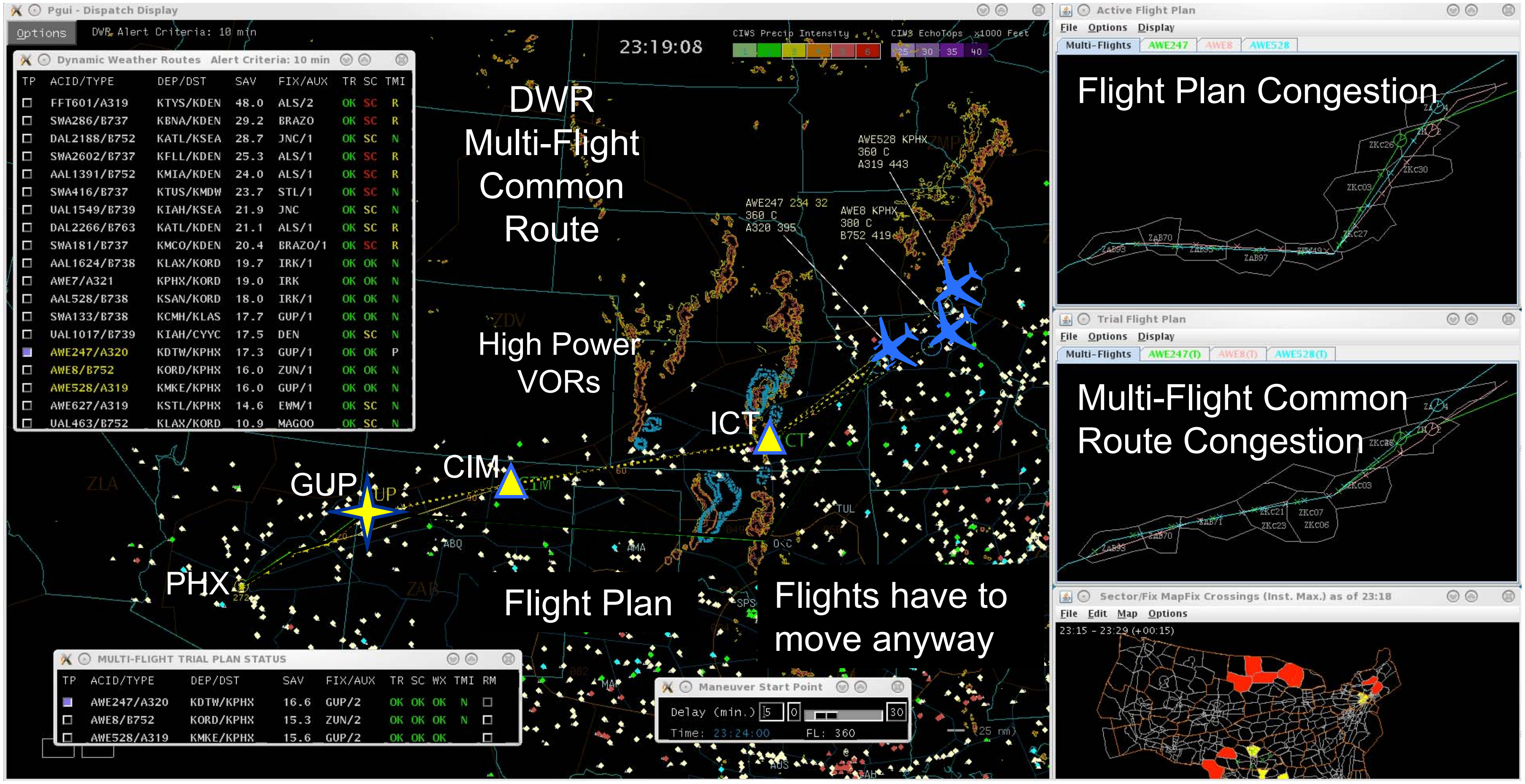
DWR Backup

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

Three American Flights to Phoenix



Dynamic Weather Routes Alert Criteria: 10 min

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
☐	FFT601/A319	KTYS/KDEN	48.0	ALS/2	OK	SC	R
☐	SWA286/B737	KBNA/KDEN	29.2	BRAZO	OK	SC	R
☐	DAL2188/B752	KATL/KSEA	28.7	JNC/1	OK	SC	N
☐	SWA2602/B737	KFLL/KDEN	25.3	ALS/1	OK	SC	R
☐	AAL1391/B752	KMIA/KDEN	24.0	ALS/1	OK	SC	R
☐	SWA416/B737	KTUS/KMDW	23.7	STL/1	OK	SC	N
☐	UAL1549/B739	KIAH/KSEA	21.9	JNC	OK	SC	N
☐	DAL2266/B763	KATL/KDEN	21.1	ALS/1	OK	SC	R
☐	SWA181/B737	KMCO/KDEN	20.4	BRAZO/1	OK	SC	R
☐	AAL1624/B738	KLAX/KORD	19.7	IRK/1	OK	OK	N
☐	AWE7/A321	KPHX/KORD	19.0	IRK	OK	OK	N
☐	AAL528/B738	KSAN/KORD	18.0	IRK/1	OK	OK	N
☐	SWA133/B738	KCMH/KLAS	17.7	GUP/1	OK	OK	N
☐	UAL1017/B739	KIAH/CYYC	17.5	DEN	OK	SC	N
■	AWE247/A320	KDTW/KPHX	17.3	GUP/1	OK	OK	P
☐	AWE8/B752	KORD/KPHX	16.0	ZUN/1	OK	OK	N
☐	AWE528/A319	KMKE/KPHX	16.0	GUP/1	OK	OK	N
☐	AWE627/A319	KSTL/KPHX	14.6	EWM/1	OK	SC	N
☐	UAL463/B752	KLAX/KORD	10.9	MAGOO	OK	SC	N

MULTI-FLIGHT TRIAL PLAN STATUS

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	WX	TMI	RM
■	AWE247/A320	KDTW/KPHX	16.6	GUP/2	OK	OK	OK	N	☐
☐	AWE8/B752	KORD/KPHX	15.3	ZUN/2	OK	OK	OK	N	☐
☐	AWE528/A319	KMKE/KPHX	15.6	GUP/2	OK	OK	OK		☐

Maneuver Start Point

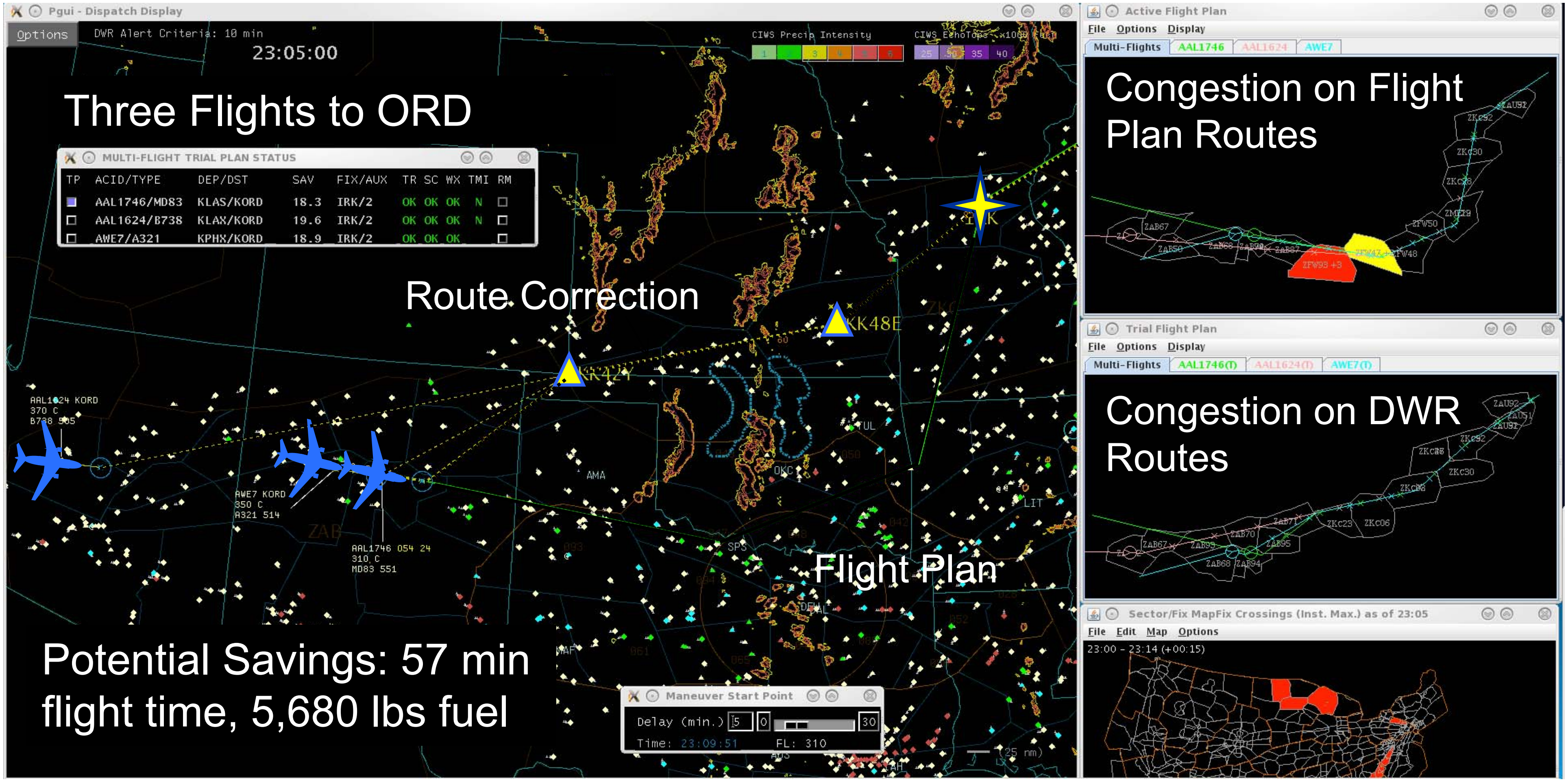
Delay (min.) 5 0 30

Time: 23:24:00 FL: 360

Automation finds common, ATC friendly route correction for 3 flights,
Potential savings: 47 min flight time, 4,874 lbs fuel, No congestion,
Common route savings 4% less than individual DWR savings

Multi-Flight Common Route

Leverages DWR Software



DWR Alert Criteria: 10 min

23:05:00

Three Flights to ORD

MULTI-FLIGHT TRIAL PLAN STATUS

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	WX	TMI	RM
■	AAL1746/MD83	KLAS/KORD	18.3	IRK/2	OK	OK	OK	N	☐
☐	AAL1624/B738	KLAX/KORD	19.6	IRK/2	OK	OK	OK	N	☐
☐	AWE7/A321	KPHX/KORD	18.9	IRK/2	OK	OK	OK		☐

Route Correction

Flight Plan

Potential Savings: 57 min flight time, 5,680 lbs fuel

Delay (min.) 5 0 30

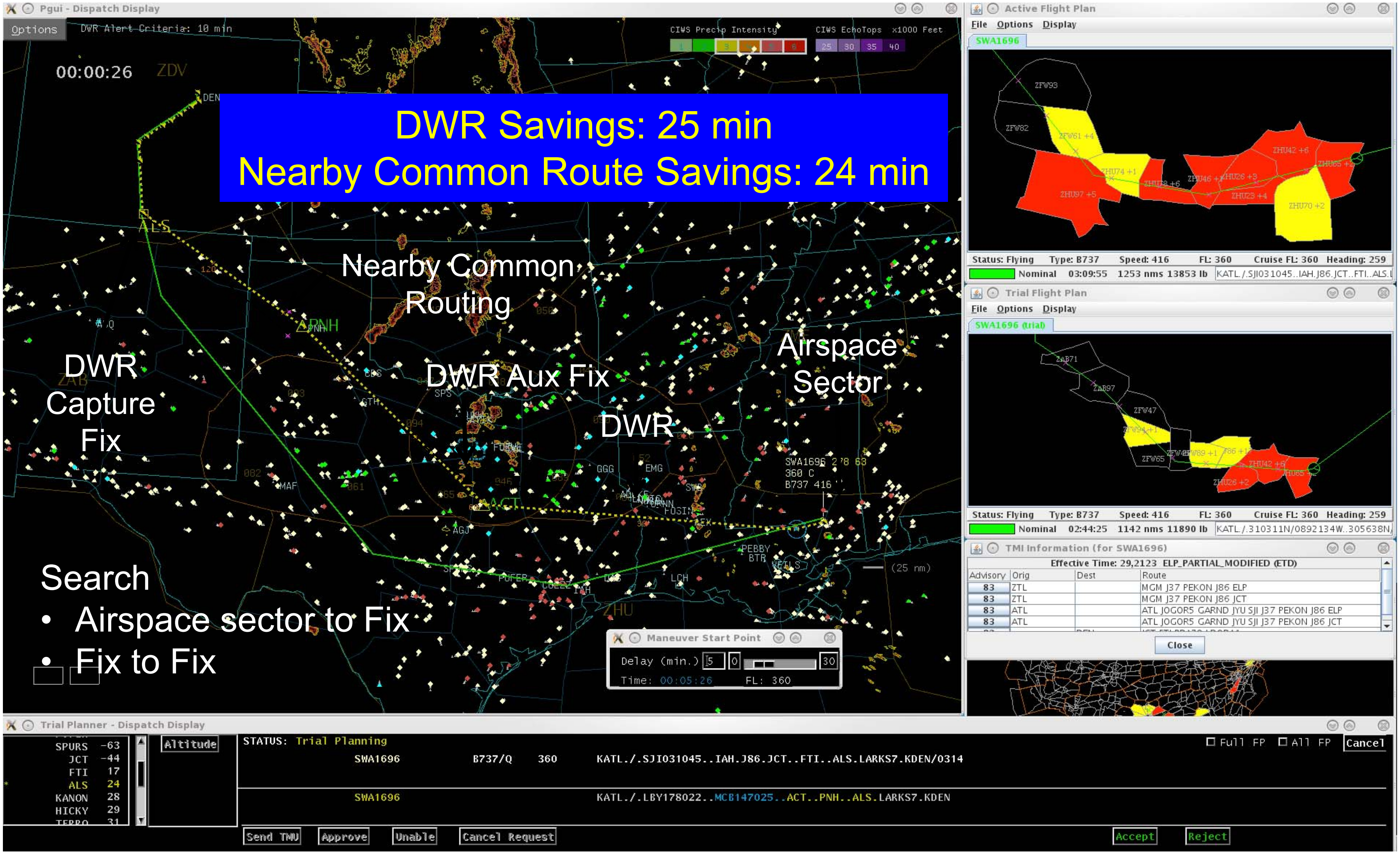
Time: 23:09:51 FL: 310

Congestion on Flight Plan Routes

Congestion on DWR Routes

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



DWR Savings: 25 min

Nearby Common Route Savings: 24 min

Nearby Common Routing

DWR Capture Fix

DWR Aux Fix

DWR

Airspace Sector

Search
- Airspace sector to Fix
- Fix to Fix

Active Flight Plan:

Status: Flying Type: B737 Speed: 416 FL: 360 Cruise FL: 360 Heading: 259

Nominal 03:09:55 1253 nms 13853 lb KATL./.SJI031045..IAH.J86.JCT..FTI..ALS.

Trial Flight Plan:

Status: Flying Type: B737 Speed: 416 FL: 360 Cruise FL: 360 Heading: 259

Nominal 02:44:25 1142 nms 11890 lb KATL./.310311N/0892134W..305638N/

Effective Time: 29,2123 ELP_PARTIAL_MODIFIED (ETD)

Advisory	Orig	Dest	Route
83	ZTL		MGM J37 PEKON J86 ELP
83	ZTL		MGM J37 PEKON J86 JCT
83	ATL		ATL JOGOR5 GARND JYU SJI J37 PEKON J86 ELP
83	ATL		ATL JOGOR5 GARND JYU SJI J37 PEKON J86 JCT

```
SPURS  -63
  JCT  -44
  FTI   17
* ALS   24
KANON   28
HICKY   29
```

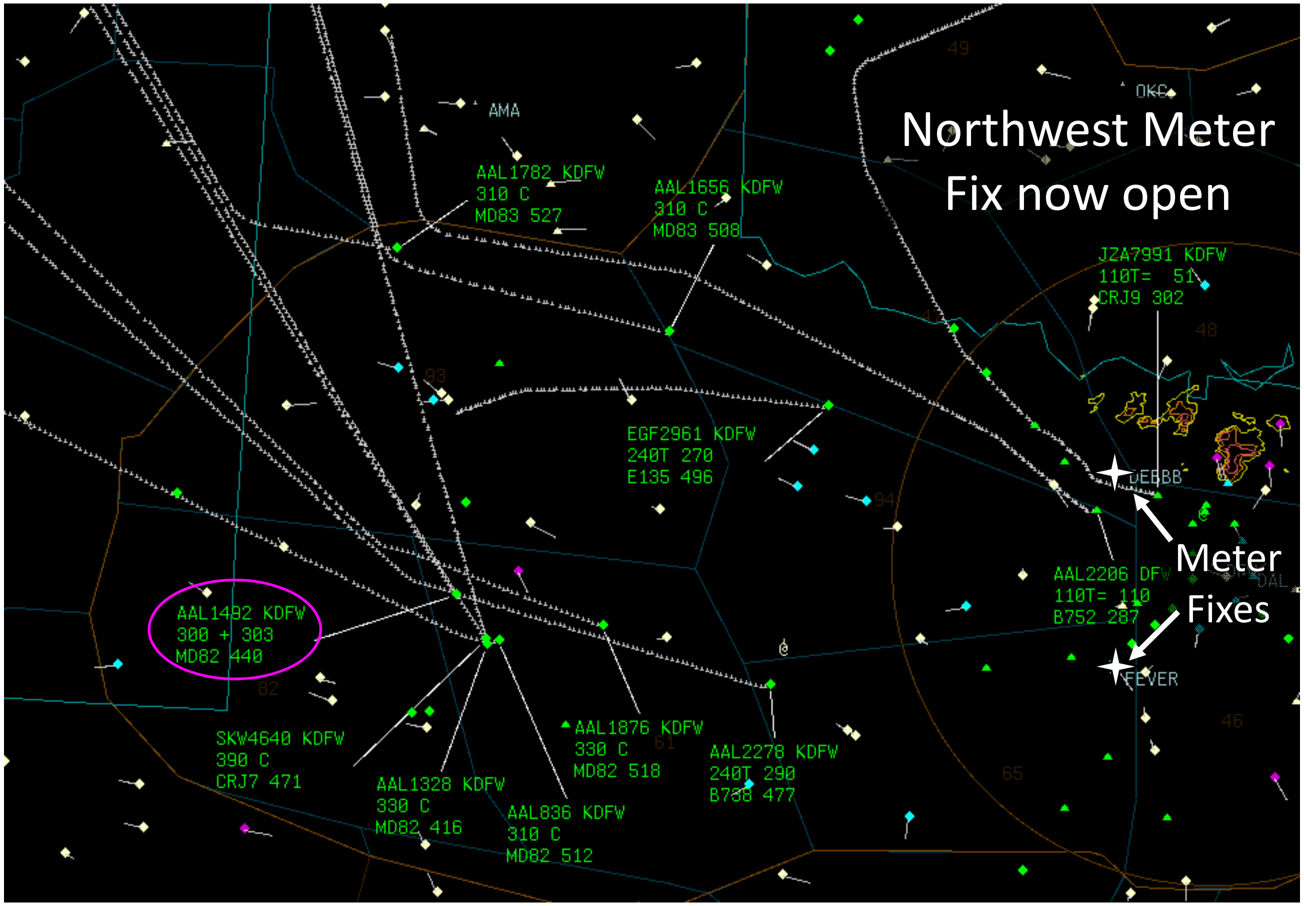
```
STATUS: Trial Planning
SWA1696    B737/Q   360   KATL./.SJI031045..IAH.J86.JCT..FTI..ALS.LARKS7.KDEN/0314

SWA1696                   KATL./.LBY178022..MCB147025..ACT..PNH..ALS.LARKS7.KDEN
```

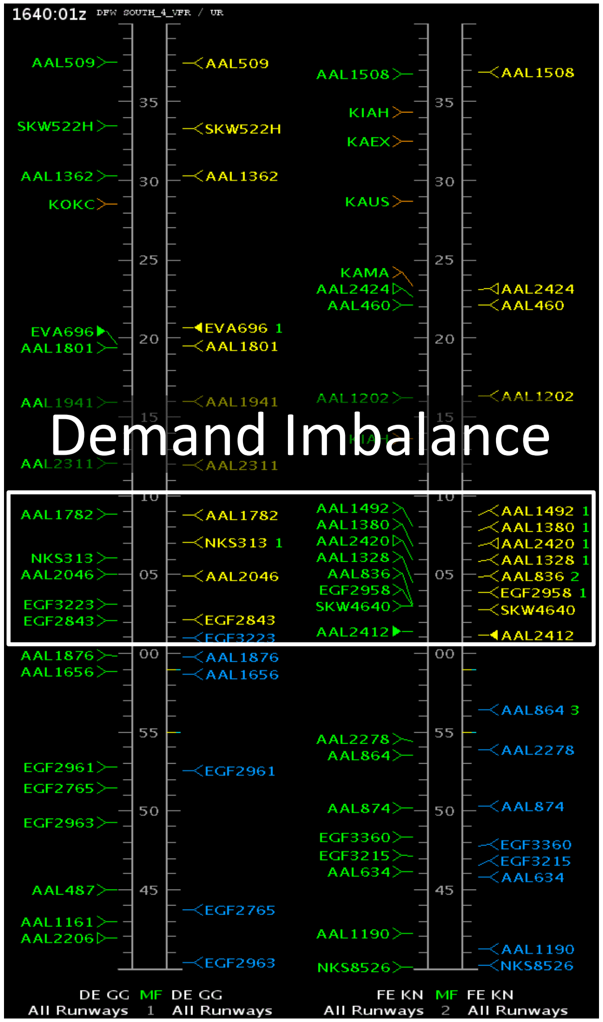
DRAW Backup

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

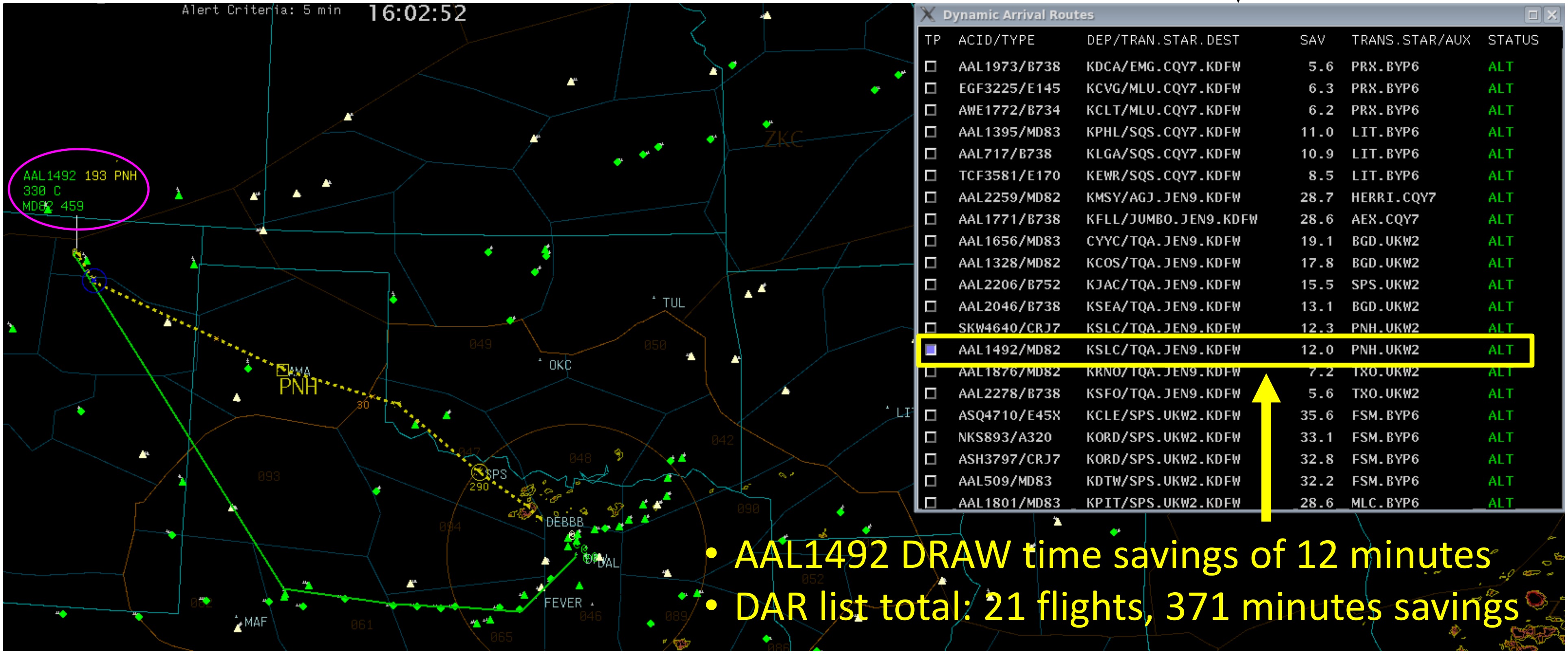


NW Meter Fix (DEBBB)

SW Meter Fix (FEVER)

Example of DRAW Time Saving Reroute to Alternate STAR

DAR List

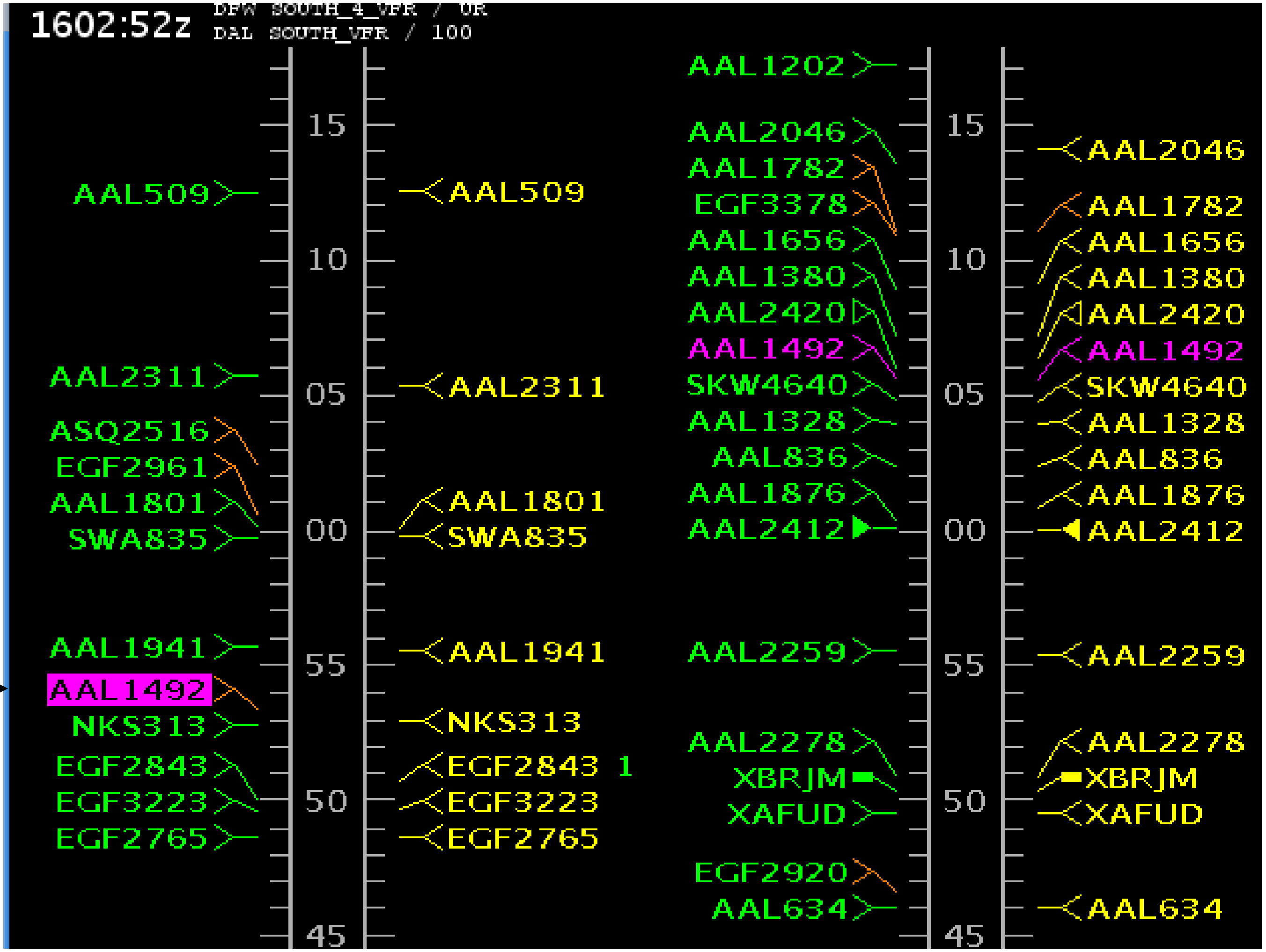


TP	ACID/TYPE	DEP/TRAN.STAR.DEST	SAV	TRANS.STAR/AUX	STATUS
☐	AAL1973/B738	KDCA/EMG.CQY7.KDFW	5.6	PRX.BYP6	ALT
☐	EGF3225/E145	KCVG/MLU.CQY7.KDFW	6.3	PRX.BYP6	ALT
☐	AWE1772/B734	KCLT/MLU.CQY7.KDFW	6.2	PRX.BYP6	ALT
☐	AAL1395/MD83	KPHL/SQS.CQY7.KDFW	11.0	LIT.BYP6	ALT
☐	AAL717/B738	KLGA/SQS.CQY7.KDFW	10.9	LIT.BYP6	ALT
☐	TCF3581/E170	KEWR/SQS.CQY7.KDFW	8.5	LIT.BYP6	ALT
☐	AAL2259/MD82	KMSY/AGJ.JEN9.KDFW	28.7	HERRI.CQY7	ALT
☐	AAL1771/B738	KFLL/JUMBO.JEN9.KDFW	28.6	AEX.CQY7	ALT
☐	AAL1656/MD83	CYYC/TQA.JEN9.KDFW	19.1	BGD.UKW2	ALT
☐	AAL1328/MD82	KCOS/TQA.JEN9.KDFW	17.8	BGD.UKW2	ALT
☐	AAL2206/B752	KJAC/TQA.JEN9.KDFW	15.5	SPS.UKW2	ALT
☐	AAL2046/B738	KSEA/TQA.JEN9.KDFW	13.1	BGD.UKW2	ALT
☐	SKW4640/CRJ7	KSLC/TQA.JEN9.KDFW	12.3	PNH.UKW2	ALT
■	AAL1492/MD82	KSLC/TQA.JEN9.KDFW	12.0	PNH.UKW2	ALT
☐	AAL1876/MD82	KRNO/TQA.JEN9.KDFW	7.2	TXO.UKW2	ALT
☐	AAL2278/B738	KSFO/TQA.JEN9.KDFW	5.6	TXO.UKW2	ALT
☐	ASQ4710/E45X	KCLE/SPS.UKW2.KDFW	35.6	FSM.BYP6	ALT
☐	NKS893/A320	KORD/SPS.UKW2.KDFW	33.1	FSM.BYP6	ALT
☐	ASH3797/CRJ7	KORD/SPS.UKW2.KDFW	32.8	FSM.BYP6	ALT
☐	AAL509/MD83	KDTW/SPS.UKW2.KDFW	32.2	FSM.BYP6	ALT
☐	AAL1801/MD83	KPIT/SPS.UKW2.KDFW	28.6	MLC.BYP6	ALT

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

DRAW Integrated with Arrival Scheduling

Proposed DRAW Estimated Time of Arrival

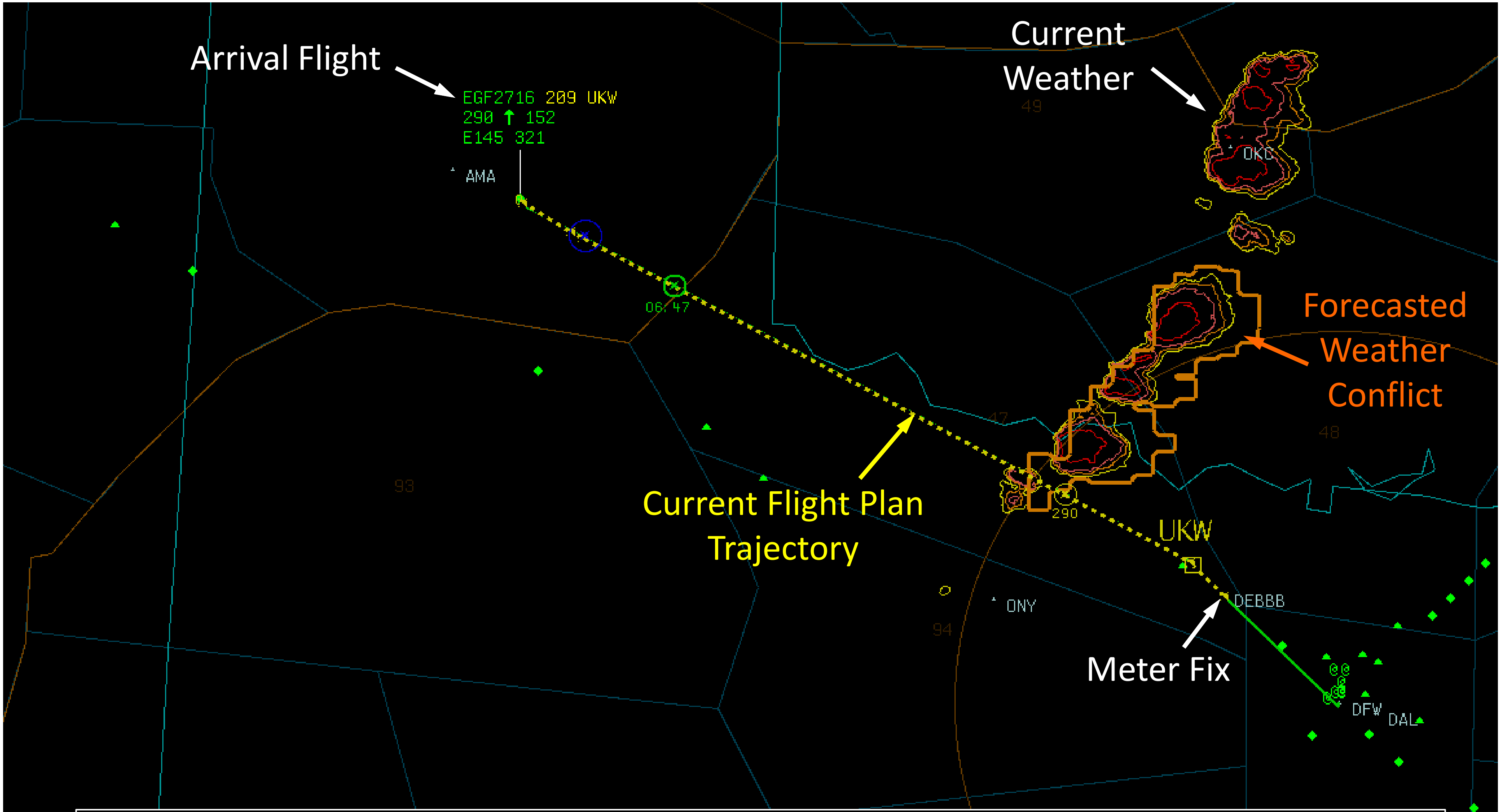


Current Estimated and Scheduled Times of Arrival

NW Meter Fix (DEBBB)

SW Meter Fix (FEVER)

Predicting the Need to Deviate



Arrival Flight

Current Weather

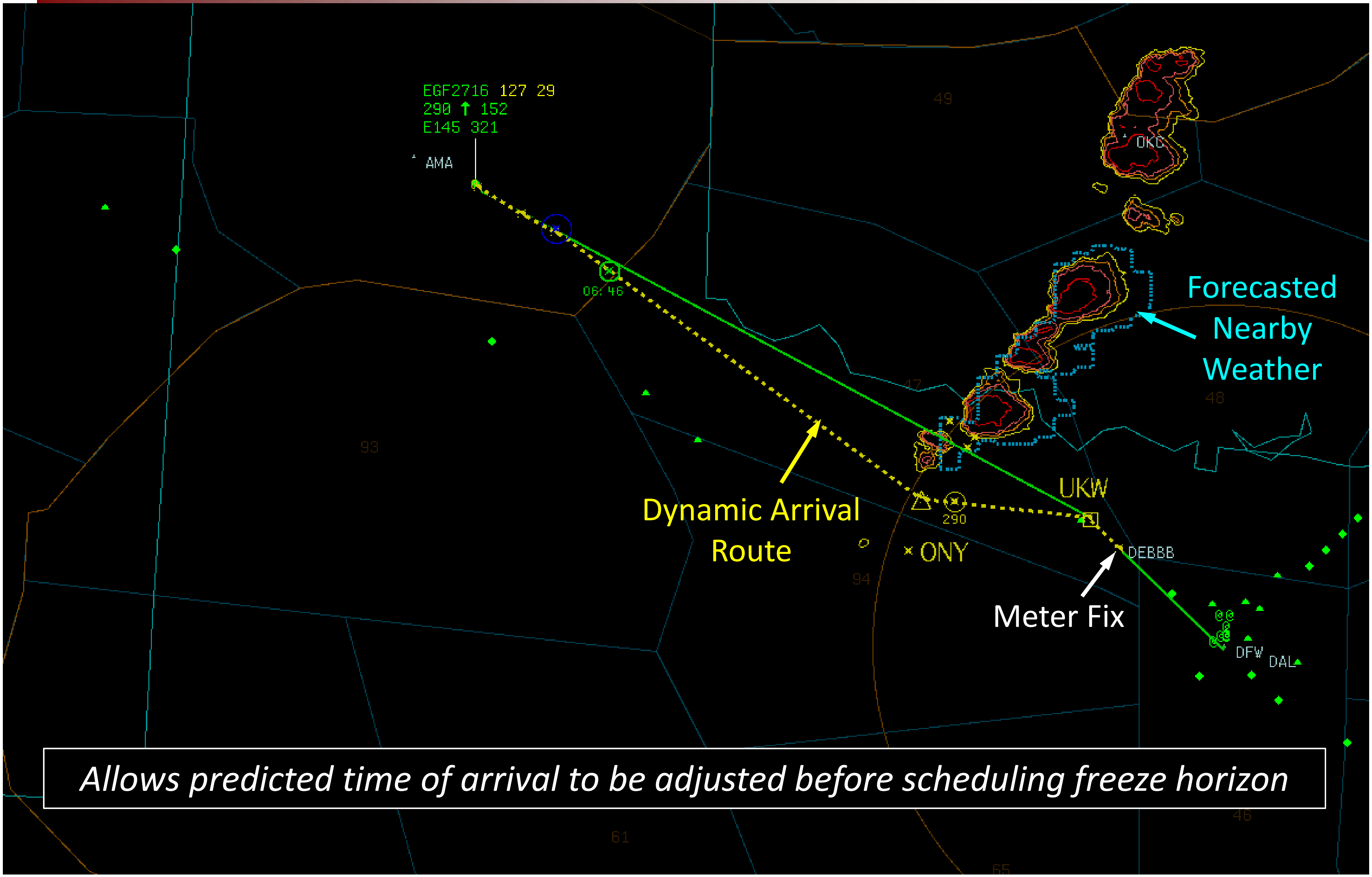
Forecasted Weather Conflict

Current Flight Plan Trajectory

Meter Fix

Arrival with Predicted Weather Conflict (need to deviate) = DRAW Candidate

Weather Adjusted Arrival Route



Forecasted Nearby Weather

Dynamic Arrival Route

Meter Fix

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

Preliminary TASAR Benefits Estimate

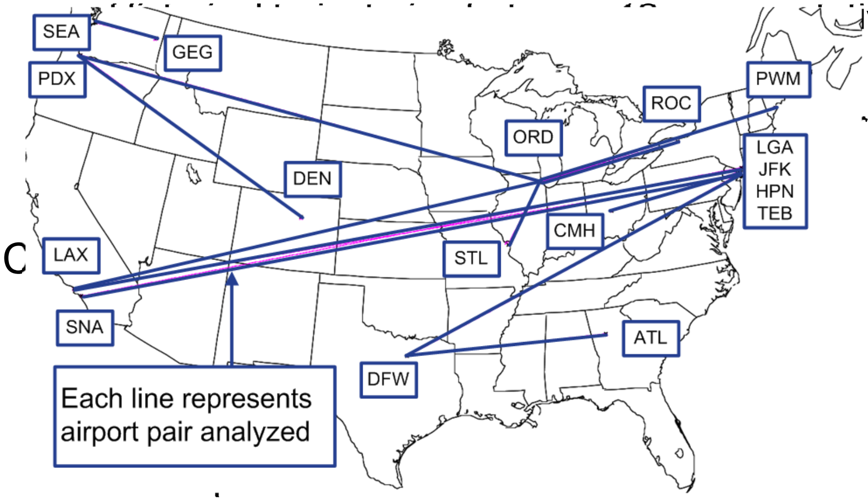
All Airspace User Classes are Projected to Benefit

Fast-time simulation study (2012)

ive airport pairs analyzed

each, five minute intervals

C



– No requests within 200 nmi of destination

Benefit per operation analyzed for different flight objectives

– Optimize time, fuel, or 50/50

Mean savings per flight

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)

Reference AIAA-2012-5684

TASAR Safety, Certification, and Operational Approval

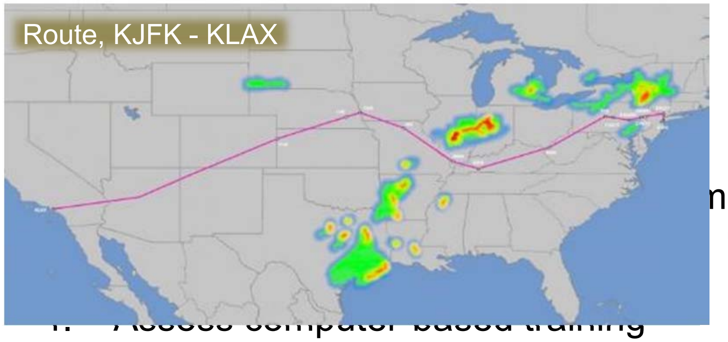
As currently defined, TASAR has a low threshold for FAA certification & operational approval

- **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



nary flight duties

4. Assess computer-based training

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

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

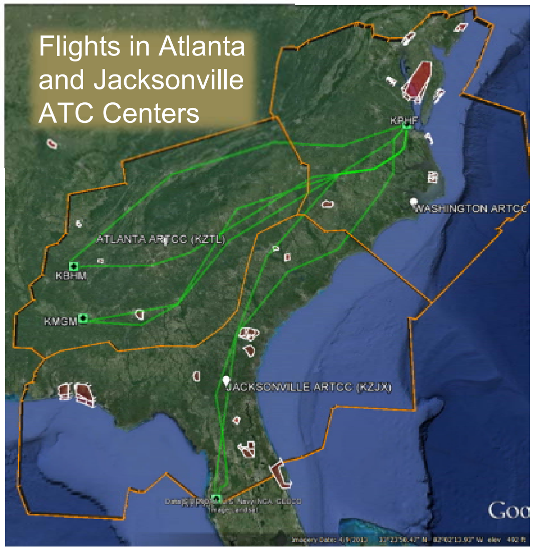
Results

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



- *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*

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

Reference AIAA-2014-2166

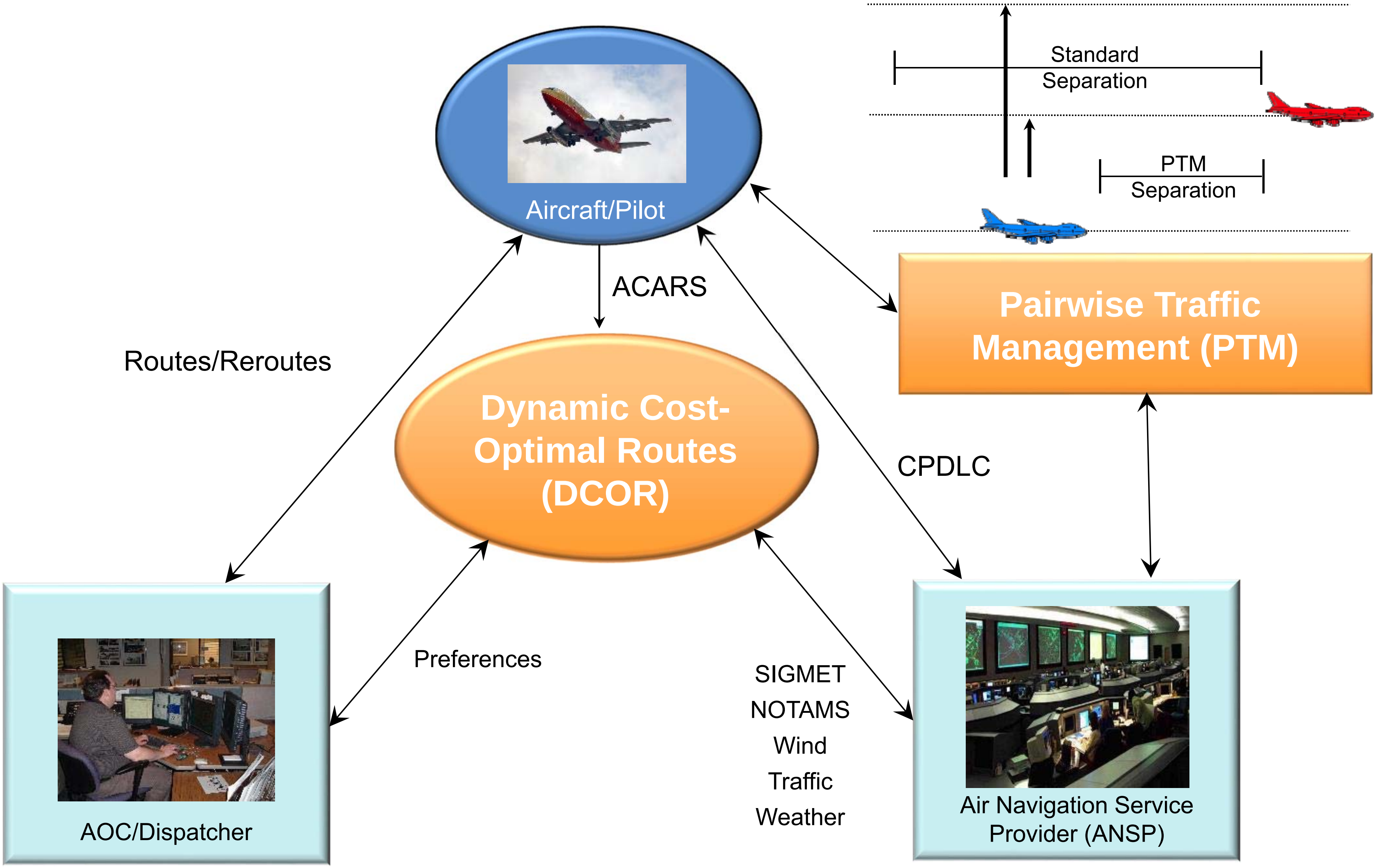
For More Information on TASAR

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



Standard Separation

PTM Separation

Aircraft/Pilot

ACARS

Pairwise Traffic Management (PTM)

Routes/Reroutes

Dynamic Cost-Optimal Routes (DCOR)

CPDLC

Preferences

SIGMET
NOTAMS
Wind
Traffic
Weather

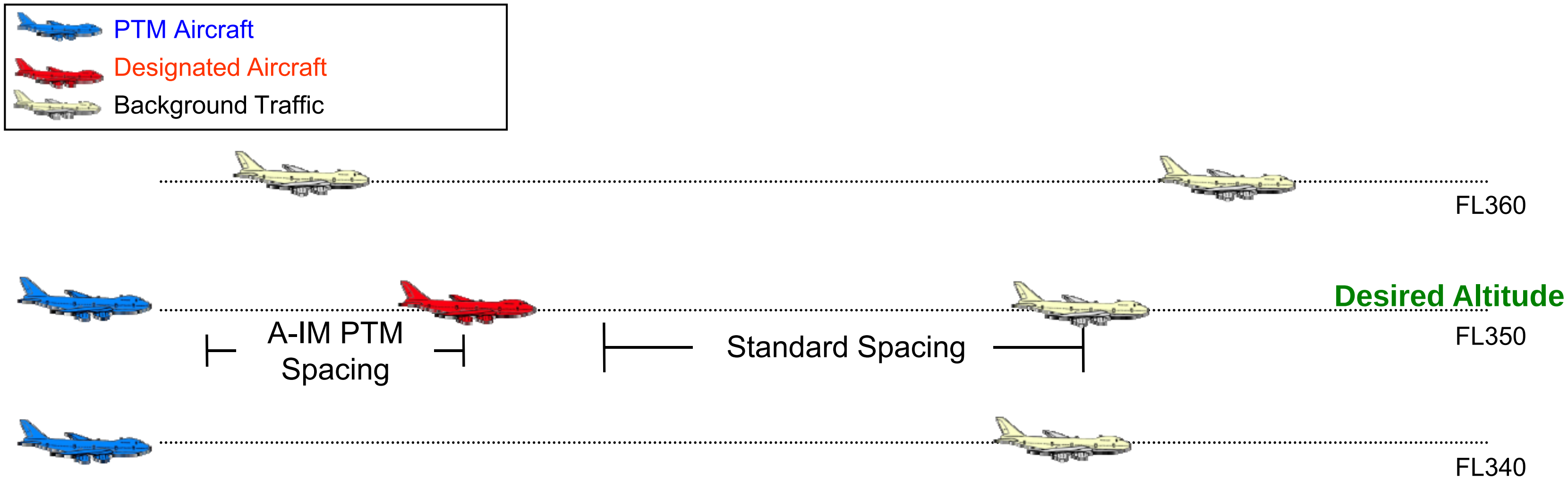
AOC/Dispatcher

Air Navigation Service Provider (ANSP)

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 = OPPORTUNITIES

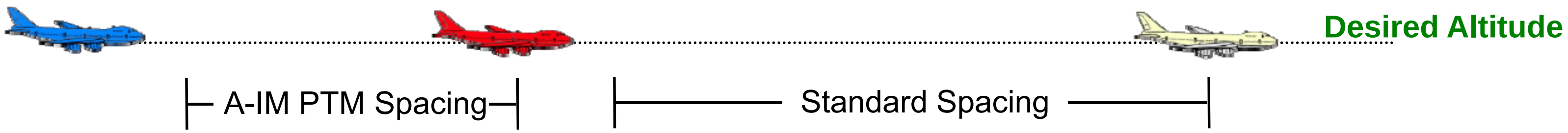
- Flights desire an optimal altitude for efficiency or ride quality

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

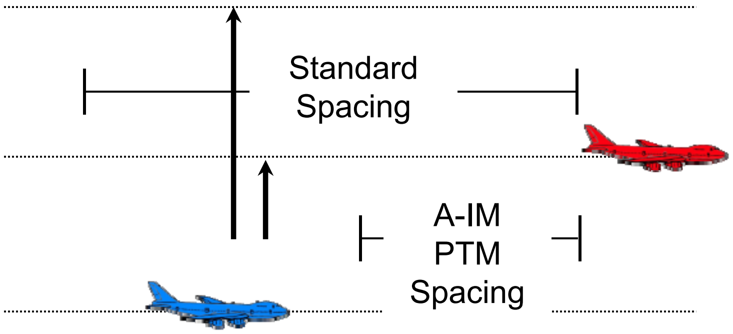
- Use PTM to enable more aircraft to operate at desired altitudes

PTM Concept Overview

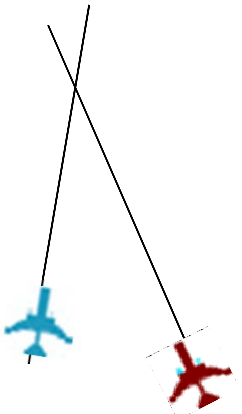
- **Operational Objective:** Use airborne surveillance and tools to manage reduced “at or greater than” inter-aircraft spacing of ATC assigned aircraft pairs that results in reduced fuel burns and delays
- **Mechanism**: Advanced Interval Management (A-IM) PTM equipment and procedures enable reduced 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

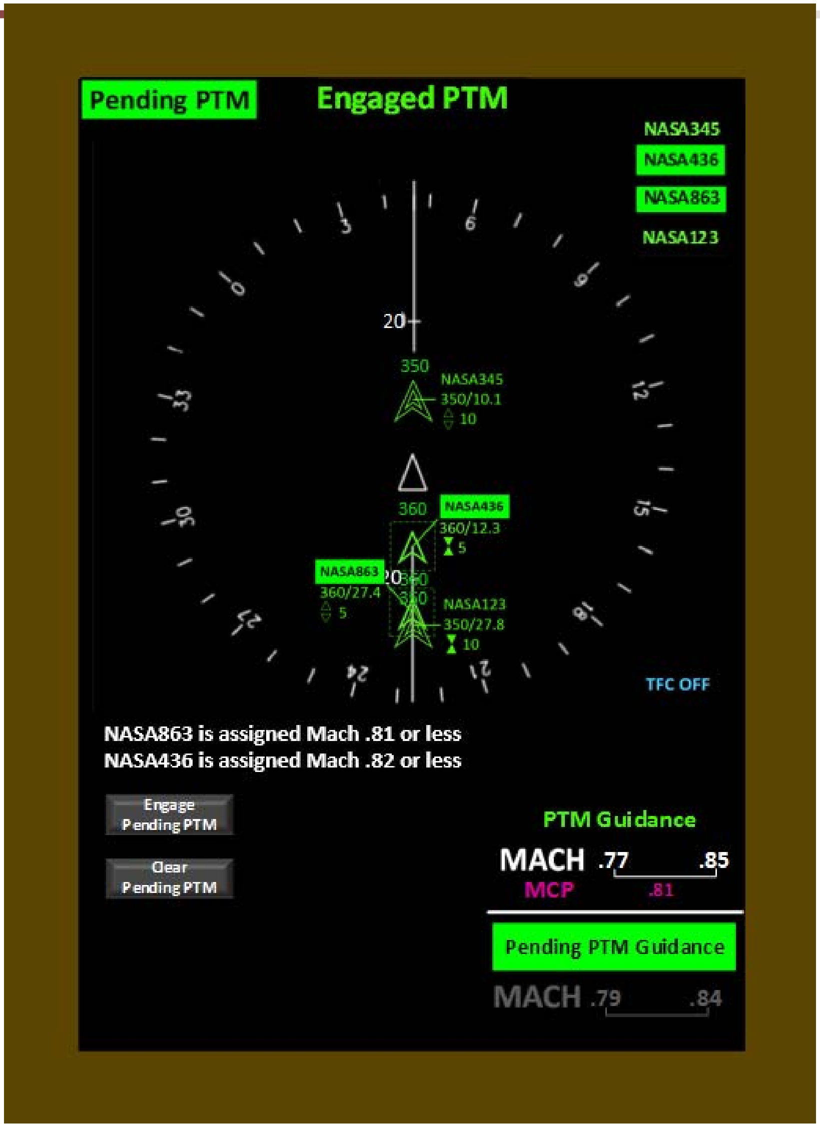
- Spaced-Based ADSB
  - Targeting 15 NM Longitudinal Separation
  - Requires significant investment with high usage cost to support that investment
  - Requires some aircraft investment if FANS 1/A is not a part of the aircraft's current equipage
- FANS 1/A and RNP-4 equipage
  - Targeting 30/30 separation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

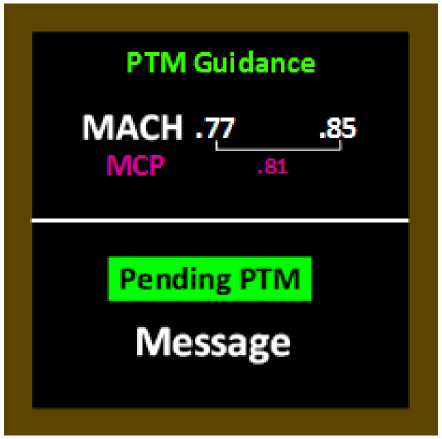
FANS 1/A	RNP10	RNP4
23%	99%	17%

Brief Introduction to the PTM HMI



NASA863 is assigned Mach .81 or less
NASA436 is assigned Mach .82 or less

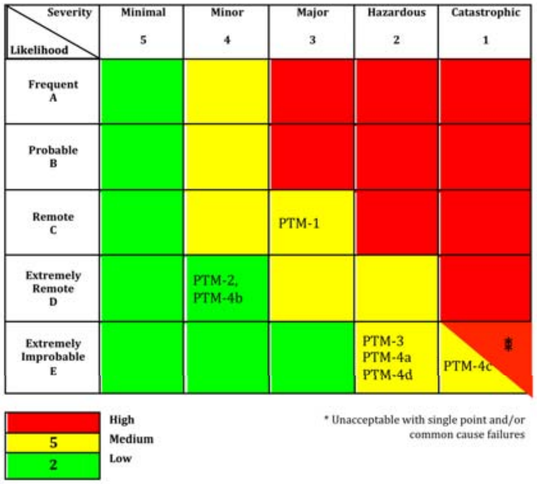
Side-Mounted Display
with touchscreen interface



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



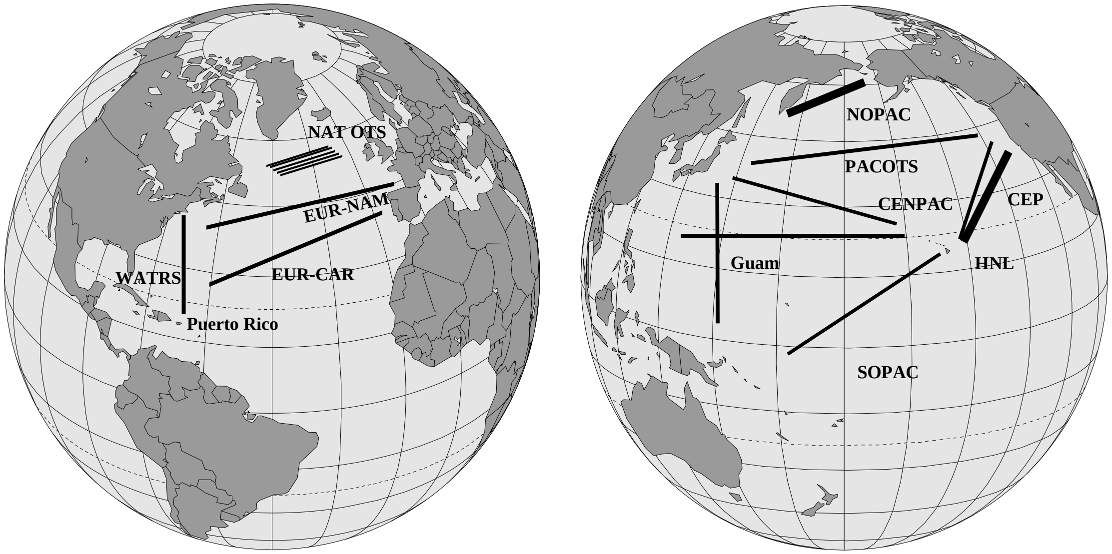
Severity / Likelihood	Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A	🟩	🟨	🟥	🟥	🟥
Probable B	🟩	🟨	🟥	🟥	🟥
Remote C	🟩	🟨	🟨 PTM-1	🟥	🟥
Extremely Remote D	🟩	🟩 PTM-2, PTM-4b	🟨	🟨	🟥
Extremely Improbable E	🟩	🟩	🟩	🟨 PTM-3 PTM-4a PTM-4d	🟨 PTM-4c 🟥 *

🟥	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)
    - Numbers are based on collision risk estimations and not on safety assessments.
    - Bandwidth may not be able to support ADS-C at 4 minute update rates
    - Mixed equipage operation is a concern
    - 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
    - Subscription cost does not guarantee benefit
    - 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