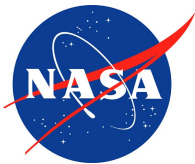


# Dynamic Weather Routes: Overview for Technology Transfer

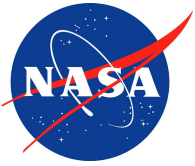
Dave McNally, Kapil Sheth, Hassan Eslami, Chester Gong  
Aviation Systems Division  
NASA Ames Research Center

Airspace Systems Program Webinar  
April 29, 2014

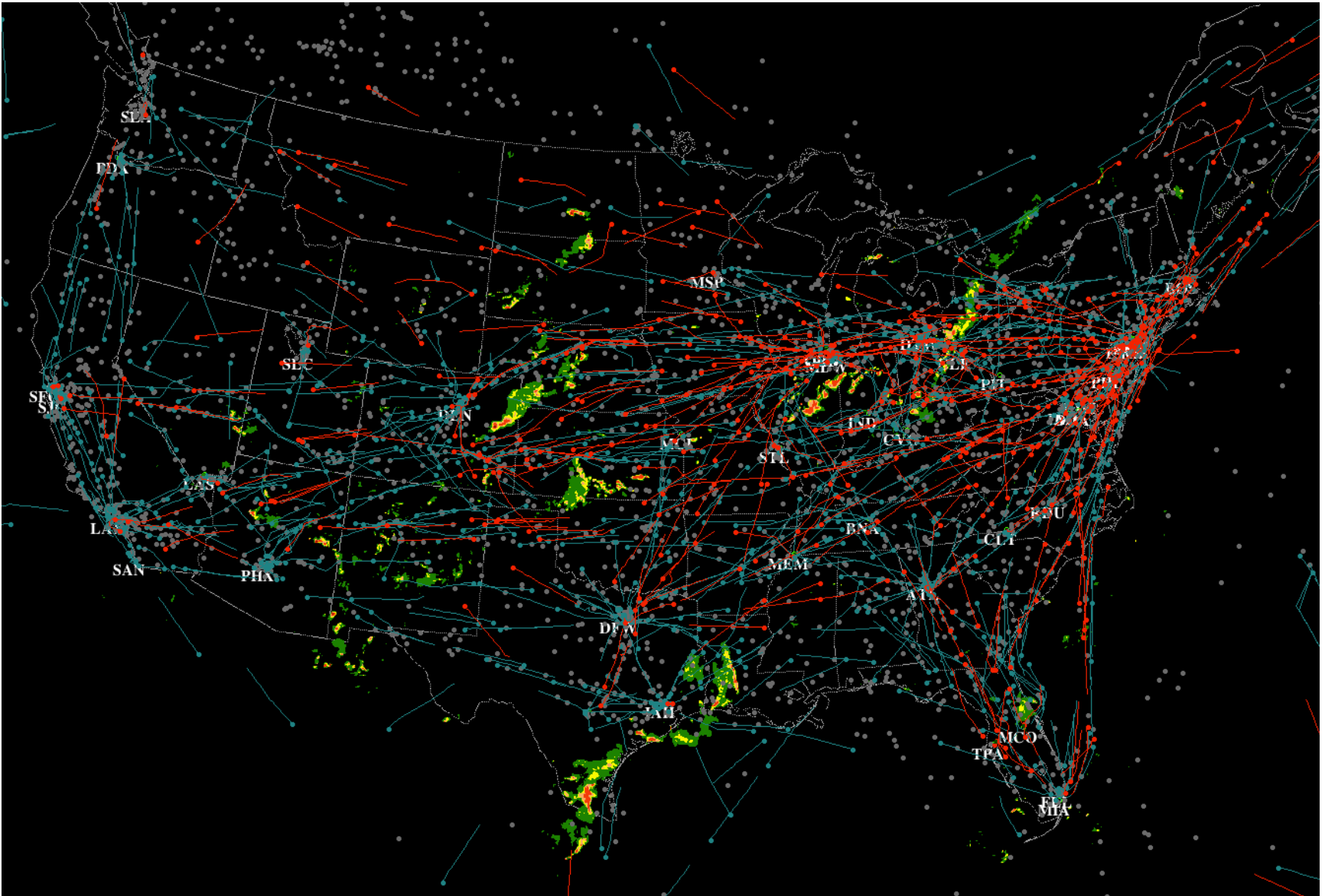


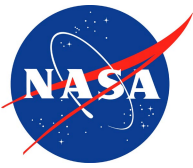
# Take Away Message

- Ground automation, continuous automatic search finds high-value route corrections, airborne flights, en route airspace
- Integrates convective weather, wind-corrected flying time, traffic conflicts, sector congestion, special use airspace, FAA route restrictions
- Net potential savings 100,000 flying minutes for 15,000 flights, Fort Worth Center in 2013
- Operational testing, American Airlines Integrated Operations Center, Fort Worth, TX, July 2012 to present



# What's the Problem





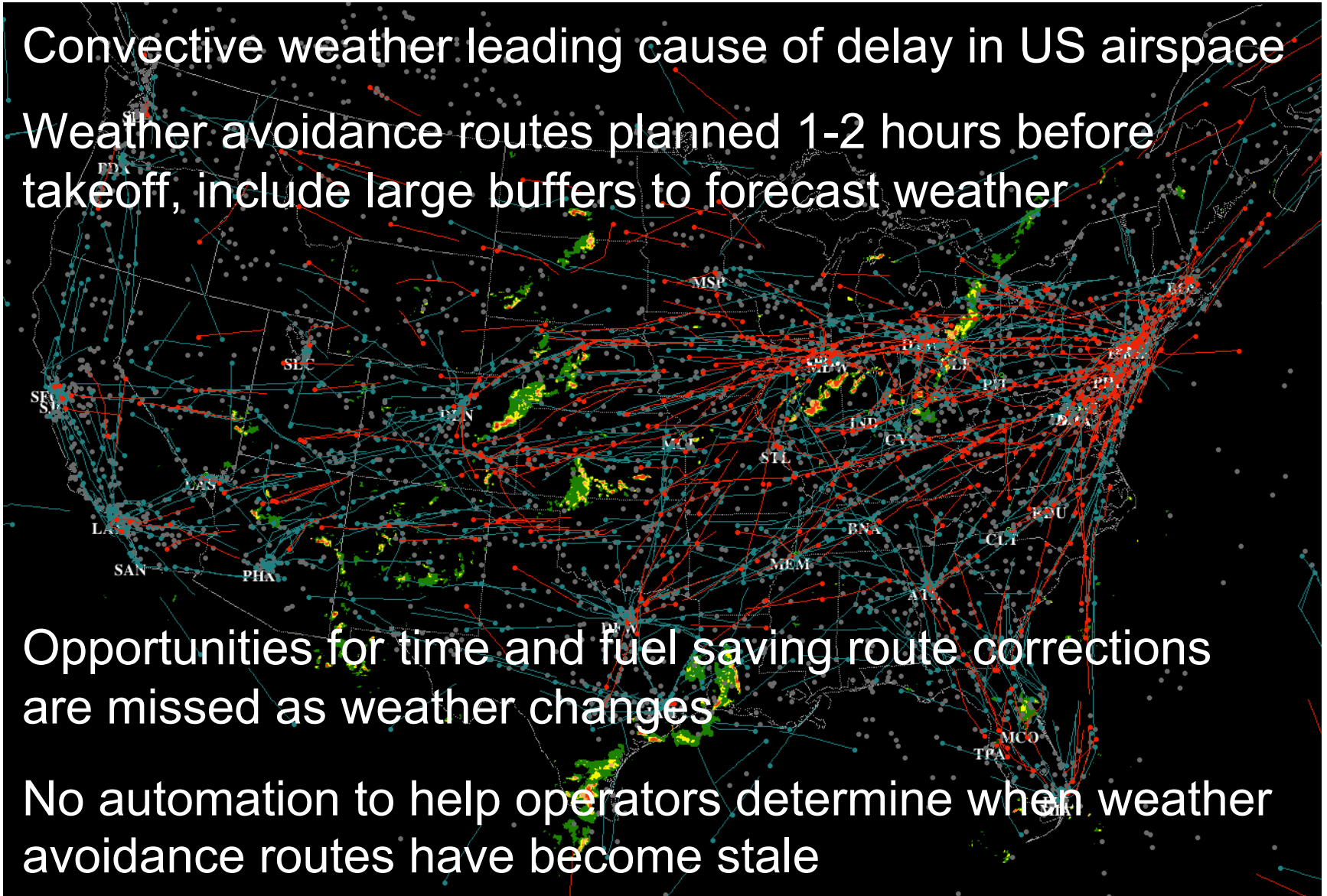
# What's the Problem

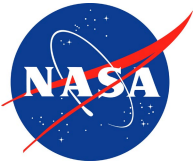
Convective weather leading cause of delay in US airspace

Weather avoidance routes planned 1-2 hours before takeoff, include large buffers to forecast weather

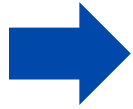
Opportunities for time and fuel saving route corrections are missed as weather changes

No automation to help operators determine when weather avoidance routes have become stale



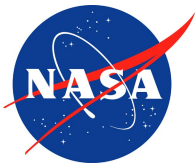


# Outline



## Building Blocks

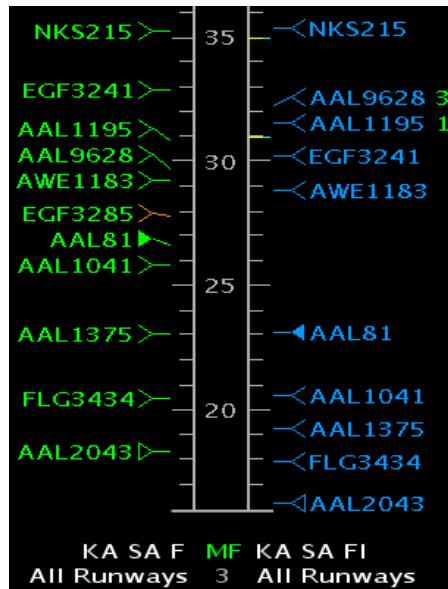
- DWR Concept, Tool, Functional Components
- Operational Trial at American Airlines
- Analysis Results
  - Potential Benefits all Fort Worth Center Flights
  - American Airlines Test Results
  - Sector Congestion Analysis
- Software Architecture and Required Inputs
- How to Acquire DWR Software
- Next Steps



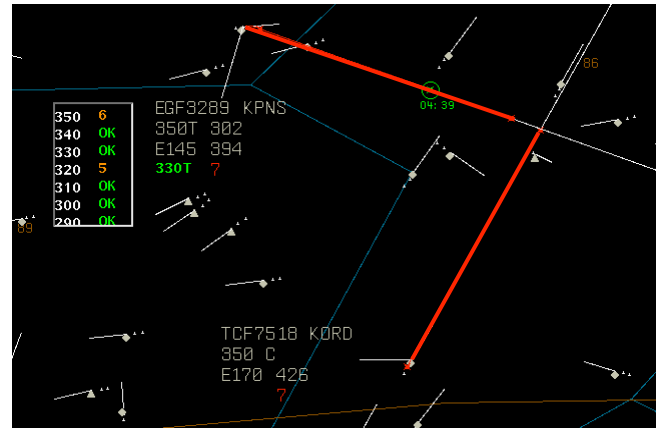
# Center/TRACON Automation System (CTAS)

## Ground-Based Trajectory Analysis Methodology and Software

### Traffic Management Advisor



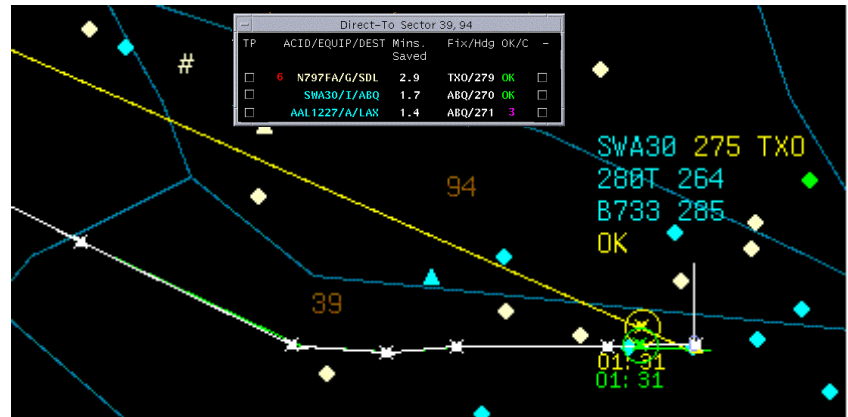
### Conflict Probe



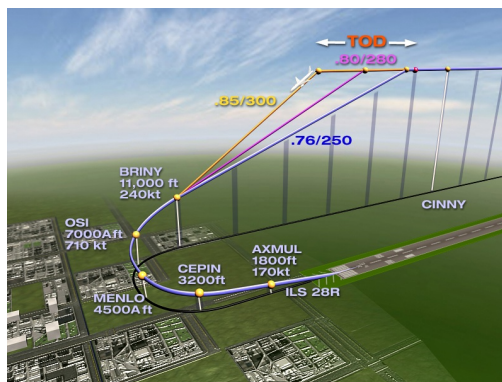
### Weather & Traffic Conflicts Integrated



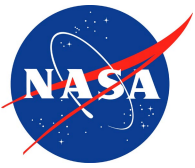
### Direct-To



### En Route Descent Advisor

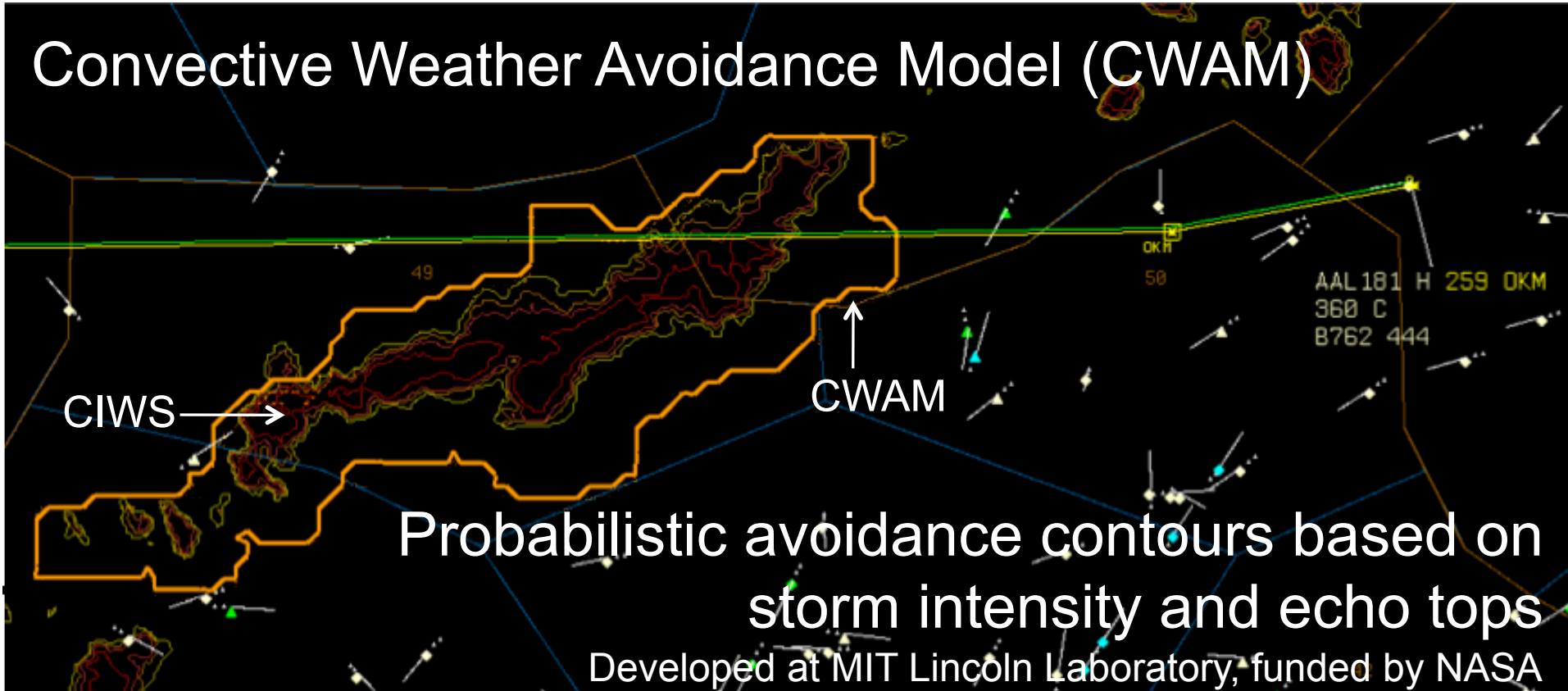






# How Does DWR Detect Conflicts with Convective Weather?

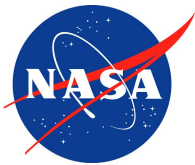
## Convective Weather Avoidance Model (CWAM)



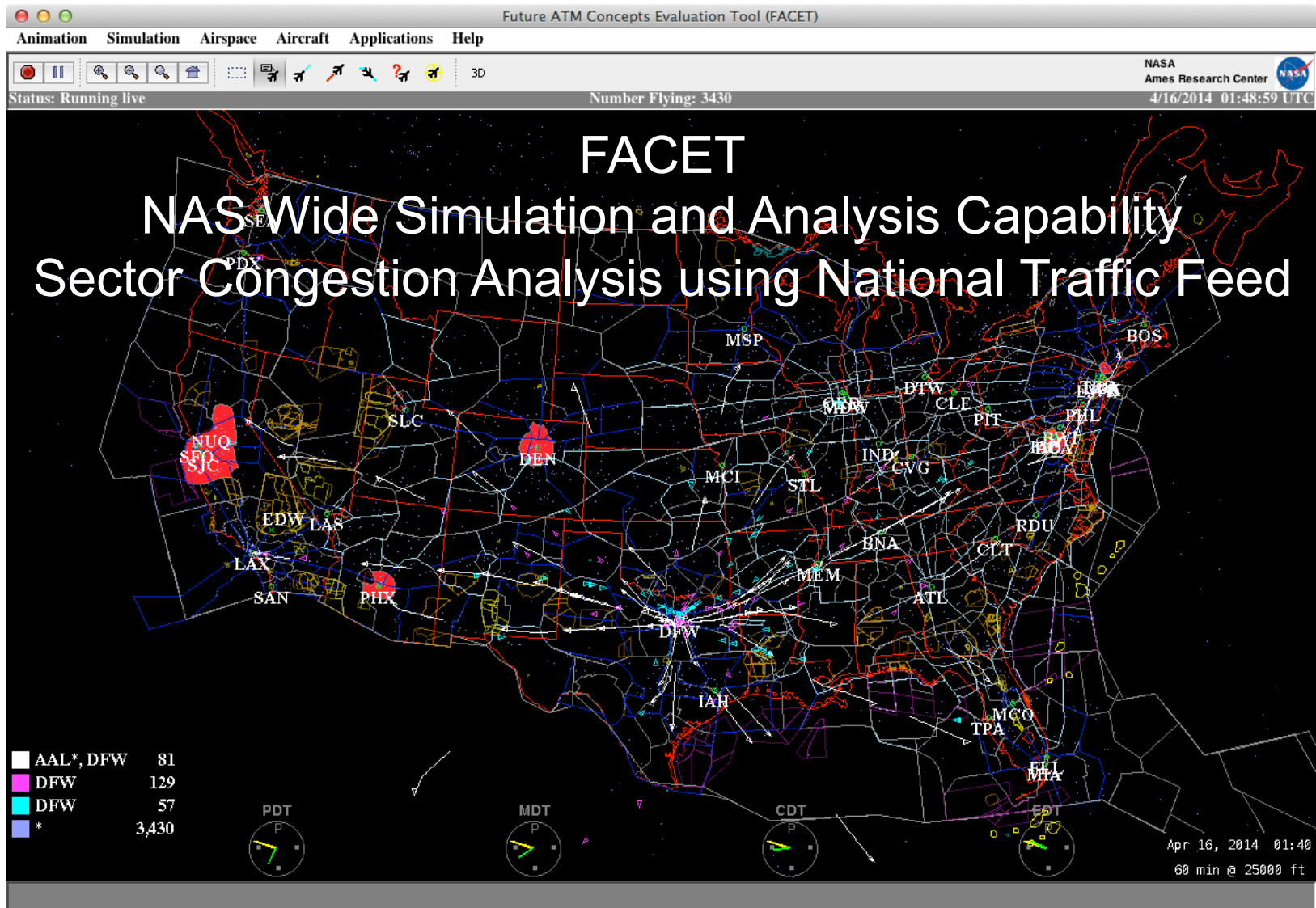
Corridor Integrated Weather System (CIWS)



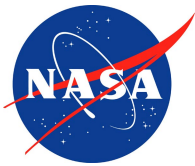
Convective Weather Avoidance Model (CWAM)



# Future ATM Concepts Evaluation Tool

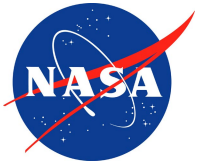




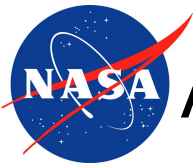


# Outline

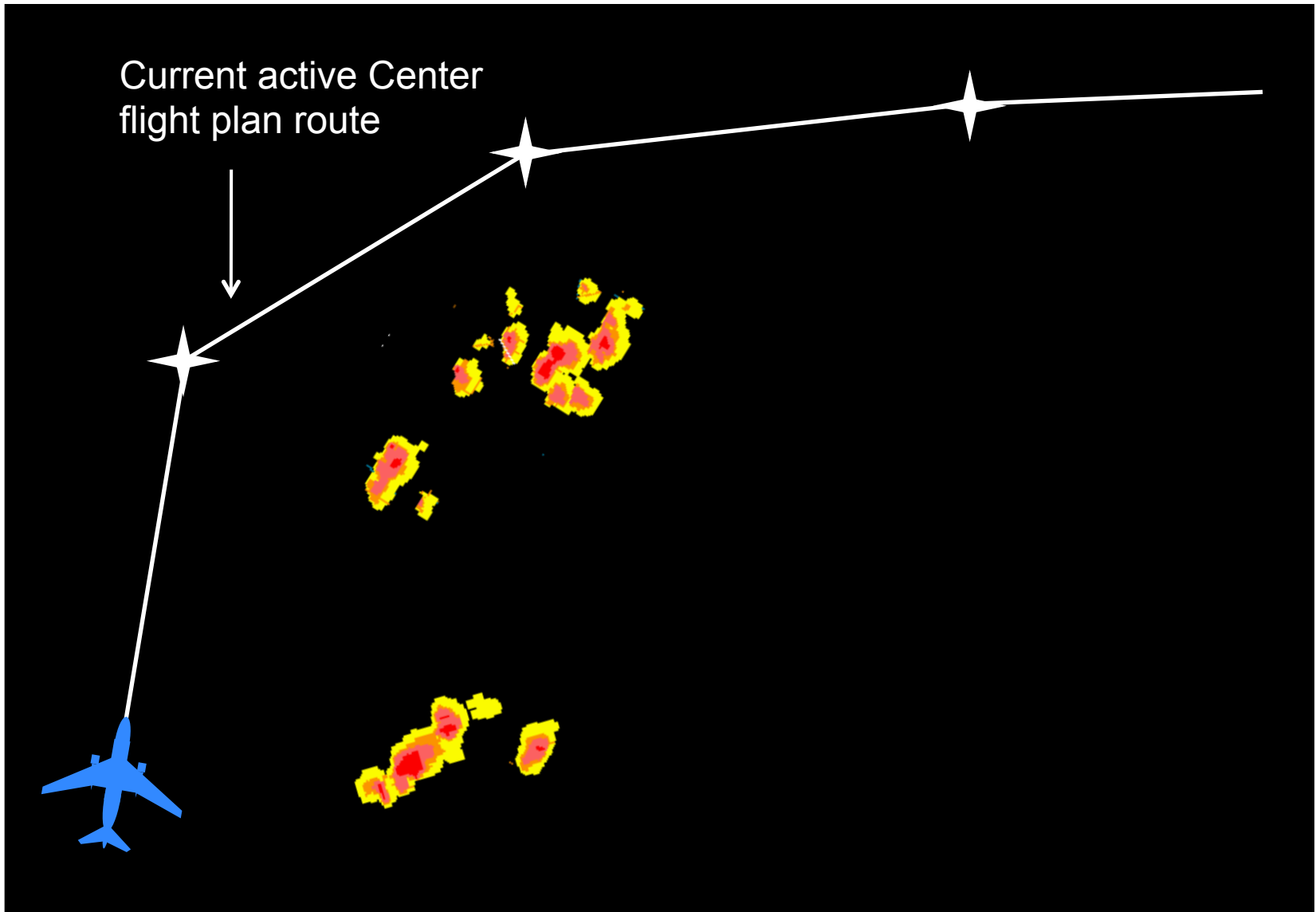
- Building Blocks
- ➔ DWR Concept, Tool, Functional Components
- Operational Trial at American Airlines
- Analysis Results
  - Potential Benefits all Fort Worth Center Flights
  - American Airlines Test Results
  - Sector Congestion Analysis
- Software Architecture and Required Inputs
- How to Acquire DWR Software
- Next Steps

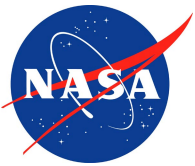


# How does DWR select flights and propose route corrections?

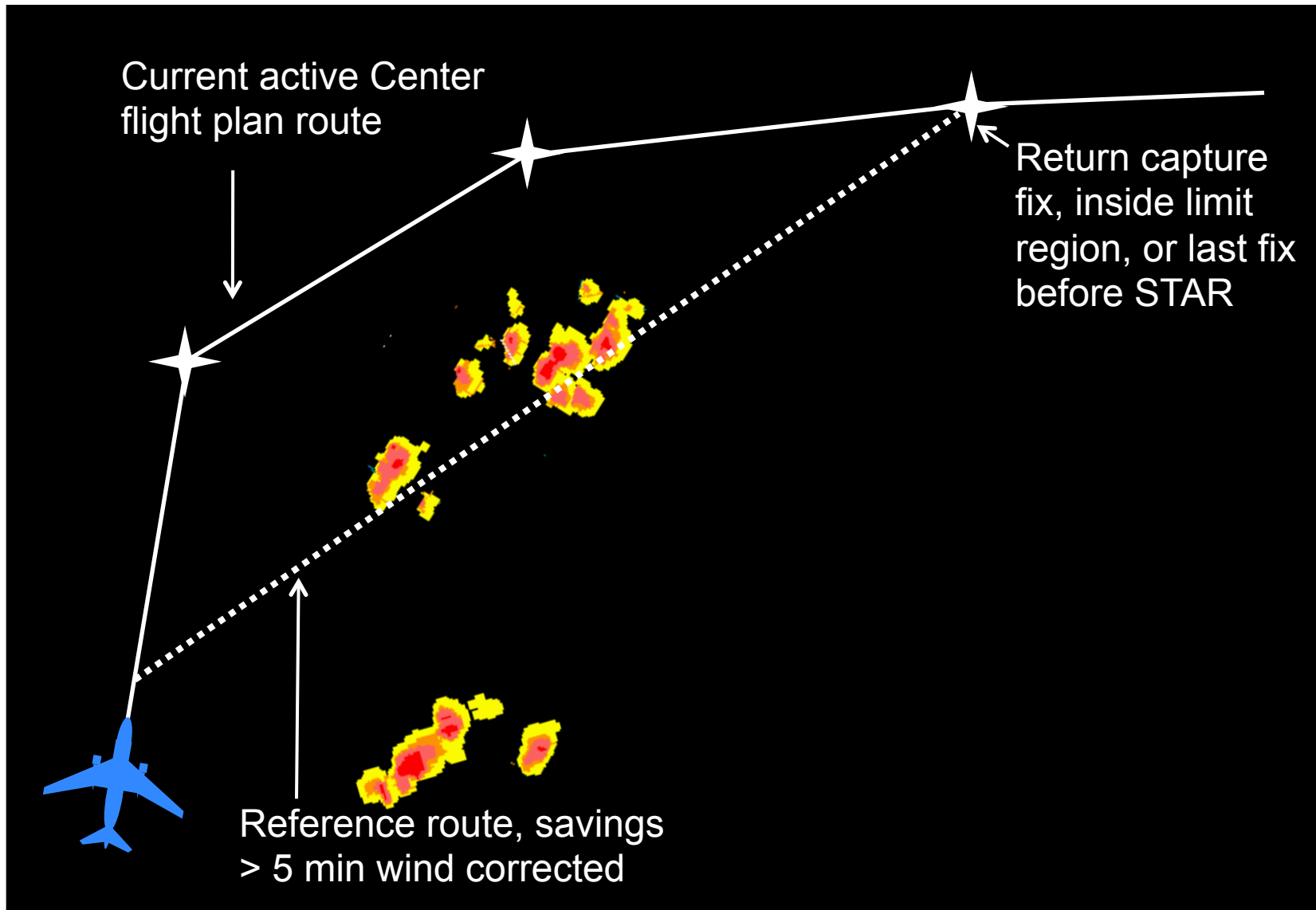


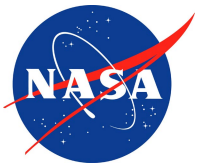
# Analyze Airborne Flights, En Route Airspace



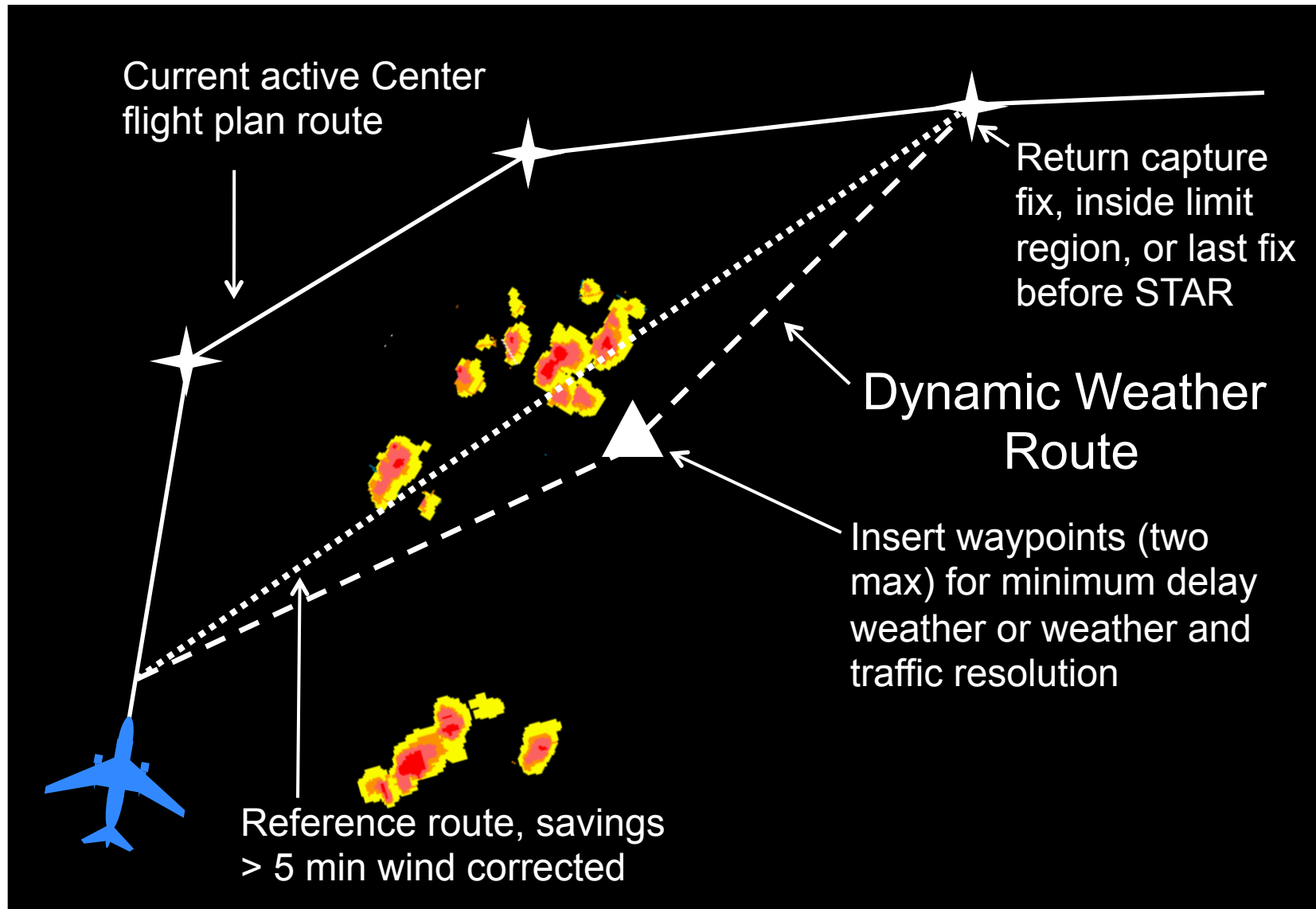


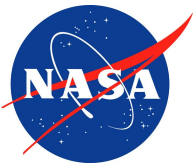
# Find Inefficient Route Segments



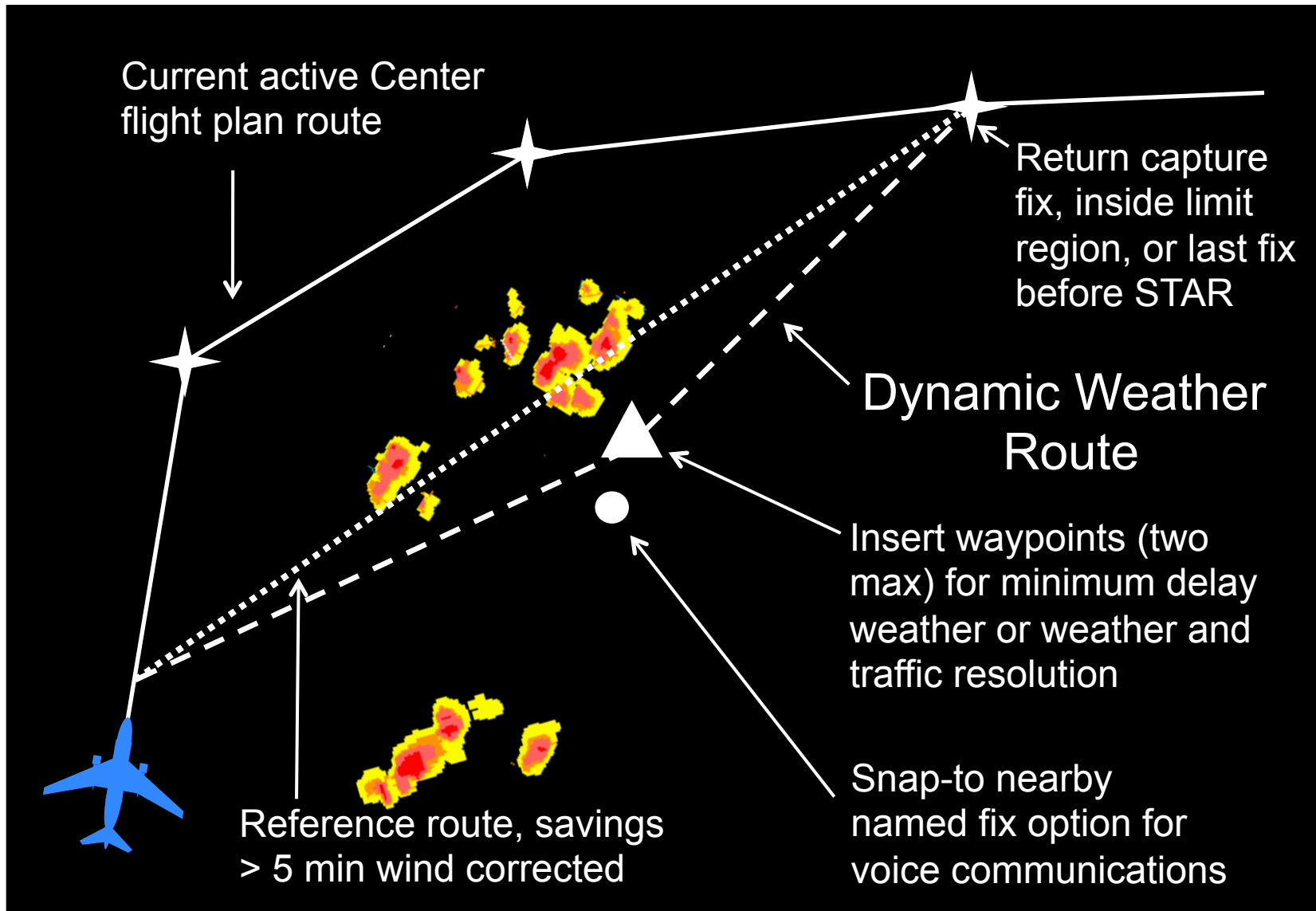


# Resolve Weather and Traffic Conflicts

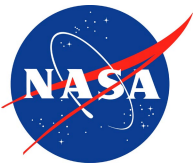




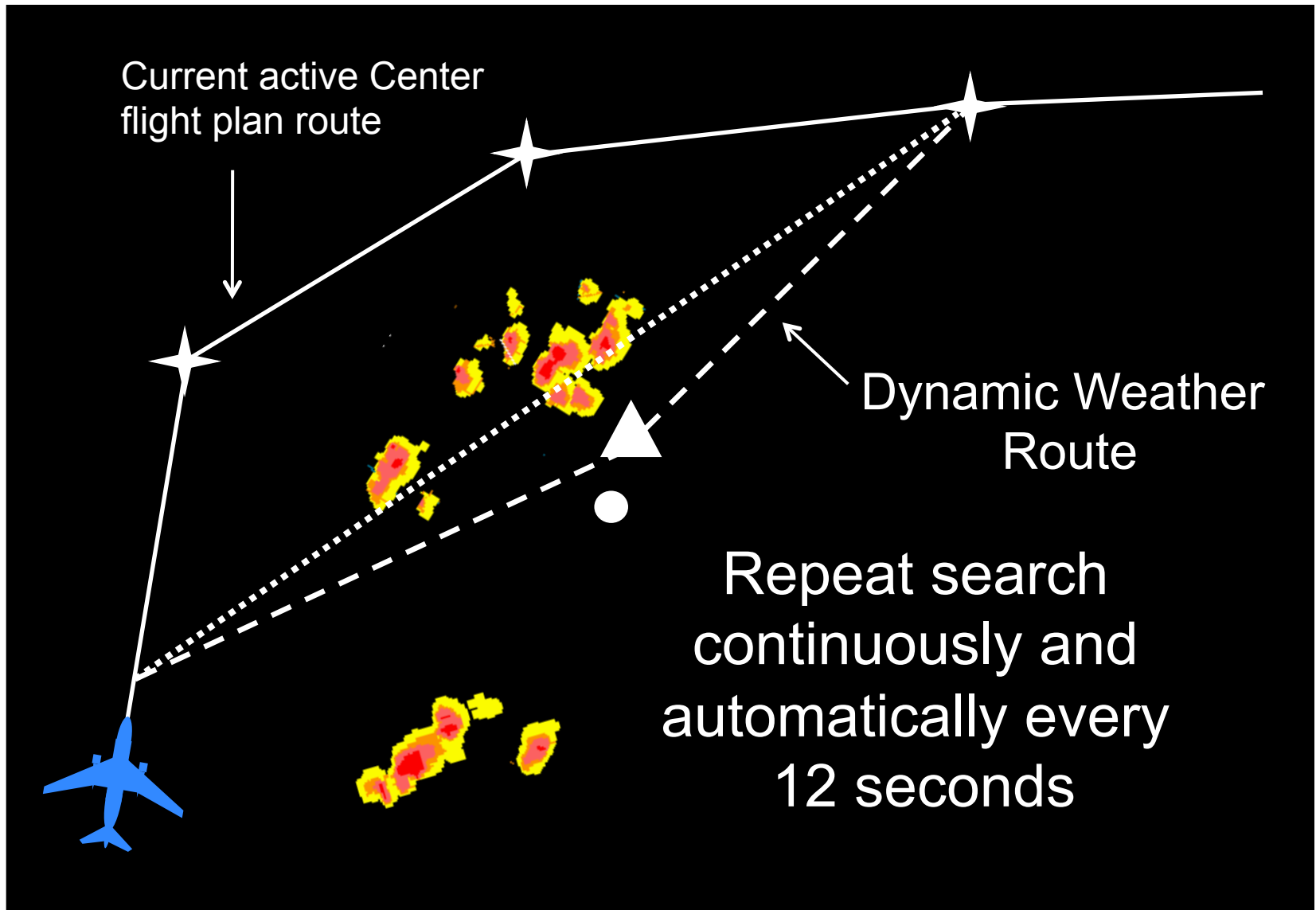
# Snap to Nearby Named Fixes

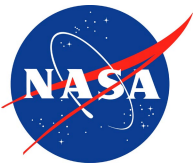




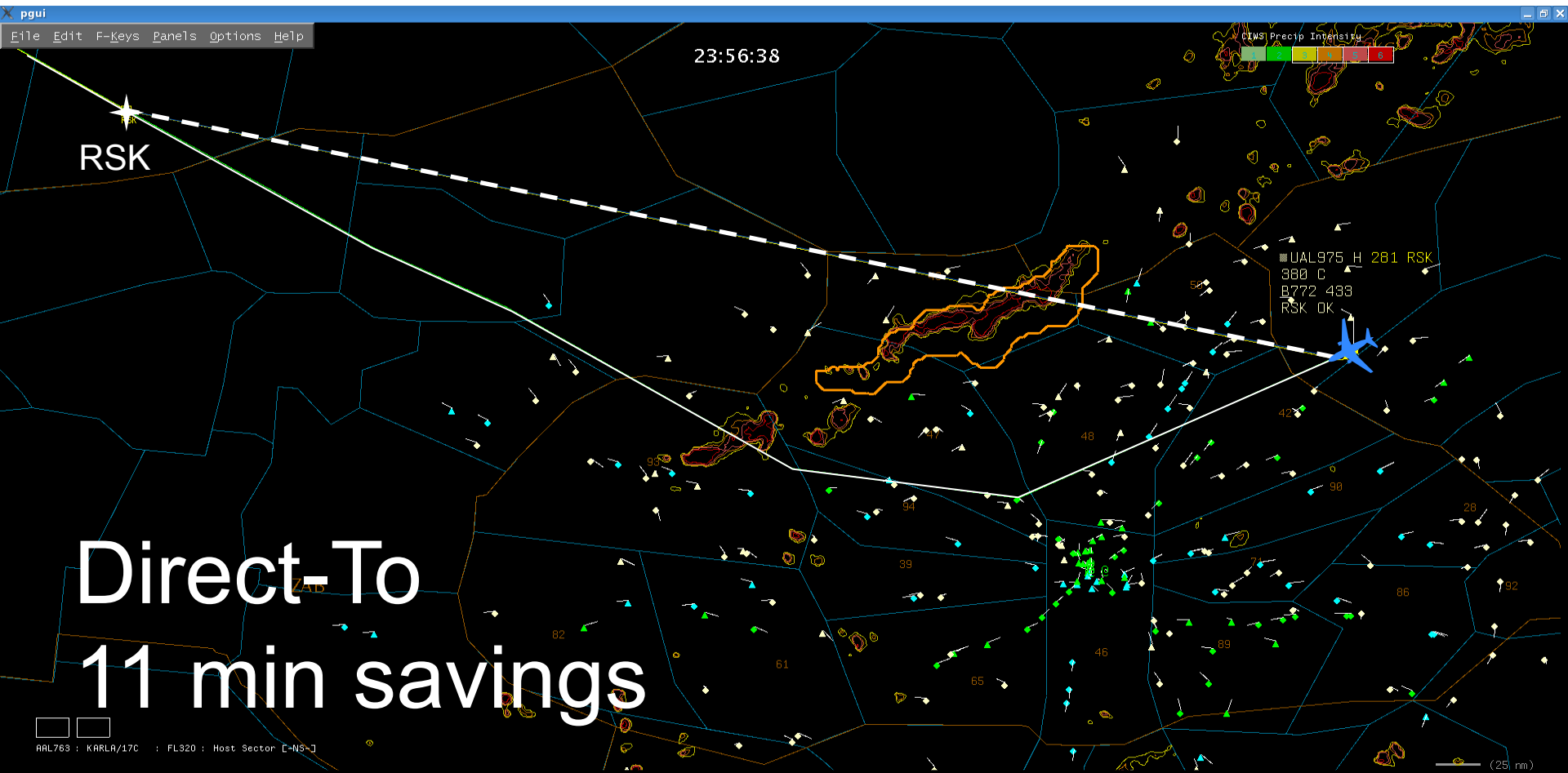


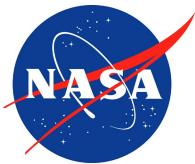
# Continuous Automatic Search



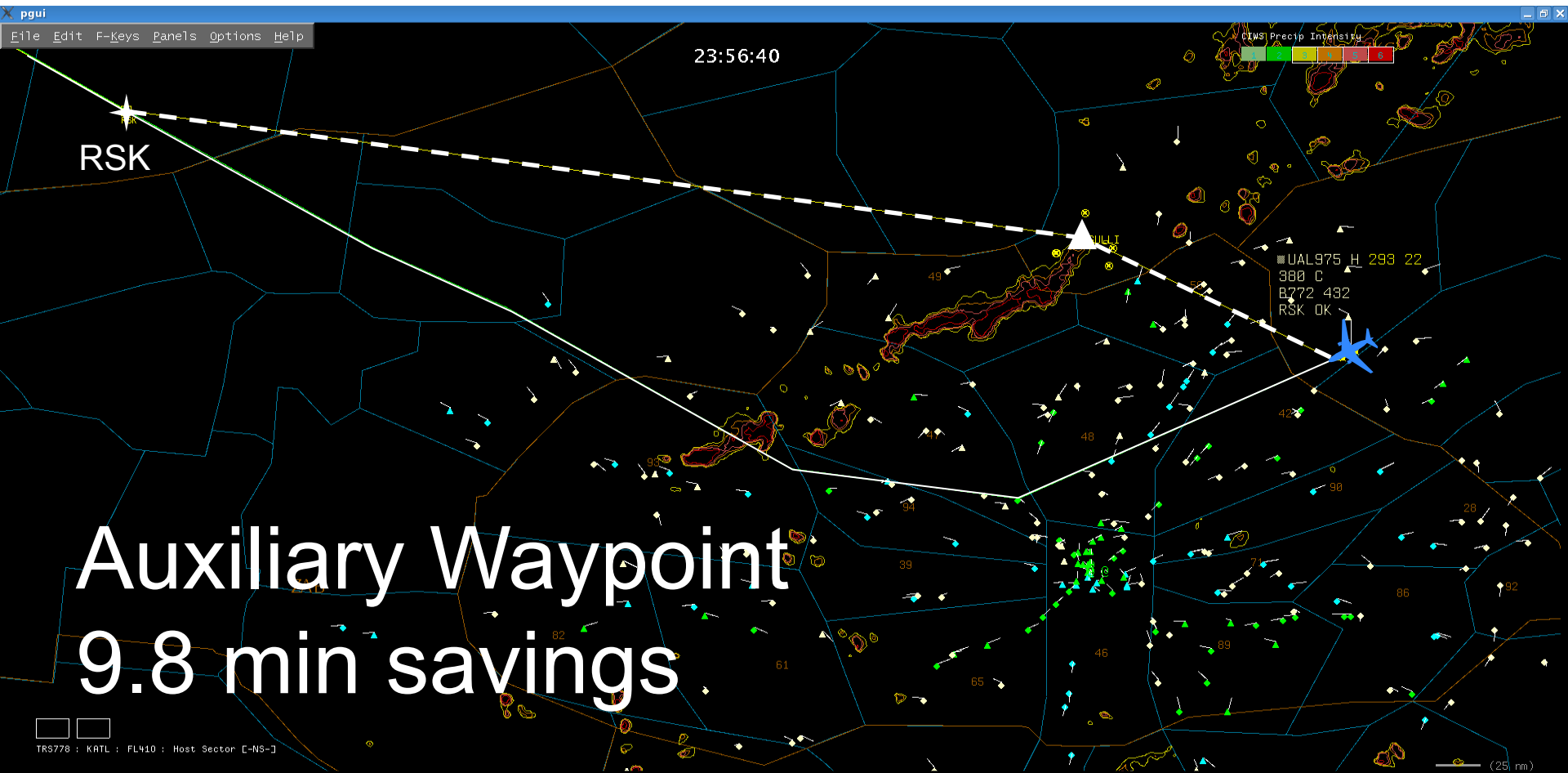


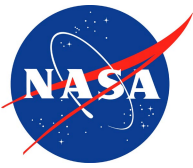
# Sample: UAL975 IAD to SFO



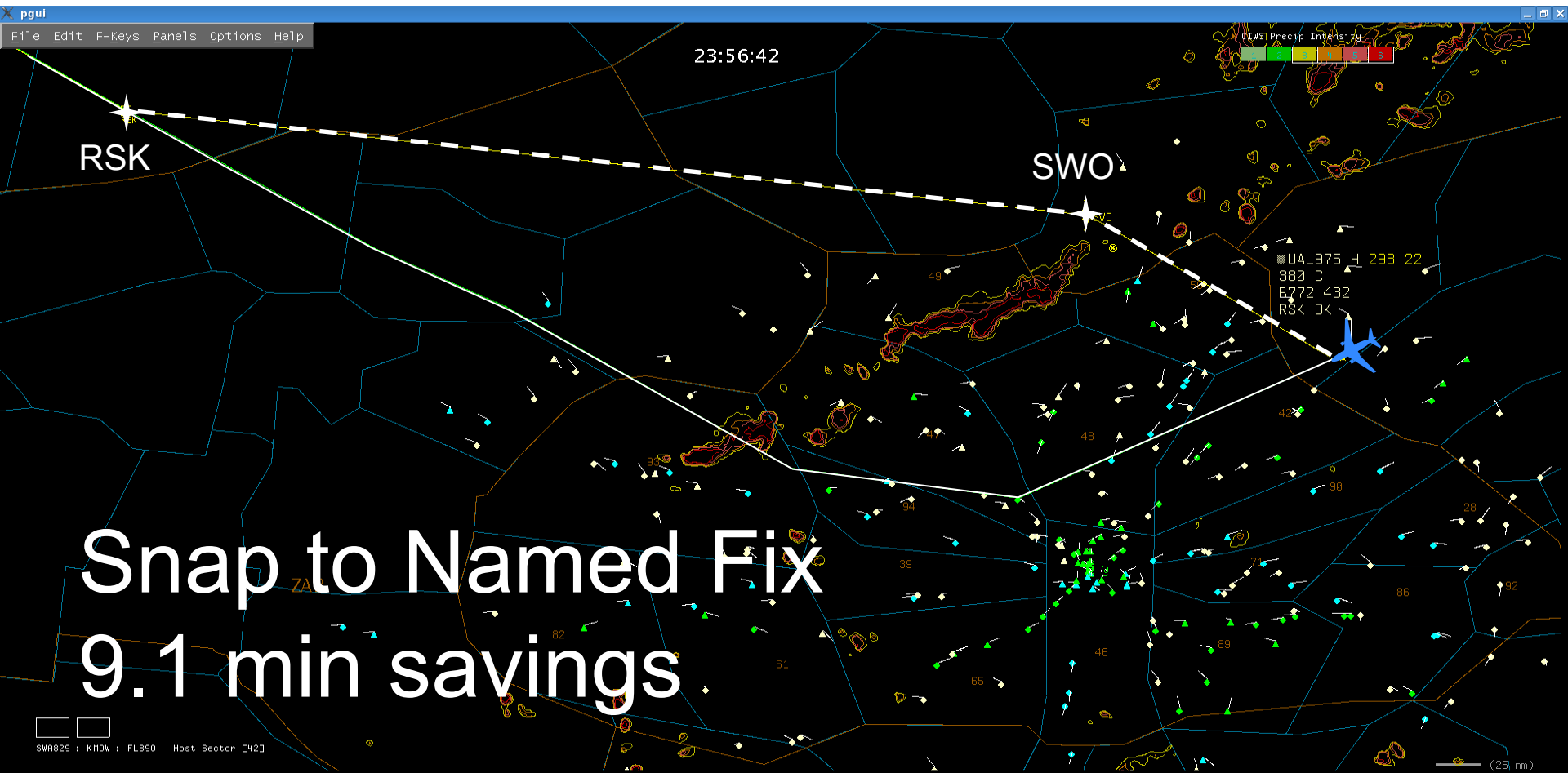


# Sample: UAL975 IAD to SFO

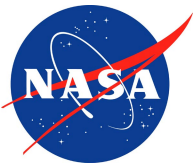




# Sample: UAL975 IAD to SFO

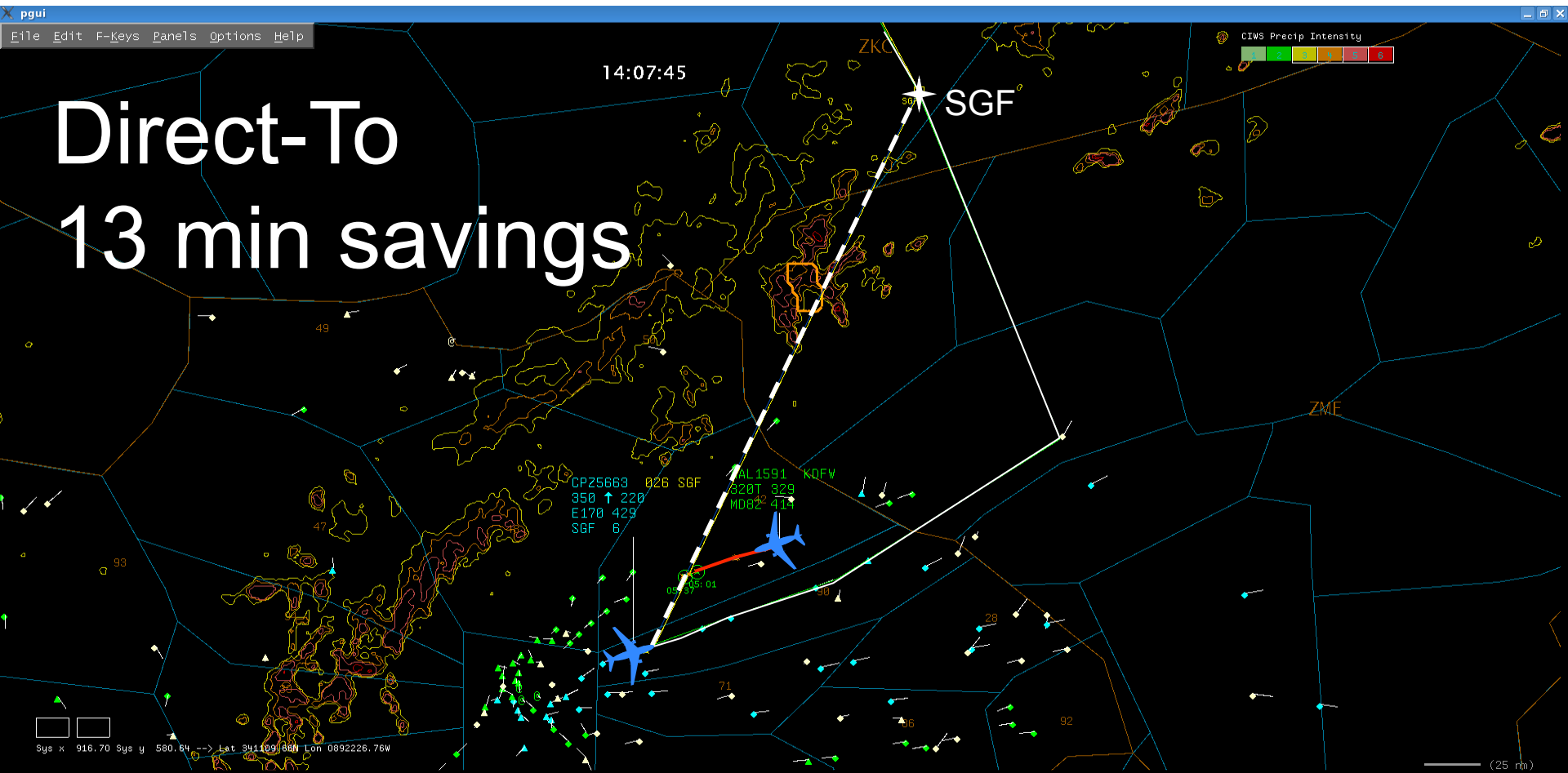


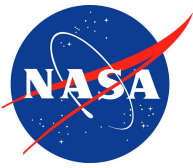
Snap to Named Fix  
9.1 min savings



# Sample: CPZ5663 DFW to MSP

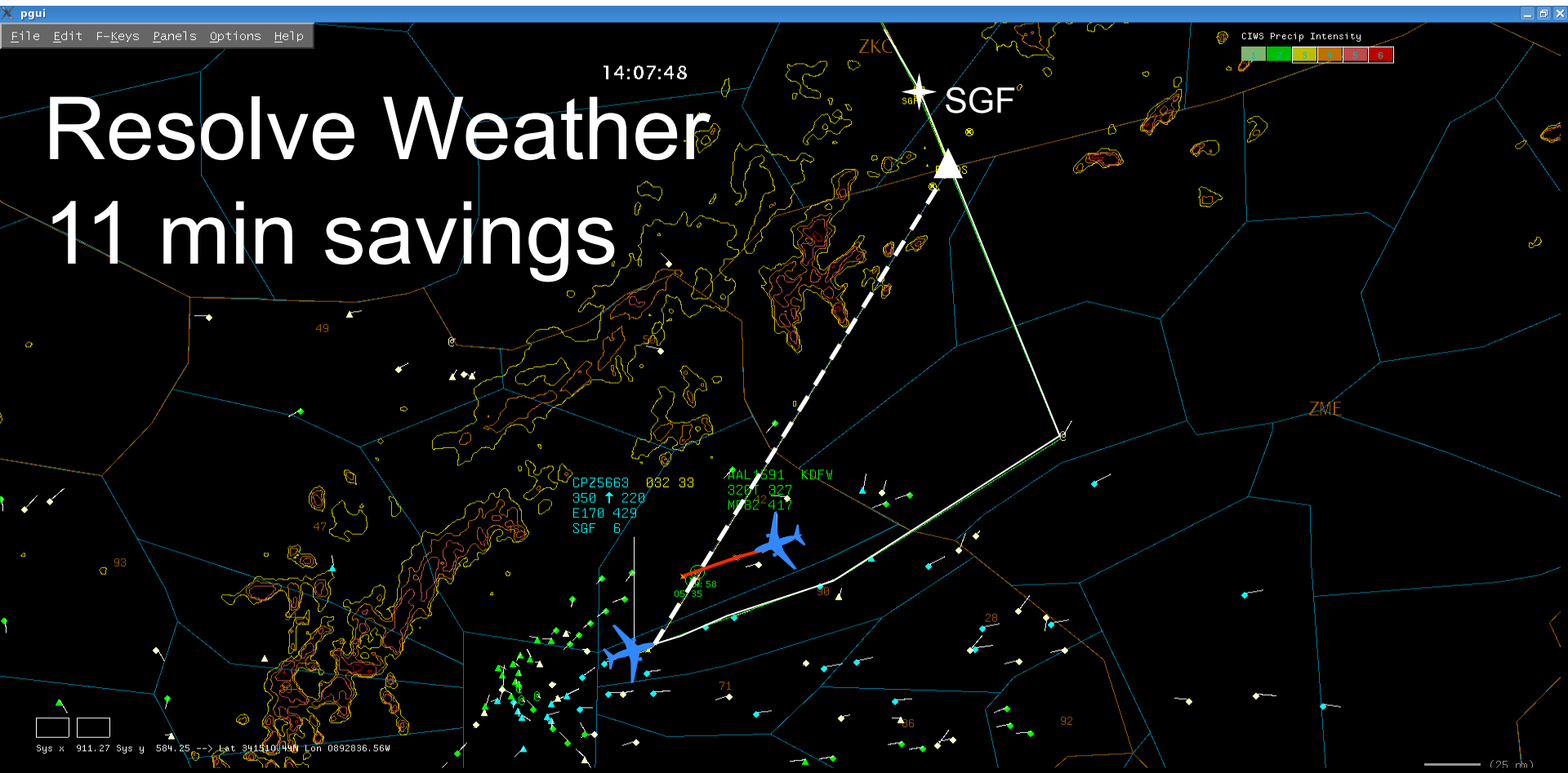
Direct-To  
13 min savings



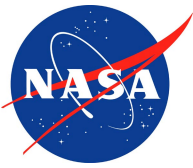


# Sample: CPZ5663 DFW to MSP

Resolve Weather  
11 min savings

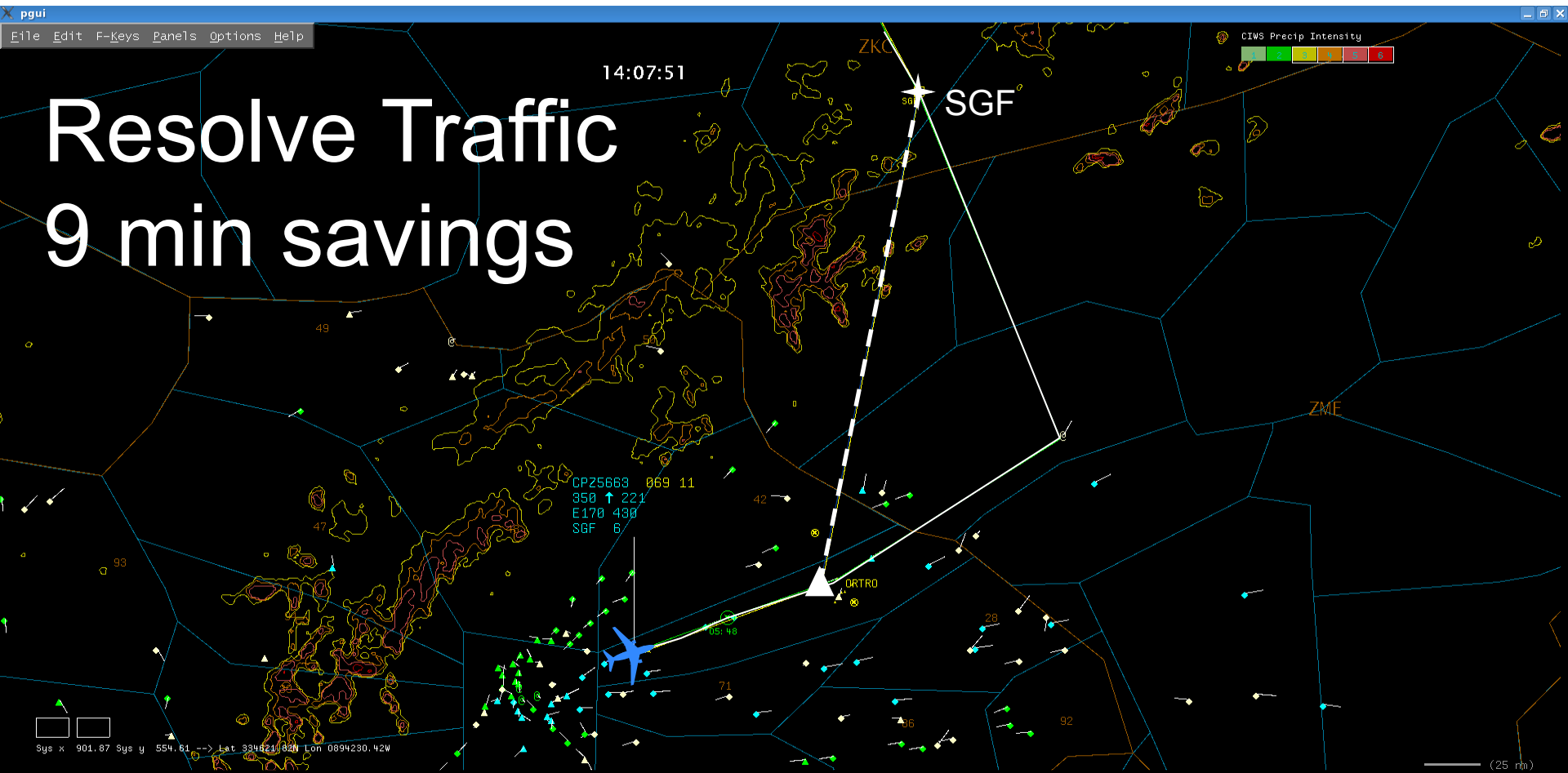


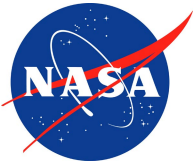




# Sample: CPZ5663 DFW to MSP

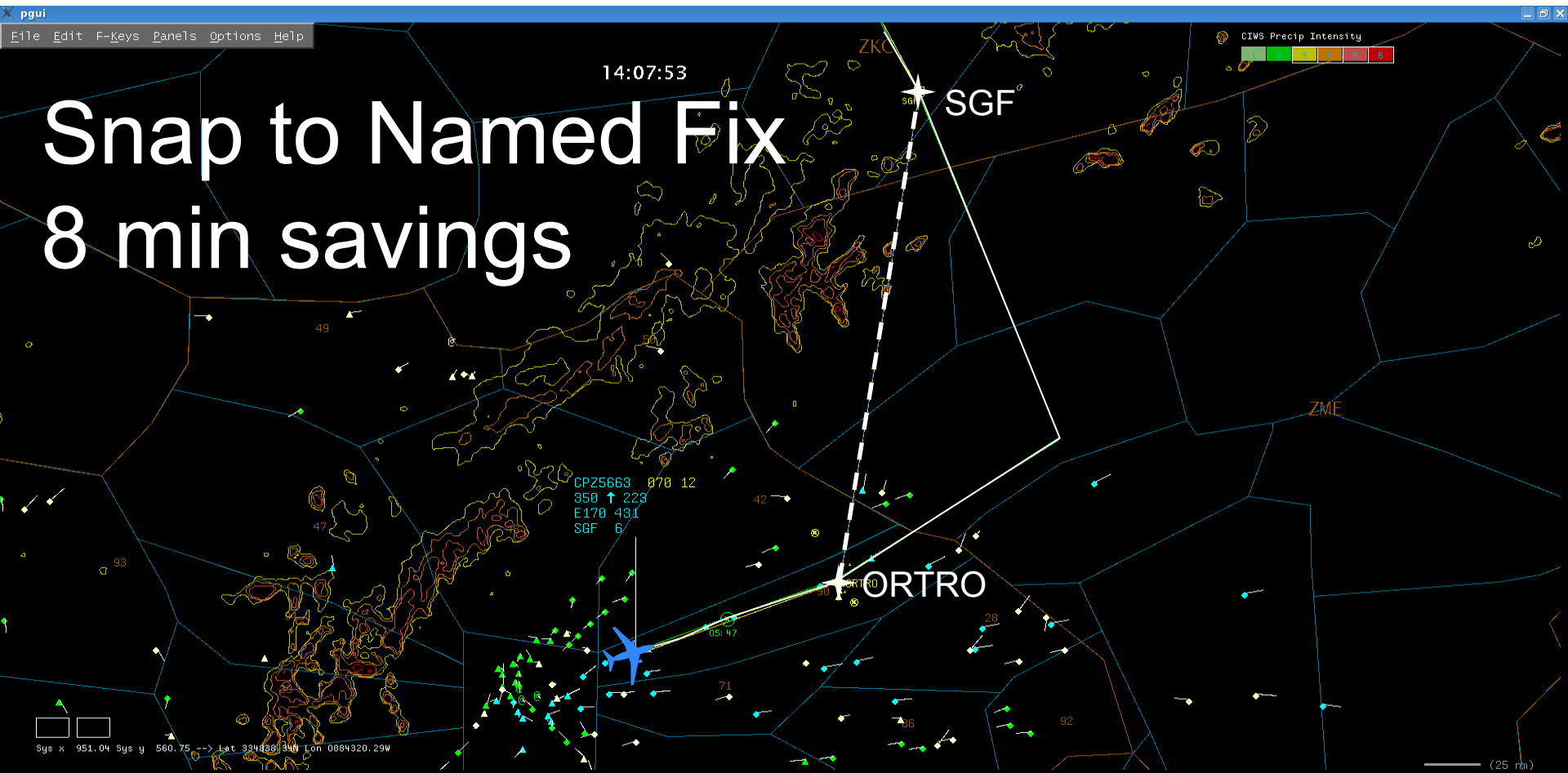
## Resolve Traffic 9 min savings

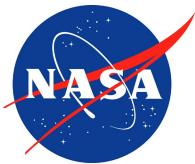




# Sample: CPZ5663 DFW to MSP

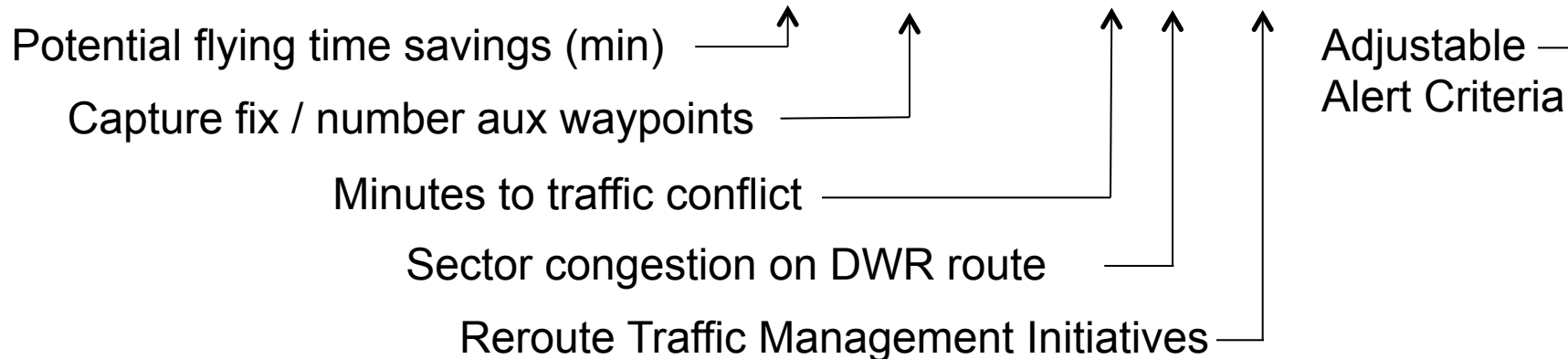
Snap to Named Fix  
8 min savings

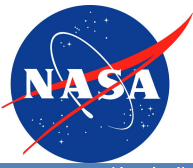




# DWR Flight List

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI	STATUS
<input type="checkbox"/>	DAL2188/B752	KATL/KSEA	29.4	JNC/1	OK	SC	N	
<input type="checkbox"/>	AAL2295/MD82	KDFW/KSLC	15.0	JNC/1	OK	OK	R	
<input type="checkbox"/>	UAL745/B752	KLGA/KDEN	10.7	TODDE/1	9	OK	N	
<input type="checkbox"/>	UAL652/B752	KDEN/KIAD	9.0	SJI/1	OK	SC	R	
<input type="checkbox"/>	AAL473/MD82	KDFW/MMGL	7.2	JCT	OK	SC	R	
<input type="checkbox"/>	NKS719/A319	KDFW/KDEN	6.7	FTI	OK	OK	R	
<input type="checkbox"/>	EGF3601/CRJ7	KELP/KORD	6.3	STL	OK	OK	N	
<input type="checkbox"/>	SWA2714/B737	KLAX/KSTL	5.8	SGF/1	OK	SC	N	





# User Interface with Trial Planner

The screenshot displays the Trial Planner interface with several key components:

- Dynamic Weather Routes Table:**

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input type="checkbox"/>	AAL599/B752	KMIA/KORD	45.8	IRK/1	OK	OK	R
<input type="checkbox"/>	AAL1406/MD83	KRSW/KORD	39.2	IRK	OK	OK	R
<input type="checkbox"/>	AAL1651/B738	KTPA/KORD	30.9	IRK/1	OK	SC	R
<input type="checkbox"/>	AAL1509/B752	KMIA/KORD	21.0	IRK	OK	OK	R
- Map:** Shows flight routes (Flight Plan and DWR Route) and a maneuver start point (blue circle) with a maneuver start point dialog box.
- Active Flight Plan Window:**

**Congestion on Flight Plan**

Status: Flying Type: B738 Speed: 445 FL: 340 Cruise FL: 340 Heading: 285  
 Nominal 01:46 hrs 924 nms 9471 lb | KTPA./DECOD293009..MMB..SLN..IRK.BENI
- Trial Flight Plan Window:**

**Congestion on DWR**

Status: Flying Type: B738 Speed: 445 FL: 340 Cruise FL: 340 Heading: 285  
 Nominal 01:15 hrs 664 nms 6595 lb | KTPA./335347N/0952937W..341433N/0

**TMI Information (for AAL1651)**

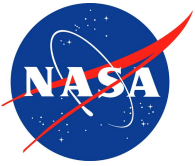
Effective Time: 08,0134 SOUTH\_2\_ORD (ETD)

Advisory	Orig	Dest	Route
7	ZTL ZJX ZMA	ORD	ATL HVQ APE ZANLA WATSN1
- Trial Planner - AAL Dispatch Display:**

Altitude STATUS: Trial Planning

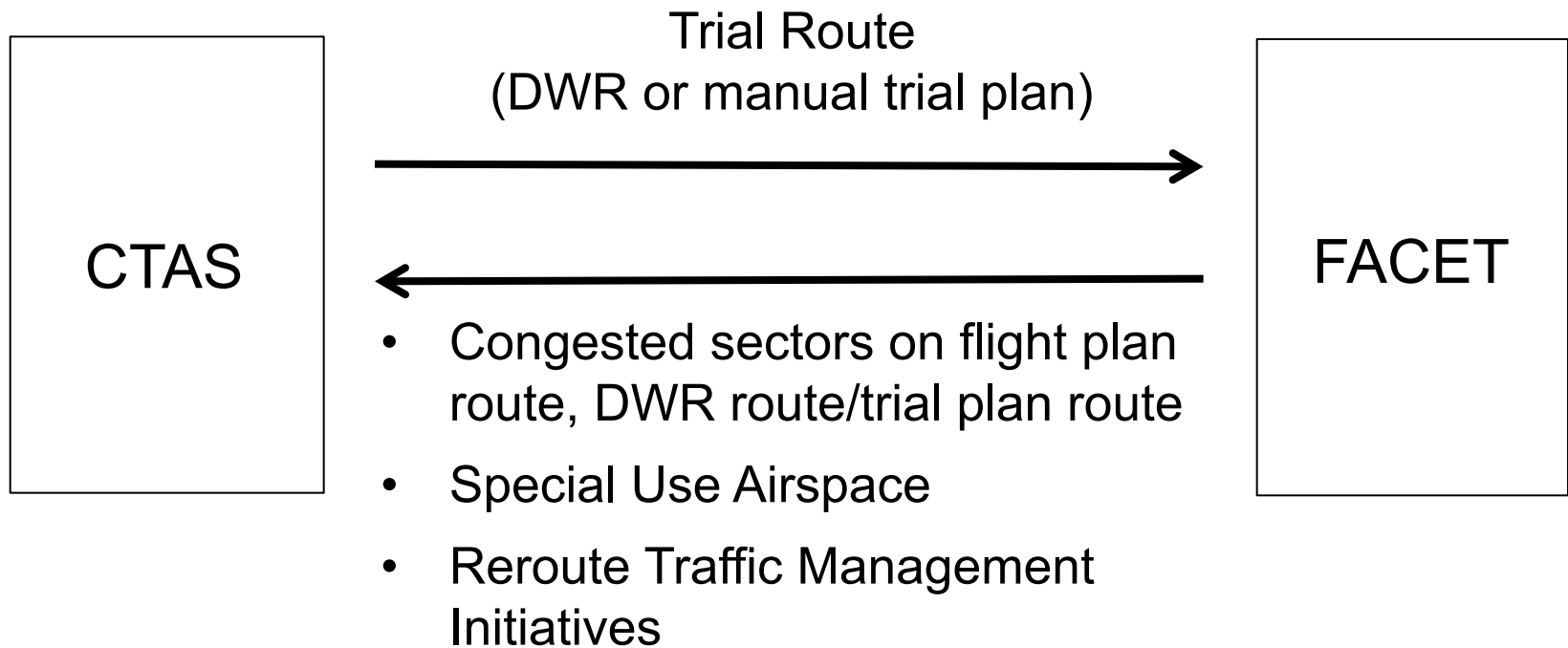
MMB	-11	AAL1651	B738/Q	340	KTPA./DECOD293009..MMB..SLN..IRK.BENKY1.KORD
SLN	12	AAL1651			KTPA./DECOD293011..AQR153010..TUL..IRK.BENKY1.KORD
IRK	31/006				
ORD	32				

Buttons: Send TMI, Approve, Unable, Cancel Request, Accept, Reject

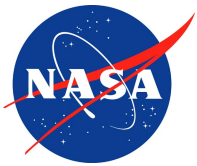


# CTAS/FACET Integration

## Real-time two-way communication



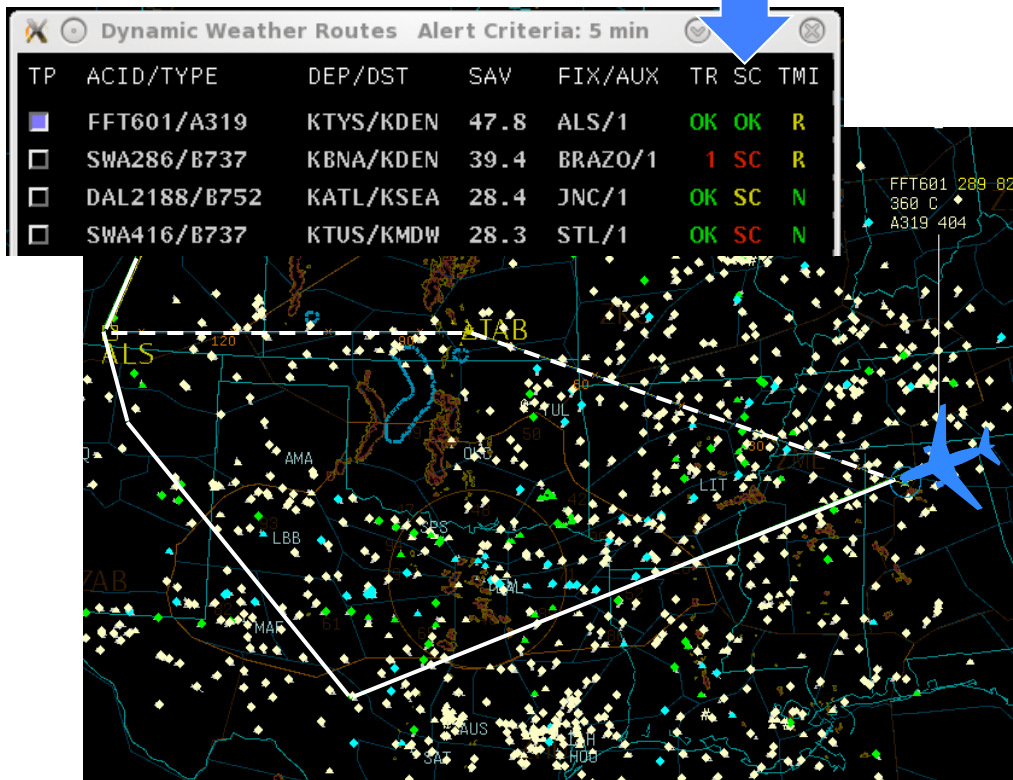
Congested Sectors: Predicted red or yellow based on Monitor Alert Parameter (MAP)



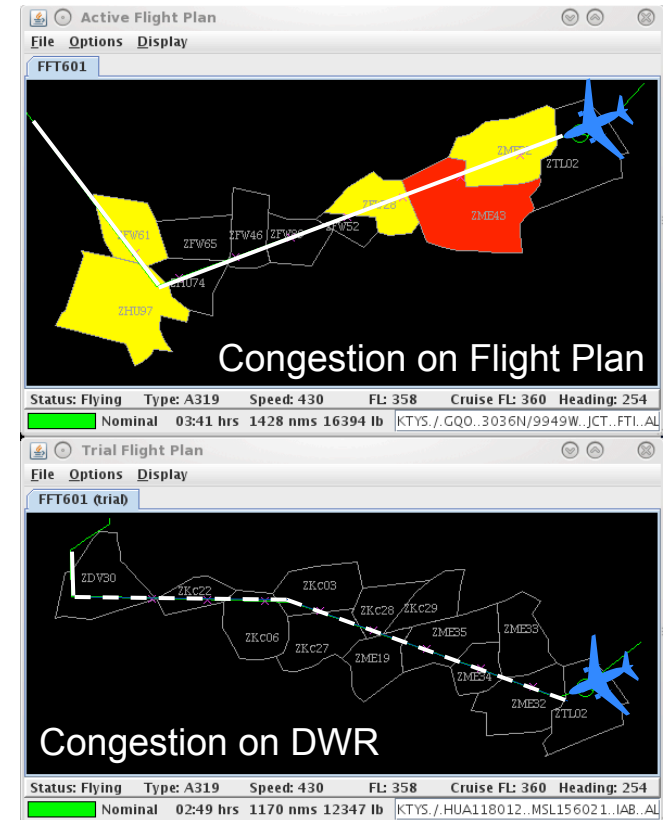
# Sector Congestion

Future Air Traffic Management (ATM) Concepts Evaluation Tool (FACET)  
Integrated for Sector Congestion Analysis

## Congestion on DWR

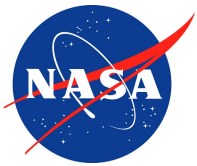


## Sector Congestion



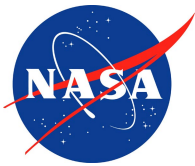
For user information only, currently no filtering based on sector congestion data



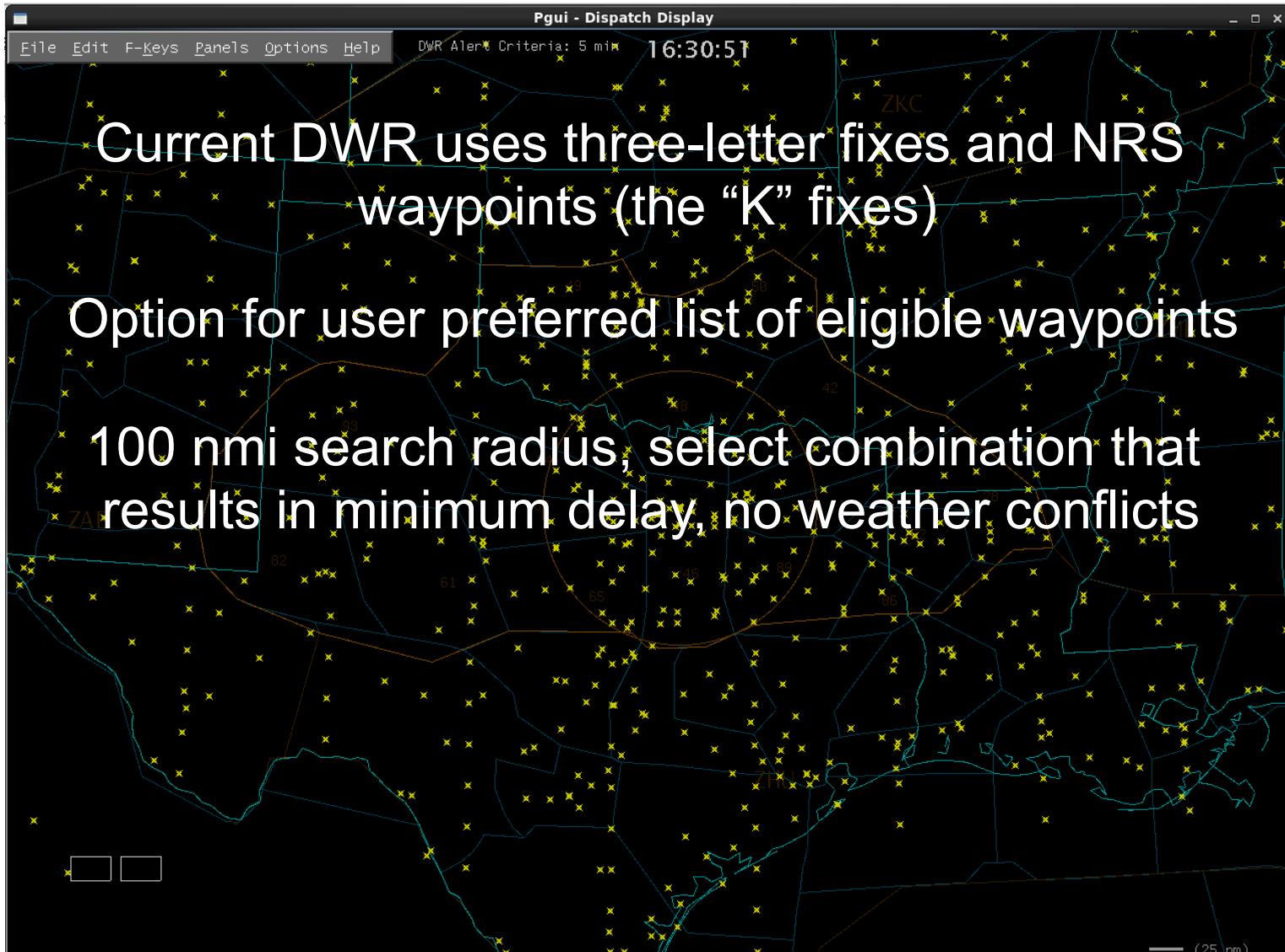


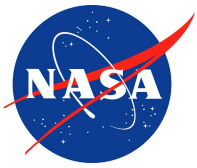
# Movie 1

## Sample DWR Routes from AA Trial

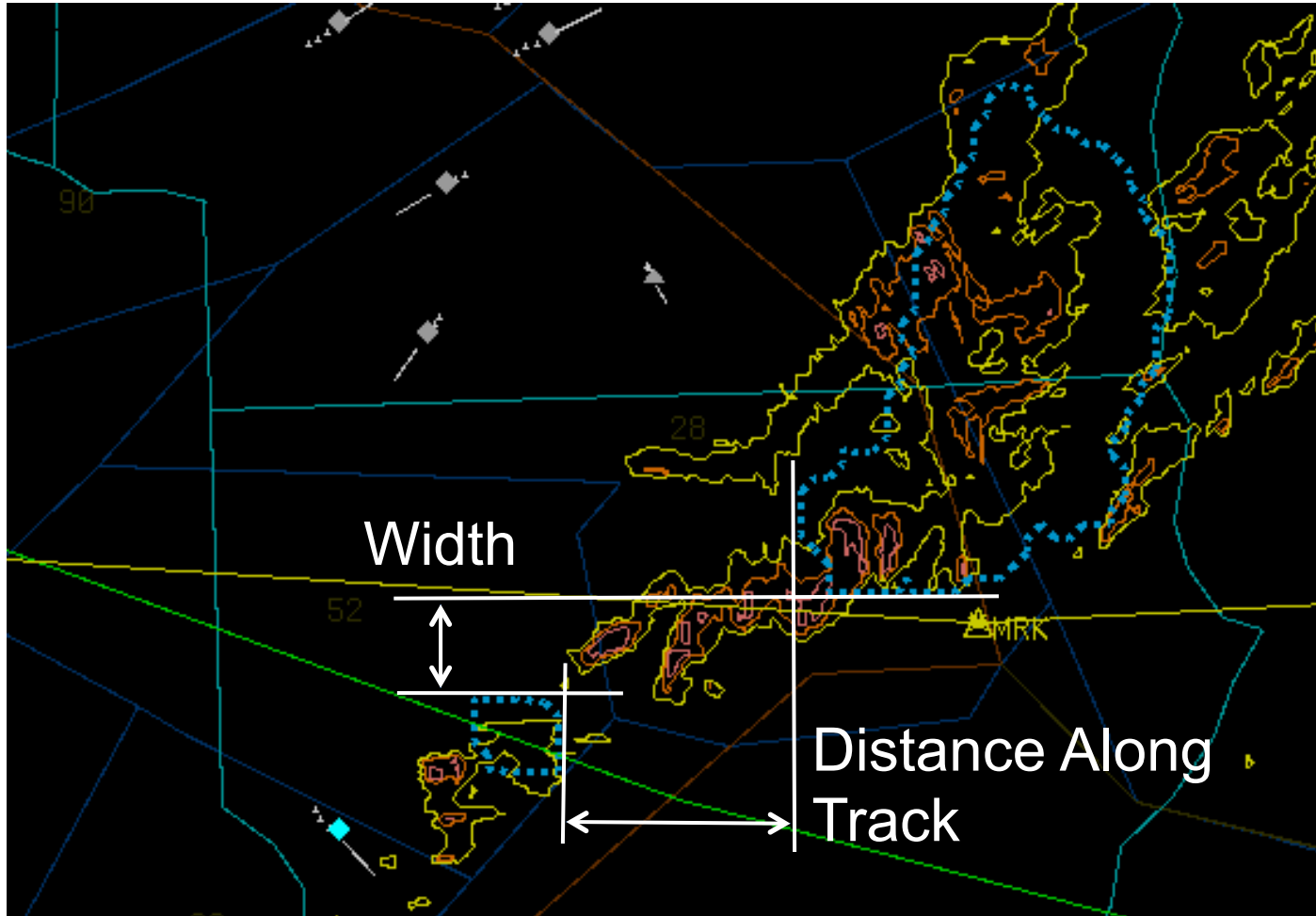


# How are snap to fixes selected for auxiliary waypoints?

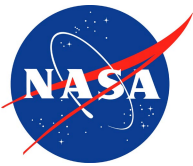




# Weather Gap Detection



Default Width: 25 nmi  
Default Distance Along Track: 50 nmi



# Special Use Airspace

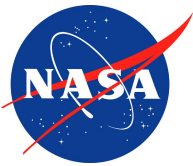
**SUAs Scheduled to be Active**

**Crosses SAA: 5107B\_partC, 5107B\_partF**

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input type="checkbox"/>	DAL2188/B752	KATL/KSEA	37.3	JNC/1	OK	OK	N
<input type="checkbox"/>	DAL161/B738	KJFK/KLAS	17.3	GUP/1	OK	OK	R
<input checked="" type="checkbox"/>	UAL463/B752	KLAX/KORD	17.3	MAG00/1	OK	SC	N
<input type="checkbox"/>	UAL745/B752	KLGA/KDEN	15.5	TODDE/1	OK	SC	N
<input type="checkbox"/>	AWE1210/A321	KPHX/KPHL	13.5	SJI/1	7	SC	R
<input type="checkbox"/>	UAL652/B752	KDEN/KIAD	13.3	SJI/2	OK	SC	R
<input type="checkbox"/>	VRD126/A320	KLAX/KPHL	13.2	SJI	OK	SC	R
<input type="checkbox"/>	UAL514/A319	KPHX/KORD	12.8	MAG00/1	OK	OK	N
<input type="checkbox"/>	UAL640/B752	KLAS/KORD	12.7	MAG00/1	OK	SC	N
<input type="checkbox"/>	AWE30/A320	KLAX/KPHL	12.3	SJI	OK	SC	R
<input type="checkbox"/>	AWE437/A320	KPHL/KLAS	11.4	GUP	7	SC	R
<input type="checkbox"/>	SWA3662/B737	KATL/KLAS	11.3	GREBE/1	OK	SC	R
<input type="checkbox"/>	NKS719/A319	KDFW/KDEN	10.7	FTI	6	SC	R
<input type="checkbox"/>	UAL168/B788	KIAH/KDEN	10.3	ZIGEE	OK	SC	N

**Maneuver Start Point**  
Delay (min.): 5 0 15  
Time: 22:38:05 FL: 350

**Trial Planner - Dispatch Display**  
STATUS: Trial Planning  
UAL463 B752/Q 350 KLAS/.EWM..ACT..RZC.J105.BAYLI.J181.MAG00.BENKY1.KORD/0129  
UAL463 KLAS/.DMN264029..DMN069013..BFK..MAG00.BENKY1.KORD  
Buttons: Send TMU, Approve, Unable, Cancel Request, Accept, Reject



# Reroute Traffic Management Initiatives

**Pgui - Dispatch Display**

Options DWR Alert Criteria: 5 min

23:06:23

**Dynamic Weather Routes** Alert Criteria: 5 min

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input checked="" type="checkbox"/>	FFT601/A319	KTYS/KDEN	47.8	ALS/1	0	OK	R
<input checked="" type="checkbox"/>	SWA286/B737	KBNA/KDEN	39.4	BRAZO/1	0	SC	R
<input type="checkbox"/>	DAL2188/B752	KATL/KSEA	28.4	JNC/1	OK	SC	N
<input type="checkbox"/>	SWA416/B737	KTUS/KMDW	28.3	STL/1	OK	SC	N
<input type="checkbox"/>	DAL2266/B763	KATL/KDEN	27.0	ALS/1	OK	SC	R
<input type="checkbox"/>	AWE7/A321	KPHX/KORD	21.4	IRK/1	OK	OK	N
<input type="checkbox"/>	AAL1746/MD83	KLAS/KORD	21.0	IRK/1	OK	OK	N
<input type="checkbox"/>	AAL1624/B738	KLAX/KORD	20.4	IRK/1	OK	SC	N
<input type="checkbox"/>	SWA133/B738	KCMH/KLAS	19.3	GUP/1	OK	OK	N
<input type="checkbox"/>	AAL528/B738	KSAN/KORD	18.9	IRK/1	OK	OK	N
<input type="checkbox"/>	DAL161/B738	KJFK/KLAS	16.5	GUP	1	SC	R
<input type="checkbox"/>	SKW471R/CRJ2	KIAH/KCOS	16.1	TBE	OK	SC	N
<input type="checkbox"/>	AWES/B752	KORD/KPHX	16.0	BURKO/1	OK	OK	N
<input type="checkbox"/>	AAL144/B738	KLAX/KIAD	12.9	SJI	OK	SC	R
<input type="checkbox"/>	AAL2295/MD82	KDFW/KSLC	12.8	JNC	OK	OK	R
<input type="checkbox"/>	UAL1042/B739	KIAH/KDEN	12.7	ZIGEE	OK	SC	N
<input type="checkbox"/>	UAL1208/B738	KSAN/KORD	10.8	IRK/1	OK	SC	N
<input type="checkbox"/>	AWE85/A319	KPHX/KBWI	10.7	SJI	11	SC	R
<input type="checkbox"/>	UAL745/B752	KLGA/KDEN	10.5	TODDE	OK	OK	N
<input type="checkbox"/>	UAL463/B752	KLAX/KORD	10.4	MAGOO/1	OK	SC	N
<input type="checkbox"/>	VRD126/B732	KLAX/KPHL	10.3	SJI	OK	SC	R
<input type="checkbox"/>	AWE1210/A321	KPHX/KPHL	10.2	SJI	OK	SC	R
<input type="checkbox"/>	DAL1217/B752	KDTW/KLAS	9.5	ONM/1	OK	OK	N
<input type="checkbox"/>	UAL731/A319	KORD/KLAX	8.4	EWM/1	OK	SC	N
<input type="checkbox"/>	FFT382/A320	KDEN/KFLL	8.2	REDFN	OK	SC	R
<input type="checkbox"/>	VRD090/A319	KSFO/KIAD	7.4	SJI	OK	SC	R
<input type="checkbox"/>	ASQ4242/E45X	KCRW/KIAH	7.2	SWB	OK	SC	N
<input type="checkbox"/>	UAL514/A319	KPHX/KORD	6.7	MAGOO/1	OK	SC	N
<input type="checkbox"/>	AAL1531/B738	KORD/KSAN	6.2	ABQ	OK	OK	N

**Active Flight Plan**

FFT601

Status: Flying Type: A319 Speed: 430 FL: 358 Cruise FL: 360 Heading: 254

Nominal 03:41 hrs 1428 nms 16394 lb | KTYS./GQO.3036N/9949W./JCT.FTL.AL

**TMI Information (for FFT601)**

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		DEN	JCT FTI BRAZO LDORA1

almost 2 hours old

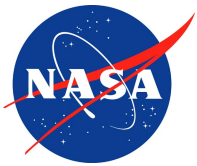
29,2123



Click more info

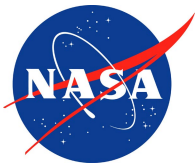
Close





# Movie 2

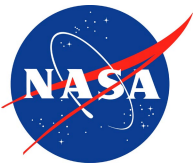
## Key DWR Functions



# Outline

- Building Blocks
- DWR Concept, Tool, Functional Components
- ➔ Operational Trial at American Airlines
- Analysis Results
  - Potential Benefits all Fort Worth Center Flights
  - American Airlines Test Results
  - Sector Congestion Analysis
- Software Architecture and Required Inputs
- How to Acquire DWR Software
- Next Steps



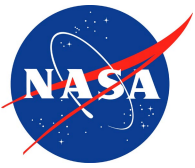


# Trial at American Airlines

American Airlines Integrated Operations Control Center, Fort Worth, Texas



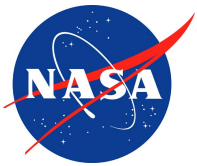




# Trial at American Airlines

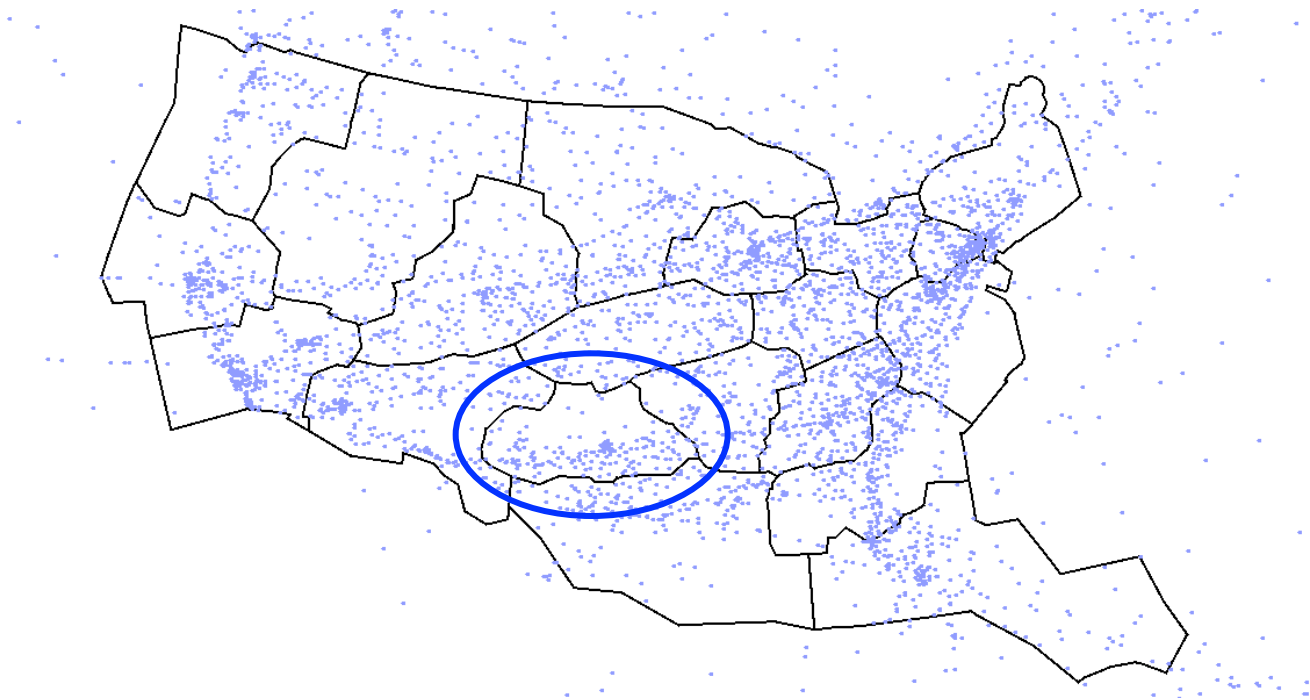


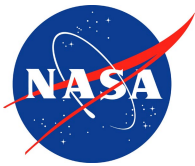
Integrated Operations Control Center, Fort Worth, Texas



# Test Operations

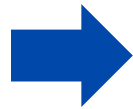
- Fort Worth Center traffic only
- System runs 23 hrs/day, 7 days/week since July 2012
- Usually staffed during heavy weather

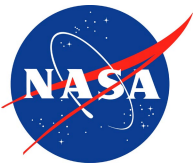




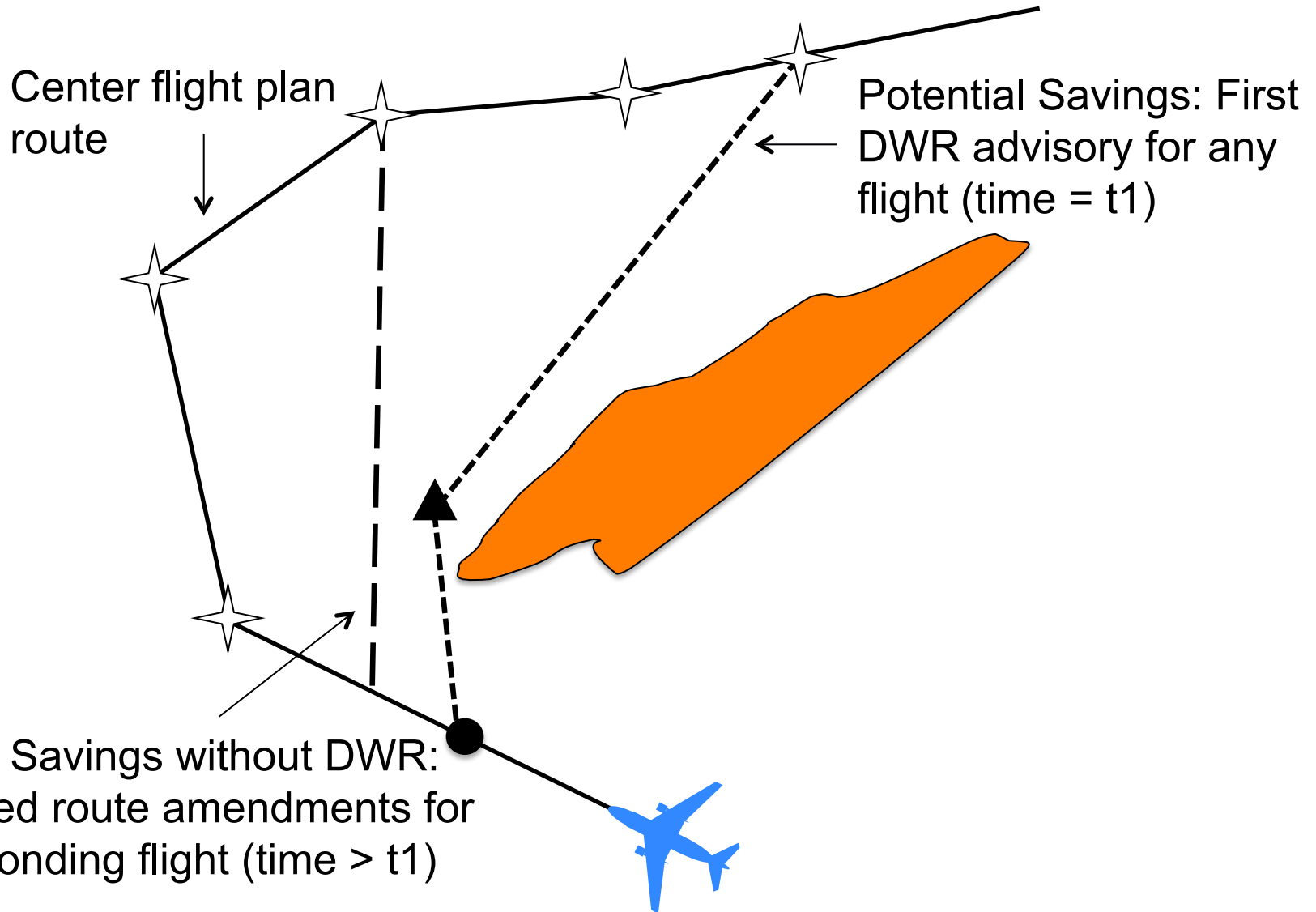
# Outline

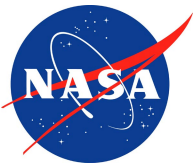
- Building Blocks
- DWR Concept, Tool, Functional Components
- Operational Trial at American Airlines
- Analysis Results
  - Potential Benefits all Fort Worth Center Flights
  - American Airlines Test Results
  - Sector Congestion Analysis
- Software Architecture and Required Inputs
- How to Acquire DWR Software
- Next Steps





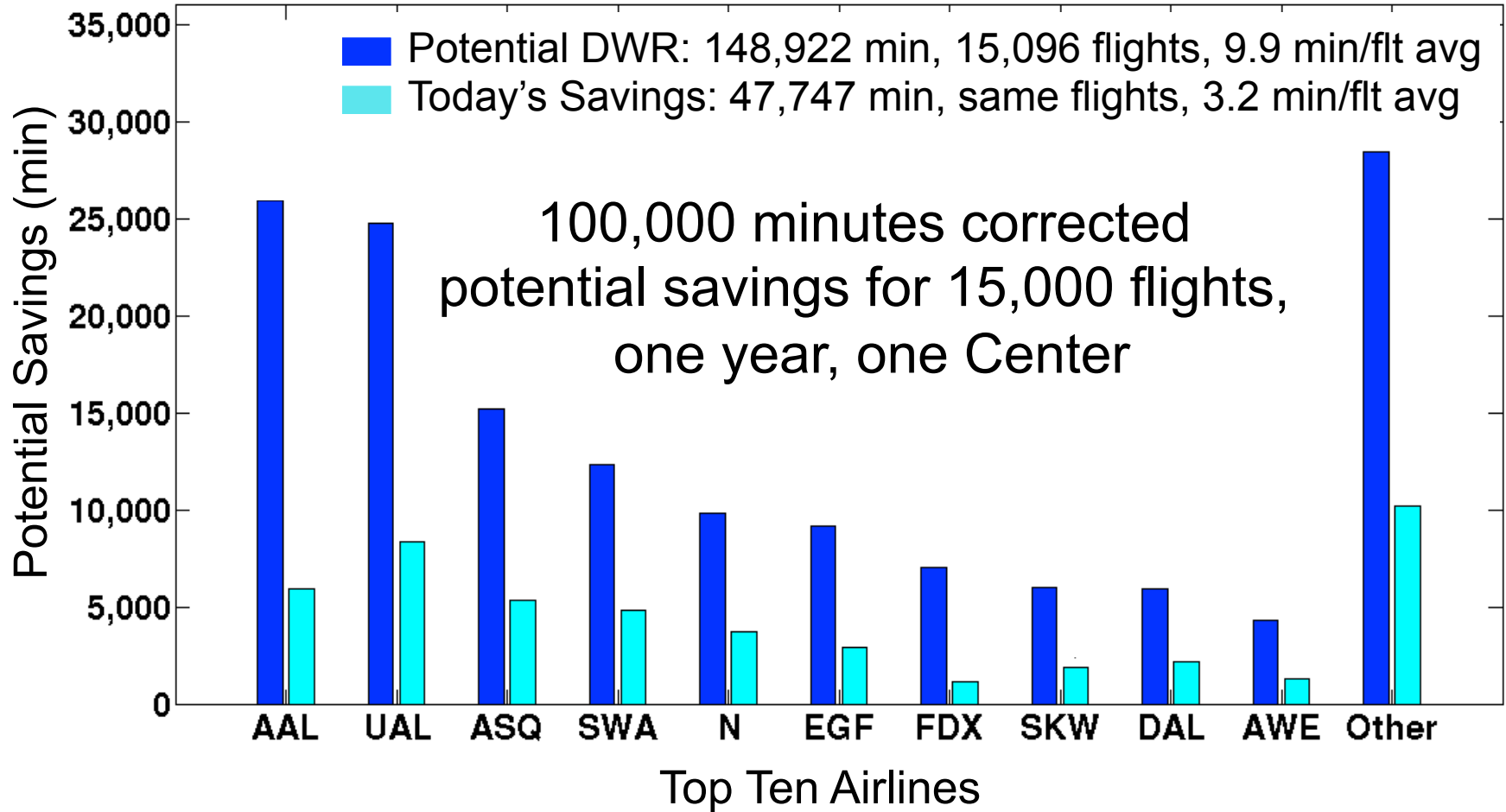
# Potential DWR Savings and Today's Savings without DWR

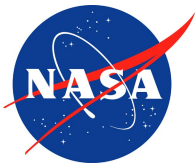




# Potential Savings in 2013

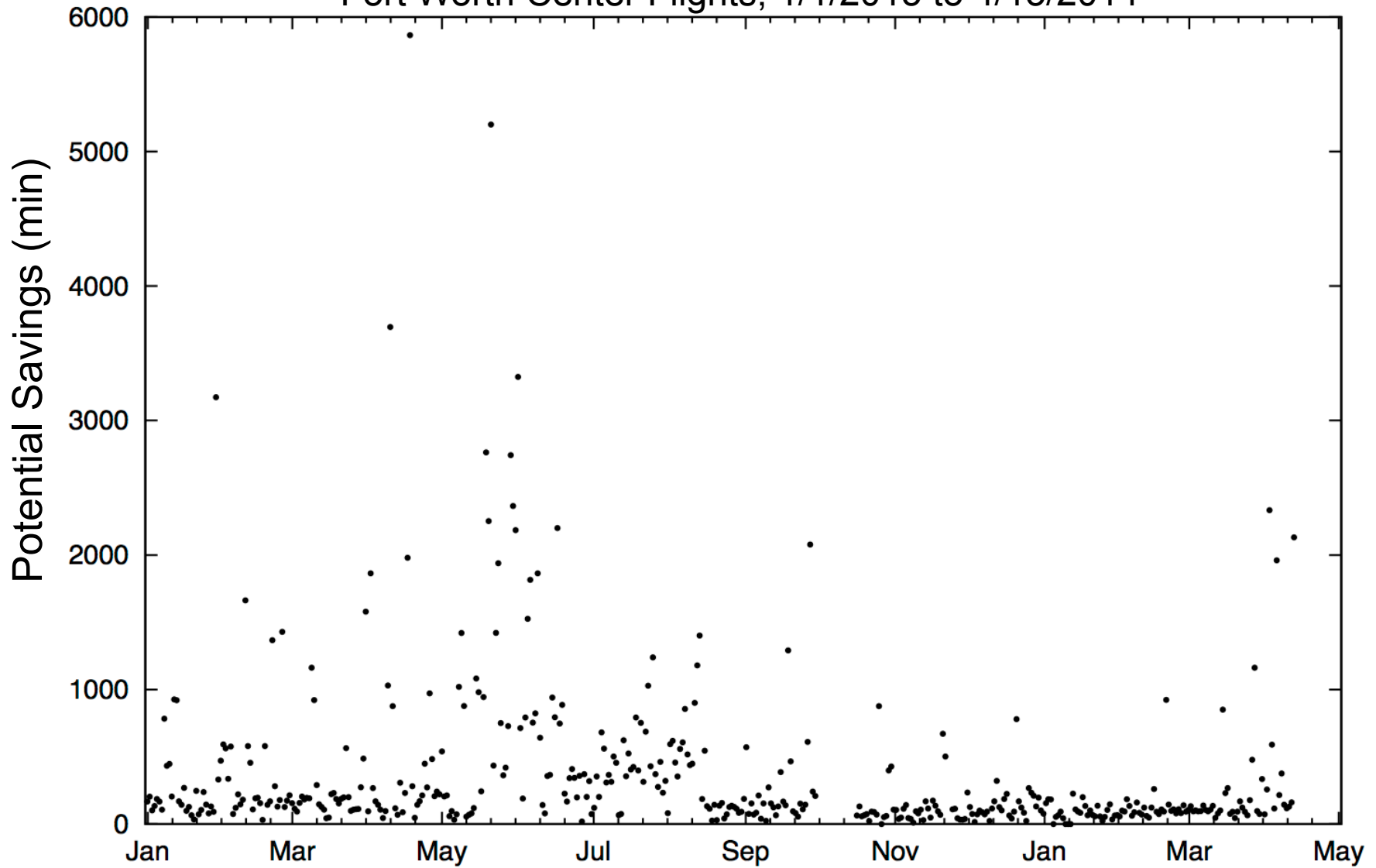
All Flights, Fort Worth Center, Savings  $\geq 5$  min

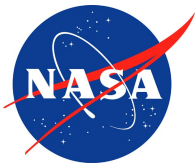




# Potential Savings by Day 2013/2014

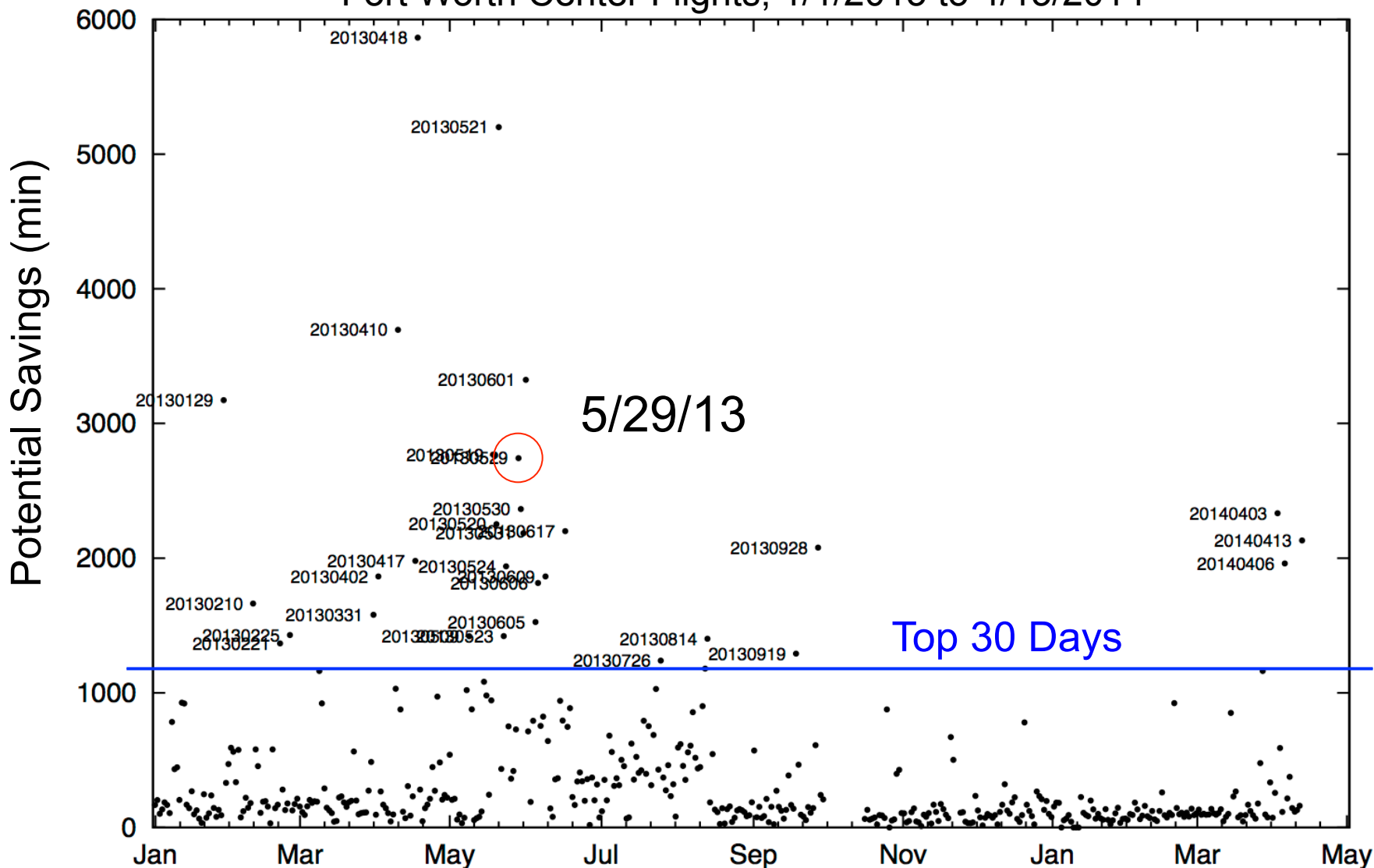
Fort Worth Center Flights, 1/1/2013 to 4/13/2014



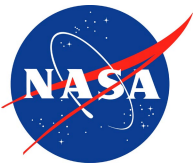


# Potential Savings by Day 2013/2014

Fort Worth Center Flights, 1/1/2013 to 4/13/2014







# Sample: Las Vegas/Chicago

**Pgui - Dispatch Display**  
Options - DWR Alert Criteria: 5 min  
22:17:55  
CIWS Precip Intensity  
CIWS EchoTops: x1000 Feet

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input type="checkbox"/>	AWE437/A320	KPHL/KLAS	17.2	GUP/1	OK	SC	R
<input type="checkbox"/>	UAL275/A320	KORD/KLAS	16.7	GUP	OK	OK	N
<input type="checkbox"/>	NKS719/A319	KDFW/KDEN	15.8	FTI	OK	OK	R
<input checked="" type="checkbox"/>	UAL640/B752	KLAS/KORD	14.6	MAG00/1	OK	OK	N
<input type="checkbox"/>	ASQ4550/E45X	KMCI/KIAH	13.1	SEEDS	OK	SC	N
<input type="checkbox"/>	SWA1204/B737	KDEN/KBWI	11.3	SJI/1	OK	SC	R
<input type="checkbox"/>	SWA2292/B737	KRDU/KLAS	9.2	GUP/1	OK	OK	N
<input type="checkbox"/>	EGF3601/CRJ7	KELP/KORD	7.6	STL	OK	SC	N

**Potential Savings: 15 min**

**Maneuver Start Point**  
Delay (min.) [5] 0 [15]  
Time: 22:22:48 FL: 330

**Active Flight Plan**  
UAL640  
Status: Flying Type: B752 Speed: 539 FL: 329 Cruise FL: 330 Heading: 96  
Nominal 02:16 hrs 1124 nms 16587 lb [KLAS./SS0043077..RUTER..INK..J50..ABI]

**Trial Flight Plan**  
UAL640 (trial)  
Status: Flying Type: B752 Speed: 539 FL: 329 Cruise FL: 330 Heading: 96  
Nominal 02:02 hrs 1014 nms 14727 lb [KLAS./315817N/1035701W..INK..DUC..N]

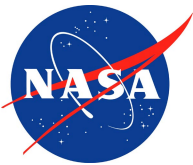
**Trial Planner - Dispatch Display**

Altitude	STATUS: Trial Planning
ABI -28	UAL640 B752/Q 330 KLAS./..RUTER..INK..J50..ABI..J66..FUZ..J42..TXK..MAP..BAYLI..J181..MAG00..BENKY1..KORD/0050
FUZ -13	
TXK -5.5	
MAP 9.9	
BAYLI 15	
MAG00 15/062	UAL640 KLAS./..MAF258090..INK..DUC..MAG00..BENKY1..KORD
ORD 15	

Send TMO Approve Unable Cancel Request Accept Reject

Future ATM Concepts Evaluation Tool (FAE) 14:30:26 Wed, 2 Apr 2014 Local





# Sample: Denver/Baltimore

**Pgui - Dispatch Display**

Options DVR Alert Criteria: 5 min

22:16:04

CIWS Precip Intensity CIWS EchoTops x1000 Feet

**Dynamic Weather Routes Alert Criteria: 5 min**

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input type="checkbox"/>	UAL275/A320	KORD/KLAS	17.8	GUP/1	OK	OK	N
<input type="checkbox"/>	NKS719/A319	KDFW/KDEN	16.5	FTI	OK	OK	R
<input type="checkbox"/>	ASQ4550/E45X	KMCI/KIAH	14.4	SEEDS	OK	SC	N
<input checked="" type="checkbox"/>	SWA1204/B737	KDEN/KBWI	12.4	SJI/1	OK	SC	R
<input type="checkbox"/>	SWA2292/B737	KRDU/KLAS	9.9	GUP/1	OK	OK	N
<input type="checkbox"/>	EGF3601/CRJ7	KELP/KORD	7.8	STL	OK	SC	N

**Potential Savings: 12 min**

**Maneuver Start Point**

Delay (min.)

Time: 22:21:00 FL: 370

**Active Flight Plan**

File Options Display

SWA1204

Status: Flying Type: B737 Speed: 475 FL: 370 Cruise FL: 370 Heading: 145

Nominal 03:36 hrs 1623 nms 15712 lb KDEN / KENTO278030 . SPURS J86 . IAH J2

**Trial Flight Plan**

File Options Display

SWA1204 (trial)

Status: Flying Type: B737 Speed: 475 FL: 370 Cruise FL: 370 Heading: 145

Nominal 03:25 hrs 1532 nms 14827 lb KDEN / 335135N/1010544W . 332115N

**TMI Information (for SWA1204)**

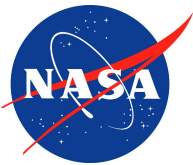
Advisory	Orig	Dest	Effective Time	LEV	EAST_2	PARTIA
67	ZDV					
67		BWI				

Close

**Trial Planner - Dispatch Display**

Altitude	STATUS: Trial Planning
IAH -4.4	SWA1204 B737/Q 370 KDEN / . KENTO278030 . SPURS J86 . IAH J2 . LCH J138 . SJI J37 . MGM J40 . TWINS . CAE J52 . RIC . OTT6 . KBWI / 0152
LCH 3.7	SWA1204 KDEN / . LBB066042 . GTH205031 . ADS . SJI J37 . MGM J40 . TWINS . CAE J52 . RIC . OTT6 . KBWI
BTR 8.7	
SJI 12/097	
CATLN 16	
MGM 21	
MCN 22	

Send TMI Approve Unable Cancel Request Accept Reject



# Sample: Atlanta/Seattle

**Potential Savings: 27 min**

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input checked="" type="checkbox"/>	DAL2188/B752	KATL/KSEA	28.2	JNC/1	OK	SC	N
<input type="checkbox"/>	AAL2295/MD82	KDFW/KSLC	15.0	JNC/1	OK	OK	R
<input type="checkbox"/>	UAL745/B752	KLGA/KDEN	11.0	TODDE/1	OK	SC	N
<input type="checkbox"/>	UAL640/B752	KLAS/KORD	8.6	MAGOO	OK	SC	N
<input type="checkbox"/>	UAL652/B752	KDEN/KIAD	7.9	SJI/1	OK	SC	R
<input type="checkbox"/>	NKS719/A319	KDFW/KDEN	7.1	FTI	OK	OK	R
<input type="checkbox"/>	SWA2714/B737	KLAX/KSTL	6.6	SGF/1	OK	SC	N
<input type="checkbox"/>	EGF3601/CRJ7	KELP/KORD	6.6	STL	OK	SC	N

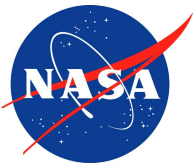
Delay (min.)	Time	FL
15	22:55:00	360

**Trial Planner - Dispatch Display**

STATUS: Trial Planning

Altitude	STATUS	Trial Planning
TANER 13	DAL2188	B752/Q 360 KATL./..IGB058008..FUZ..MQP..ABI..TXO..ABQ.J15.JNC..MTU..MLD..DNJ.J20.PDT.CHINS8.KSEA/0325
PUMPS 15	DAL2188	KATL./..ELD073045..ELD062013..KF27A..JNC..MTU..MLD..DNJ.J20.PDT.CHINS8.KSEA

Buttons: Send TMI, Approve, Unable, Cancel Request, Accept, Reject



# Sample: Atlanta/Seattle

**Potential Savings: 27 min**

**Dynamic Weather Routes Alert Criteria: 5 min**

TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input checked="" type="checkbox"/>	DAL2188/B752	KATL/KSEA	28.2	JNC/1	OK	SC	N
<input type="checkbox"/>	AAL2295/MD82	KDFW/KSLC	15.0	JNC/1	OK	OK	R
<input type="checkbox"/>	UAL745/B752	KLGA/KDEN	10.9	TODDE/1	OK	OK	N
<input type="checkbox"/>	UAL652/B752	KDEN/KIAD	9.3	SJI/1	OK	SC	R
<input type="checkbox"/>	NKS719/A319	KDFW/KDEN	7.0	FTI	OK	SC	R
<input type="checkbox"/>	SWA2714/B737	KLAX/KSTL	6.5	SGF/1	OK	SC	N
<input type="checkbox"/>	EGF3601/CRJ7	KELP/KORD	6.5	STL	OK	OK	N

**Maneuver Start Point**

Delay (min.) [5] 0 [15]

Time: 22:55:36 FL: 360

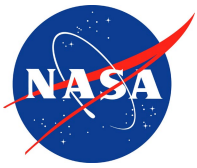
**Trial Planner - Dispatch Display**

Altitude:  STATUS: Trial Planning

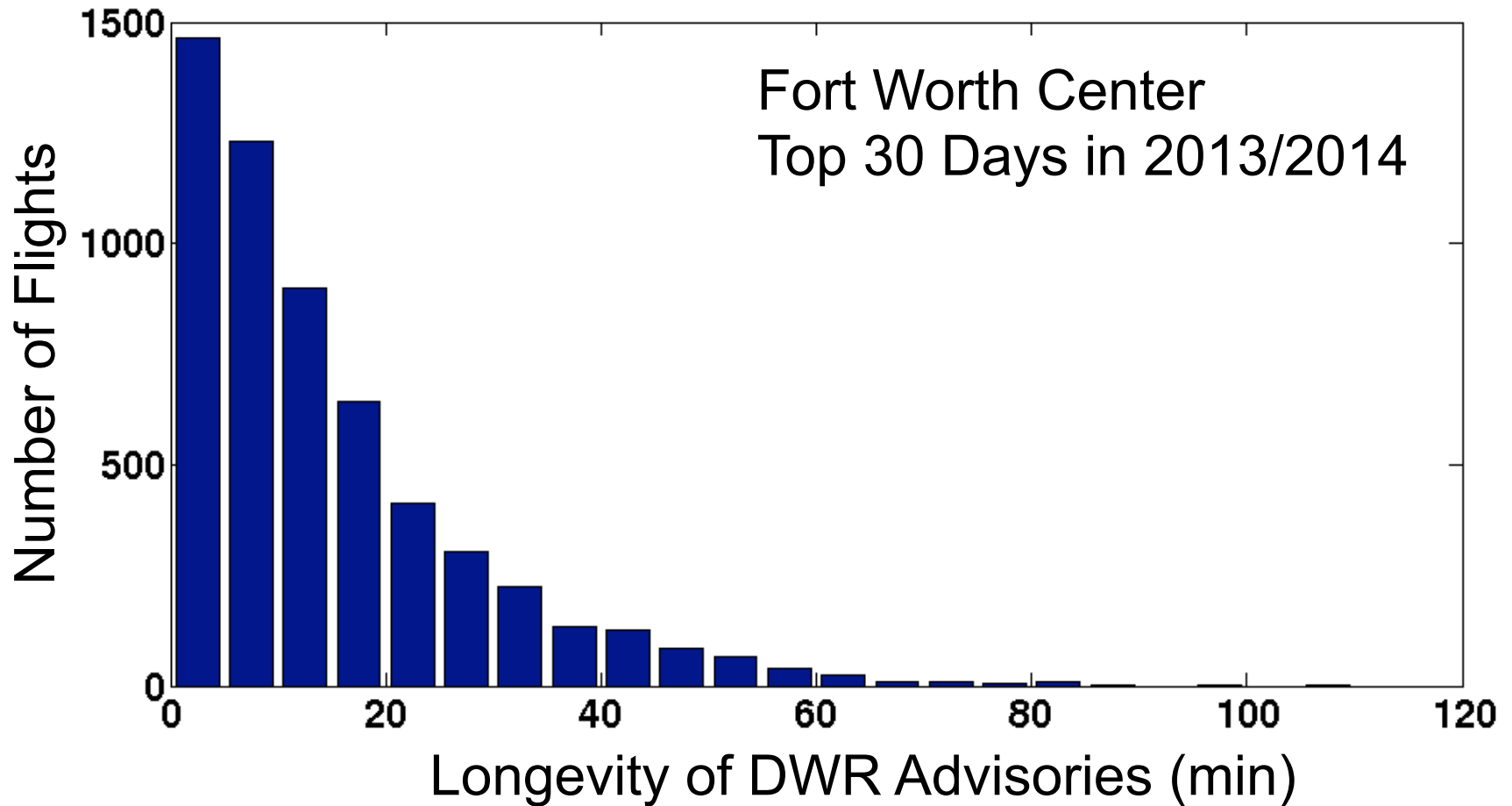
DAL2188 B752/Q 360 KATL./..IGB058008..FUZ..MQP..ABI..TXO..ABQ..J15..JNC..MTU..MLD..DNJ..J20..PDT..CHINS8..KSEA/0325

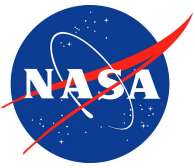
DAL2188 KATL./..ELD073041..ELD055009..KF27A..JNC..MTU..MLD..DNJ..J20..PDT..CHINS8..KSEA

Buttons: Send TNU, Approve, Unable, Cancel Request, Accept, Reject



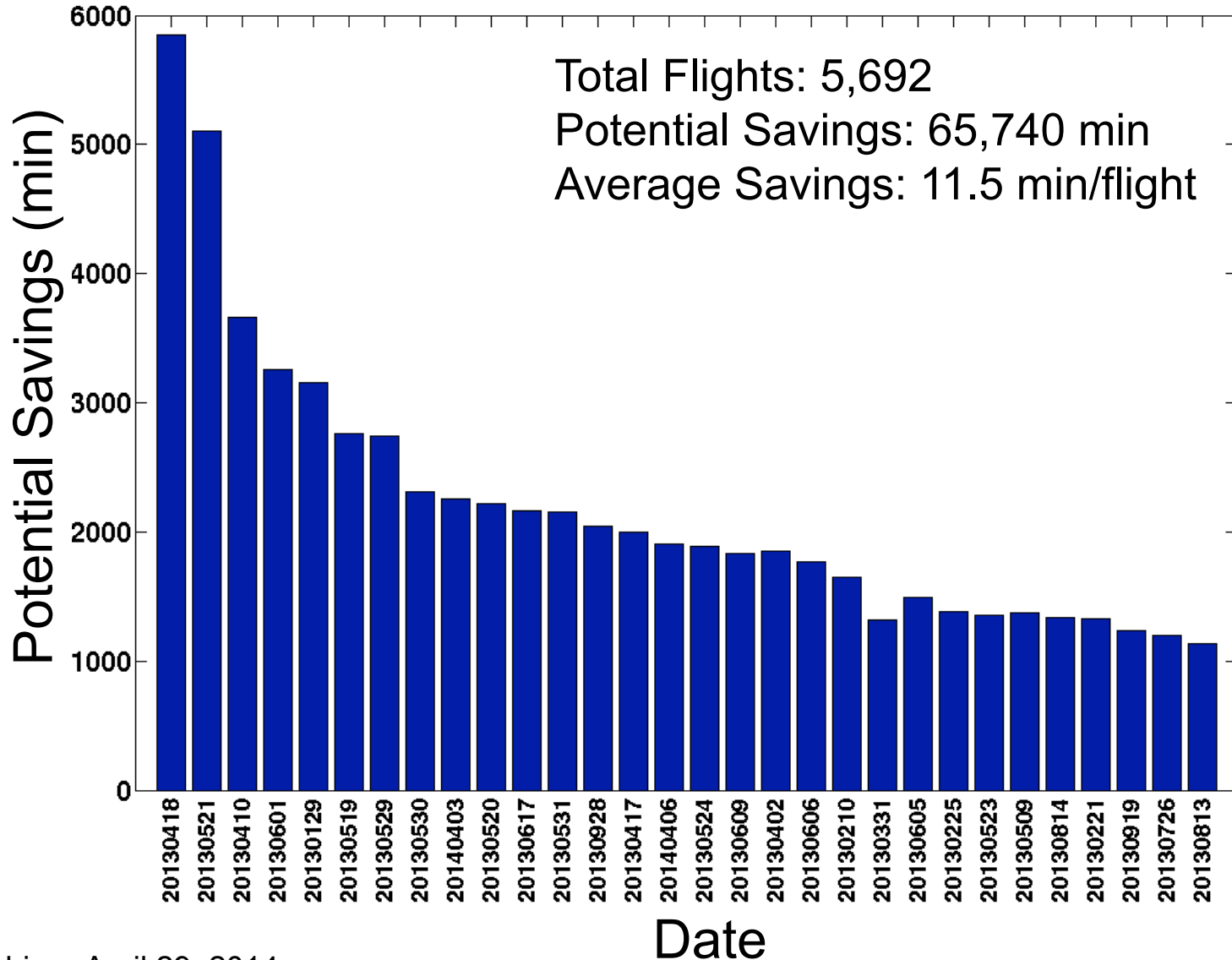
# How long does a flight stay on the DWR flight list?

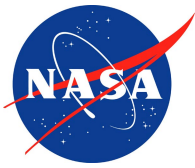




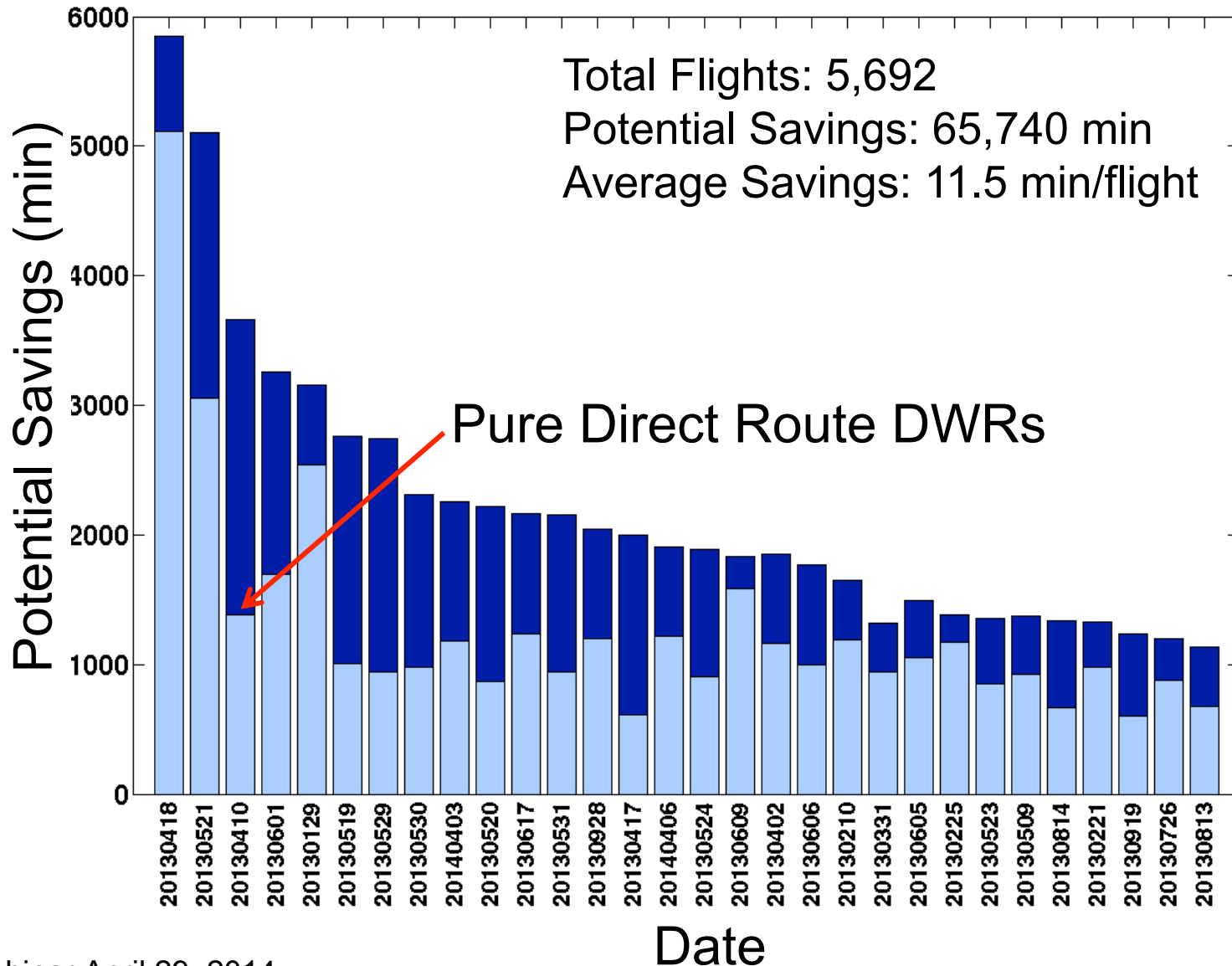
# Potential Savings All Flights

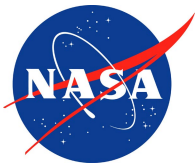
## Fort Worth Center, Top 30 Days in 2013/2014





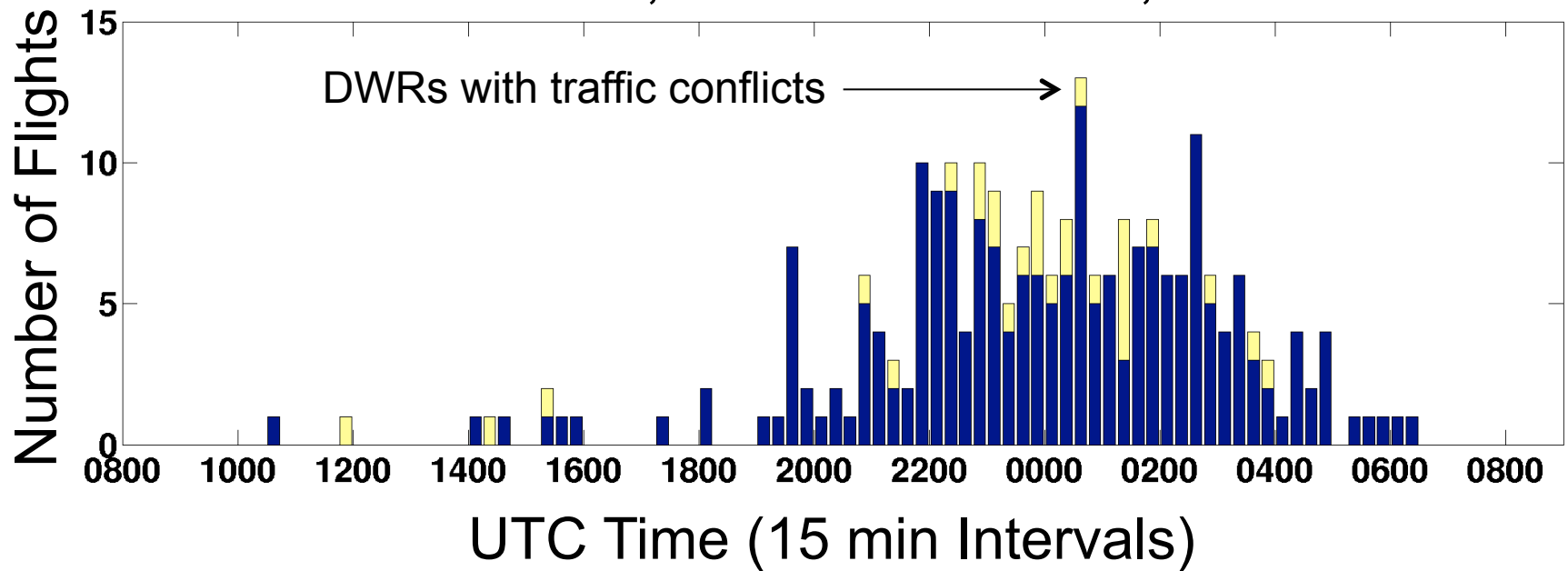
# How many DWRs are pure direct routes vs. those with auxiliary waypoints?

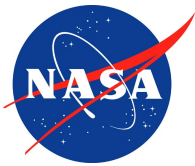




# How many flights get DWR route advisories over 15 minute intervals?

## DWR Advisories, Fort Worth Center, 5/29/2013

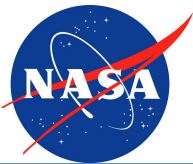




# Outline

- Building Blocks
- DWR Concept, Tool, Functional Components
- Operational Trial at American Airlines
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  - Potential Benefits all Fort Worth Center Flights
  - ➔ – American Airlines Test Results
  - Sector Congestion Analysis
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# Data Recording

The screenshot displays a flight simulation interface with several key components:

- Dynamic Weather Routes:** A table listing flight routes with their respective alert criteria.
- Active Flight Plan:** A window showing the current flight plan for AAL1651, including status, type, speed, and altitude.
- Trial Flight Plan:** A window showing a trial flight plan for AAL1651, including status, type, speed, and altitude.
- Trial Planner - AAL Dispatch Display:** A window showing the trial planning status, including aircraft type, route, and altitude.

Large white text "Advised" is overlaid on the weather map, and "Accept, Reject, Cancel" is overlaid on the bottom right of the interface. Arrows point from the text to the "Accept" and "Reject" buttons in the Trial Planner window.

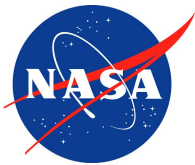
TP	ACID/TYPE	DEP/DST	SAV	FIX/AUX	TR	SC	TMI
<input type="checkbox"/>	AAL599/B752	KMIA/KORD	45.8	IRK/1	OK	OK	R
<input type="checkbox"/>	AAL1406/MD83	KRSW/KORD	39.2	IRK	OK	OK	R
<input checked="" type="checkbox"/>	AAL1651/B738	KTPA/KORD	30.9	IRK/1	OK	SC	R
<input type="checkbox"/>	AAL1509/B752	KMIA/KORD	21.0	IRK	OK	OK	R

Status:	Type:	Speed:	FL:	Cruise FL:	Heading:
Flying	B738	445	340	340	285
Nominal	01:46 hrs	924 nms	9471 lb	KTPA./DECOD293009..MMB..SLN..IRK.BENI	

Status:	Type:	Speed:	FL:	Cruise FL:	Heading:
Flying	B738	445	340	340	285
Nominal	01:15 hrs	664 nms	6595 lb	KTPA./335347N/0952937W..341433N/0	

Altitude	STATUS:	Trial Planning
MMB -11	AAL1651	B738/Q 340
SLN 12	KTPA./ .DECOD293009..MMB..SLN..IRK.BENKY1.KORD	
IRK 31/006	AAL1651	
ORD 32	KTPA./ .DECOD293011..AQR153010..TUL..IRK.BENKY1.KORD	

Buttons: Send TMI, Approve, Unable, Cancel Request, Accept, Reject, Cancel1



# Email Alerts and the Daily Report

Inbox		From	Subject
		mercury@ntx.org	DWR Alert: 8.6 min AAL1994/MD82 KDFW/KOMA MCI
		mercury@ntx.org	DWR Alert: 23.1 min AAL455/B738 DFW/AUS OIP..JCT
		mercury@ntx.org	DWR Alert: 20.2 min AAL1304/MD82 DFW/AUS MKN..COM..JCT
		mercury@ntx.org	DWR Alert: 6.6 min AAL2493/B752 DFW/LAX ALIBY
		mercury@ntx.org	DWR Alert: 11.0 min AAL2384/MD83 KDFW/KORD IRK

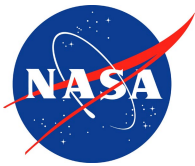
DWR Report 2013-05-30 Thu

		Flights	Estimated Savings (min)
Total DWR Initialized Flights		39	355.3
	Evaluated	29	278.7
	Accepted	25	209.7
	Rejected	3	15.9
	Canceled	1	
Total AA Initialized Flights		0	
	Accepted	0	0
Estimate of Actual Savings (ZFW Route Amendments)	Total Accepted	25	209.7
	Total ZFW Actual	11	89.9

← Advised  
 ← Evaluated  
 ← Accepted  
 ← Rejected

← Estimated Actual Savings

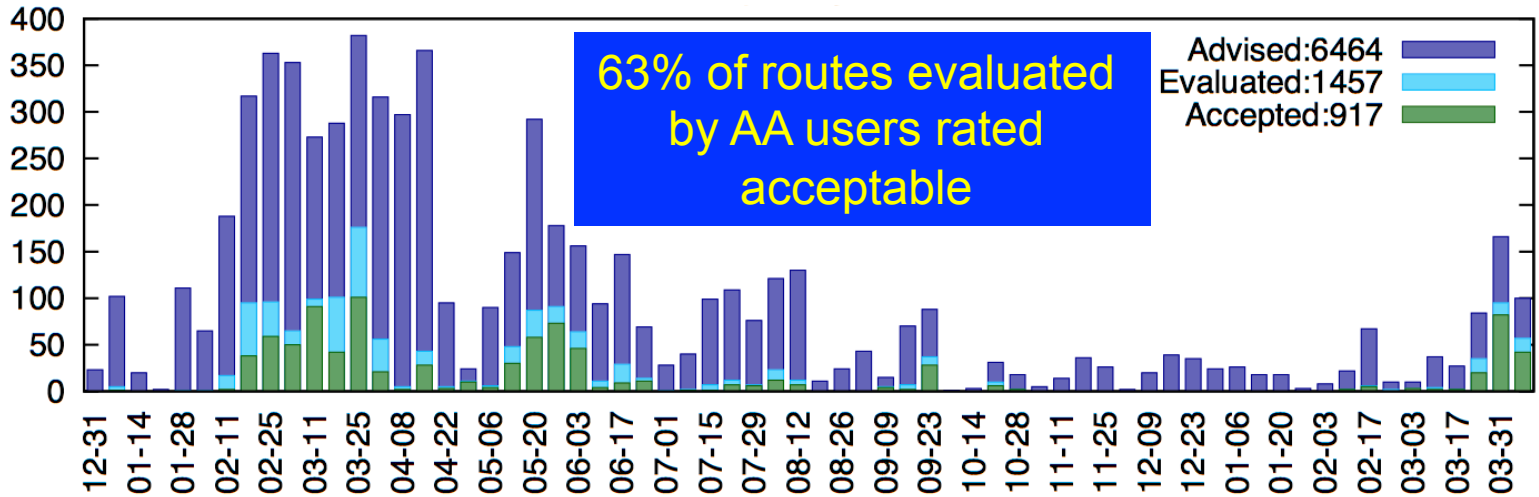
Note: sample email alerts and daily report are from different days.



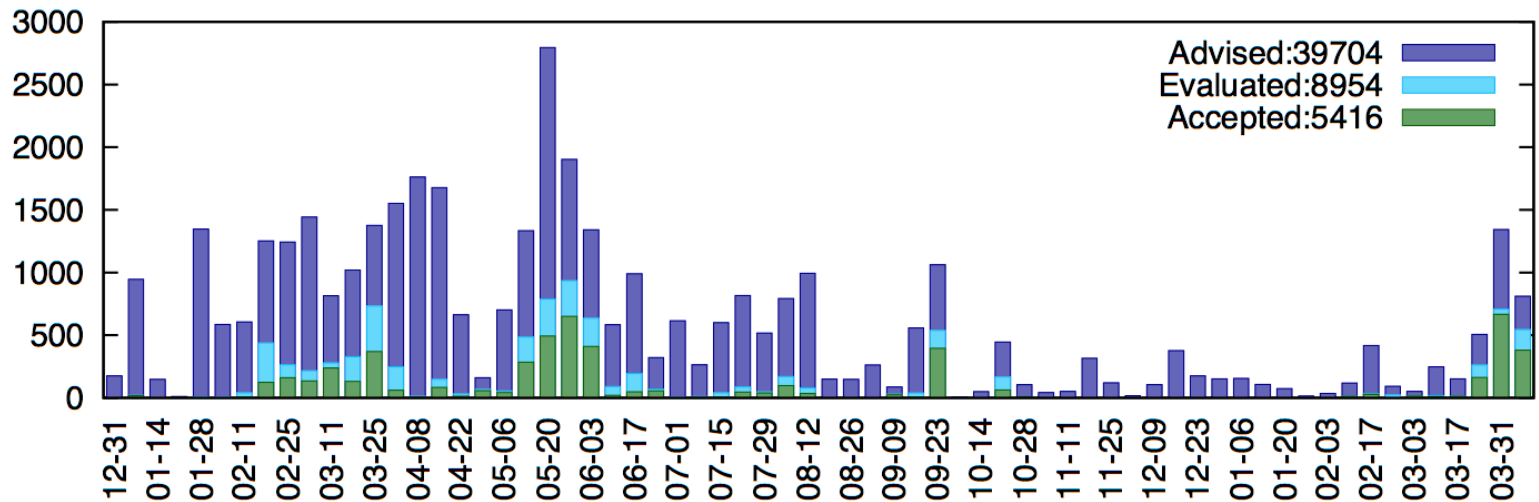
# DWR Advised Routes and AA User Actions

## AA Flights 1/1/2013 to 4/13/2014

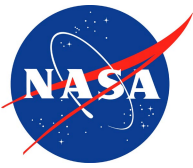
AA flights



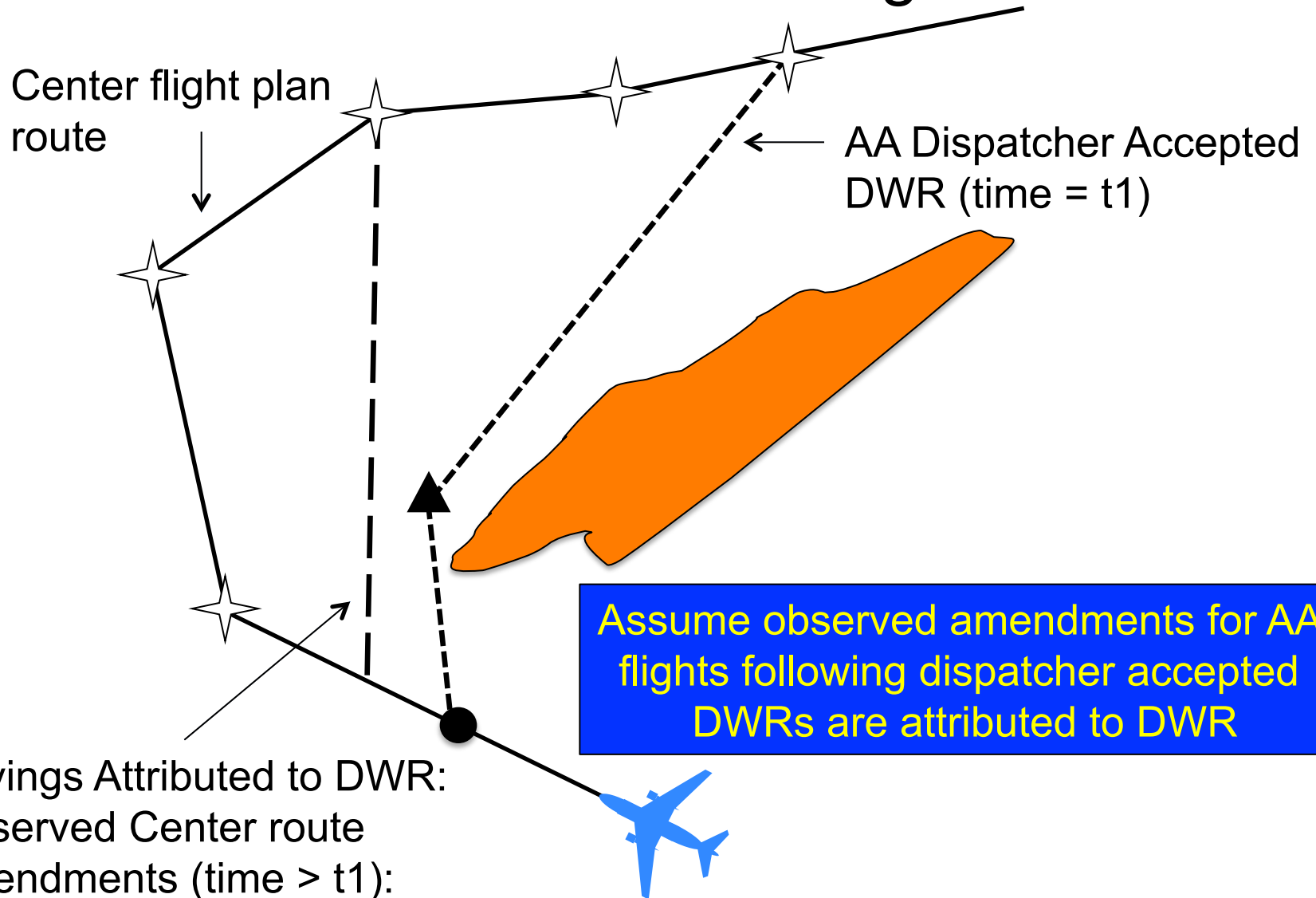
Potential flying time savings (min)

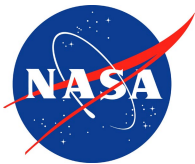


Week in 2013 and 2014



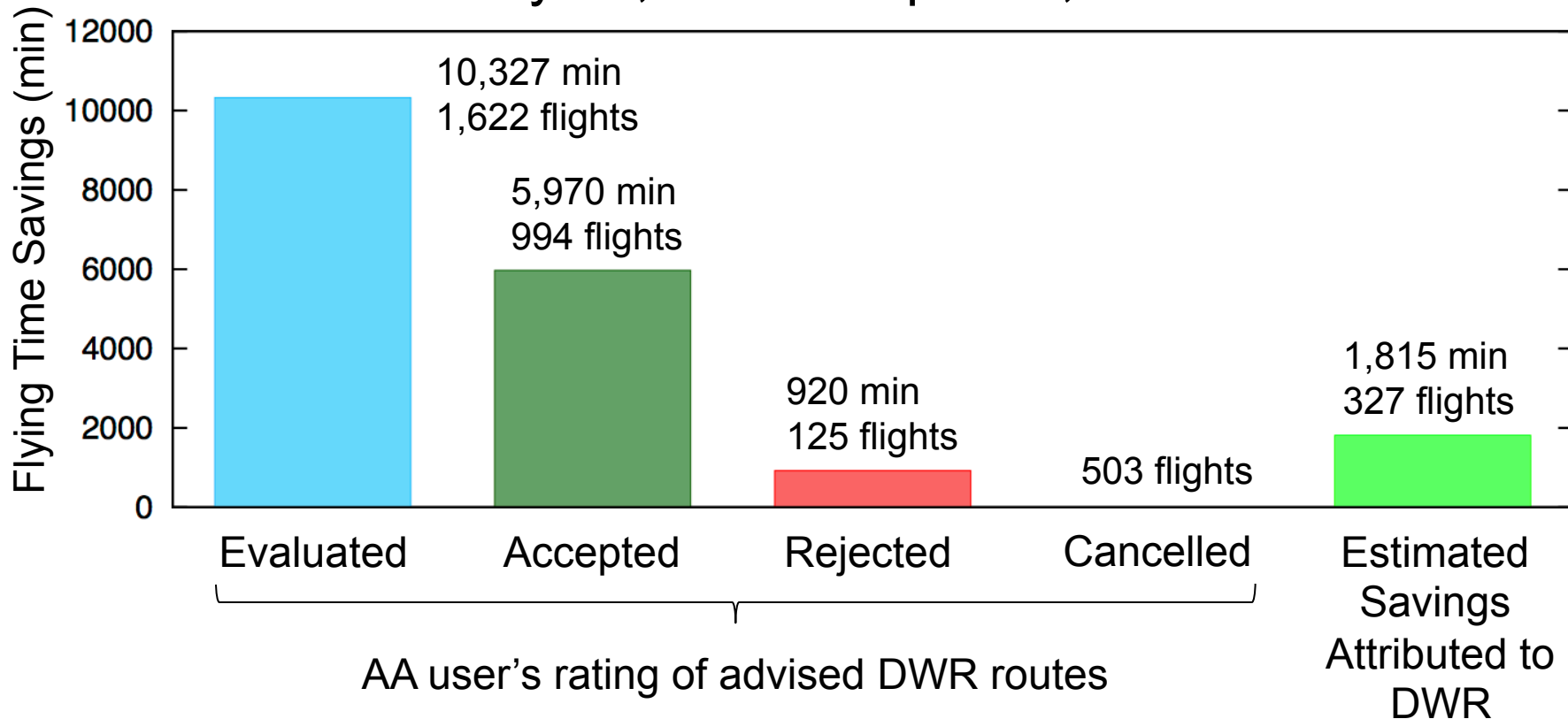
# What is the Estimated Actual Savings for American Airlines flights?



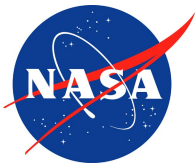


# DWR Activity at American Airlines

July 31, 2012 to April 13, 2014

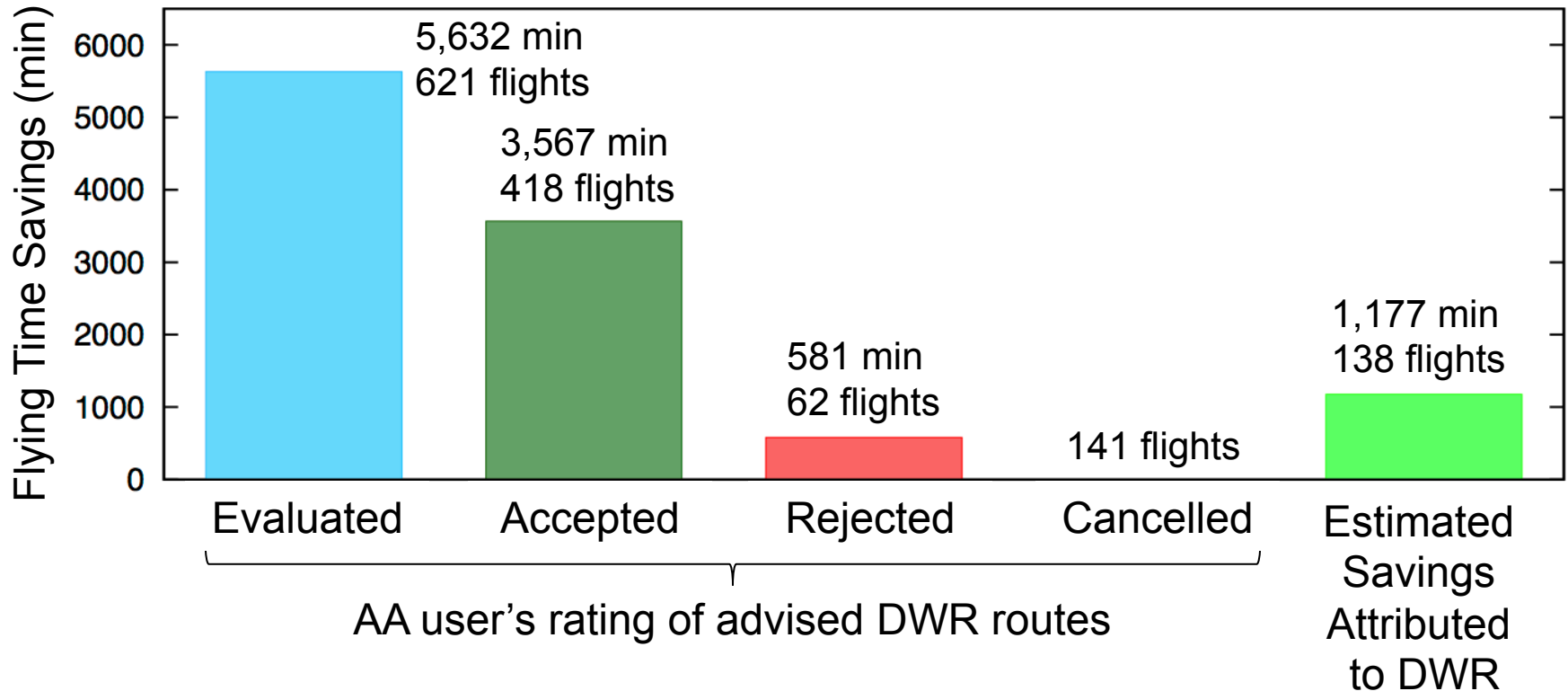


**Estimated Actual Savings Overall  
1,815 minutes for 327 revenue flights**

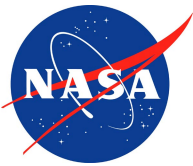


# DWR Activity at American Airlines

27 Days with High AA Value (Potential AA Savings  $\geq$  200 min),  
High AA Use (Potential Evaluated  $\geq$  20%)



**Estimated Actual Savings on 27 High-Value, High-Use Days**  
**1,177 minutes for 138 revenue flights**  
**\$4,300/day at \$100/min**



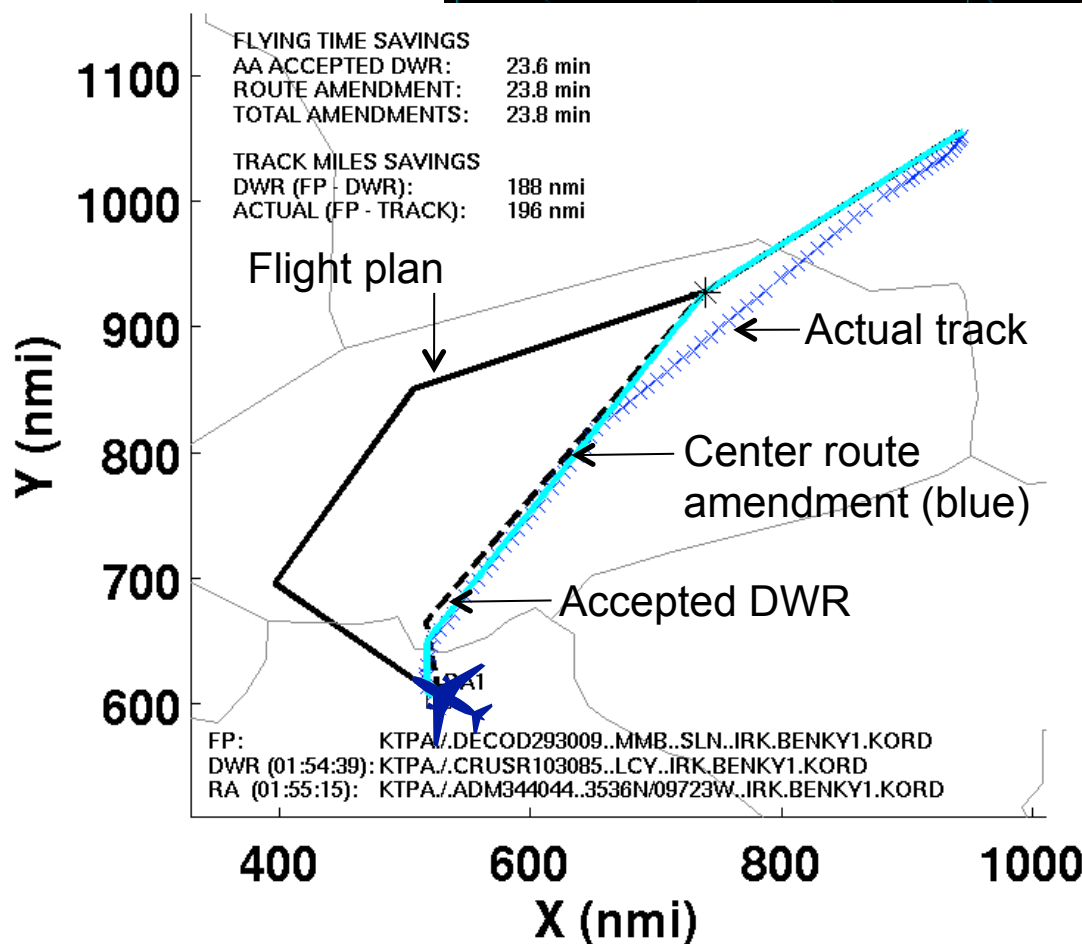
# Sample: Tampa/Chicago

pgui [oper.soc]

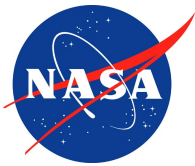
Dynamic Weather Routes - AAL

TP	ACID/TYP	DEP/DST	DRCT	DWR	FIX/VIA	TR	SC	WX
<input type="checkbox"/>	AAL /M82	KDFW/KORD	25.0	25.0	IRK/1	14	OK	OK
<input checked="" type="checkbox"/>	AAL /B738	KTPA/KORD	25.3	23.6	IRK/1	OK	OK	OK

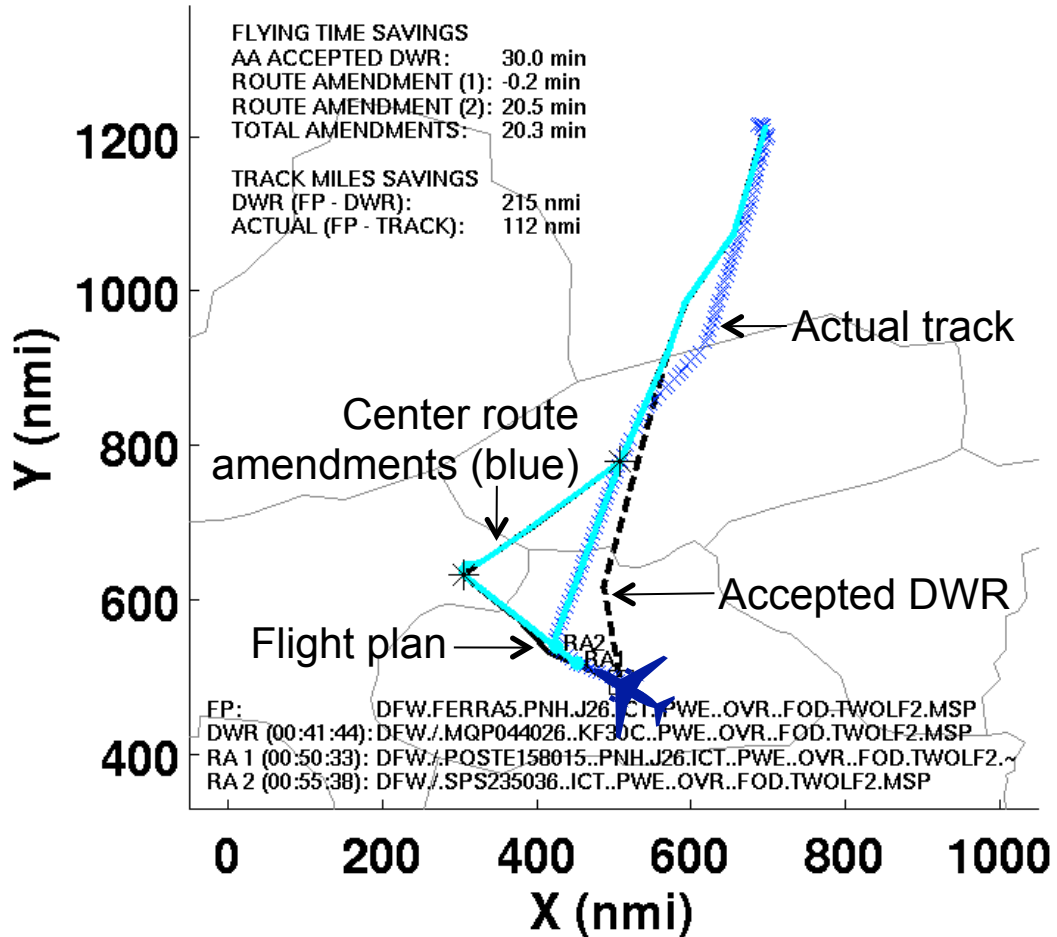
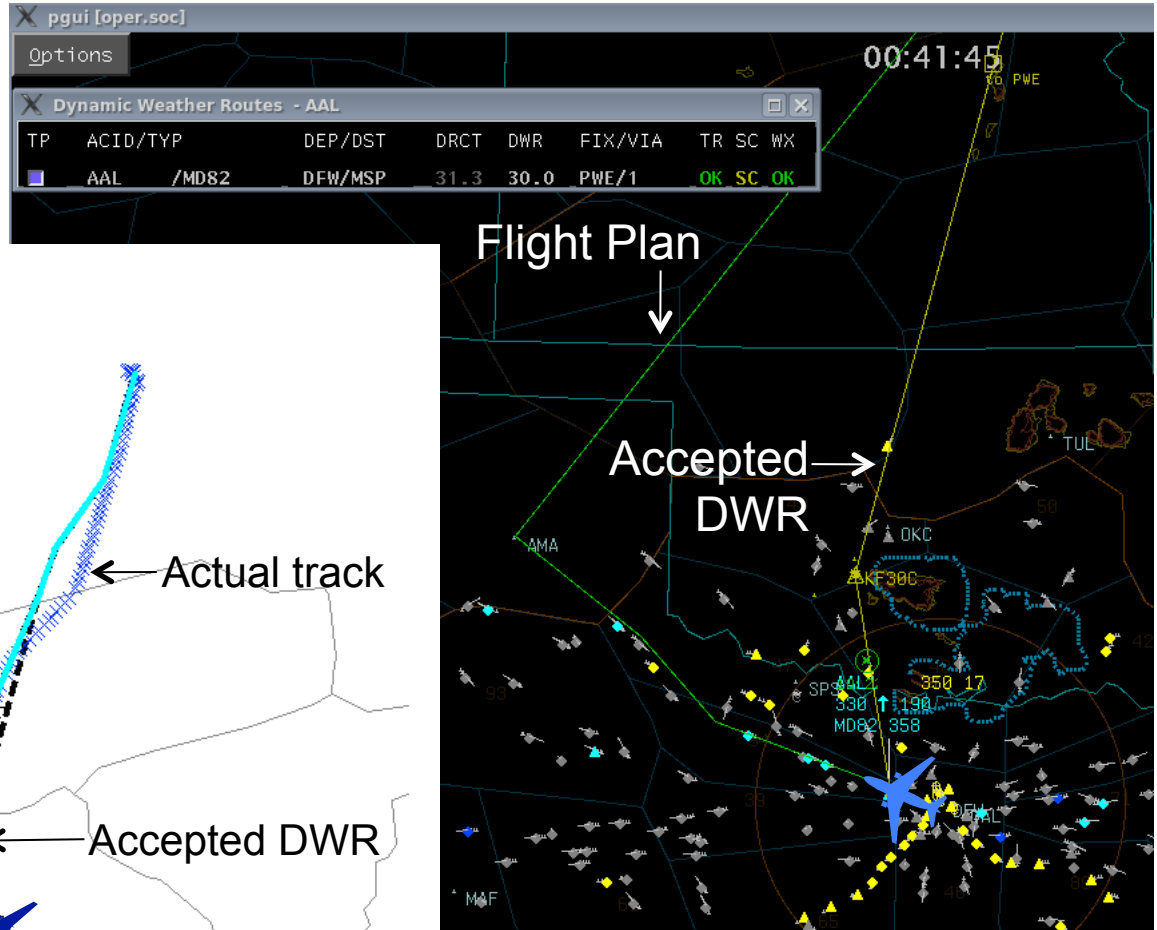
01:54:39



Estimated Actual Savings: 24 minutes

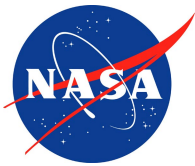


# Sample: Dallas/Minneapolis



Estimated Actual Savings: 20 minutes



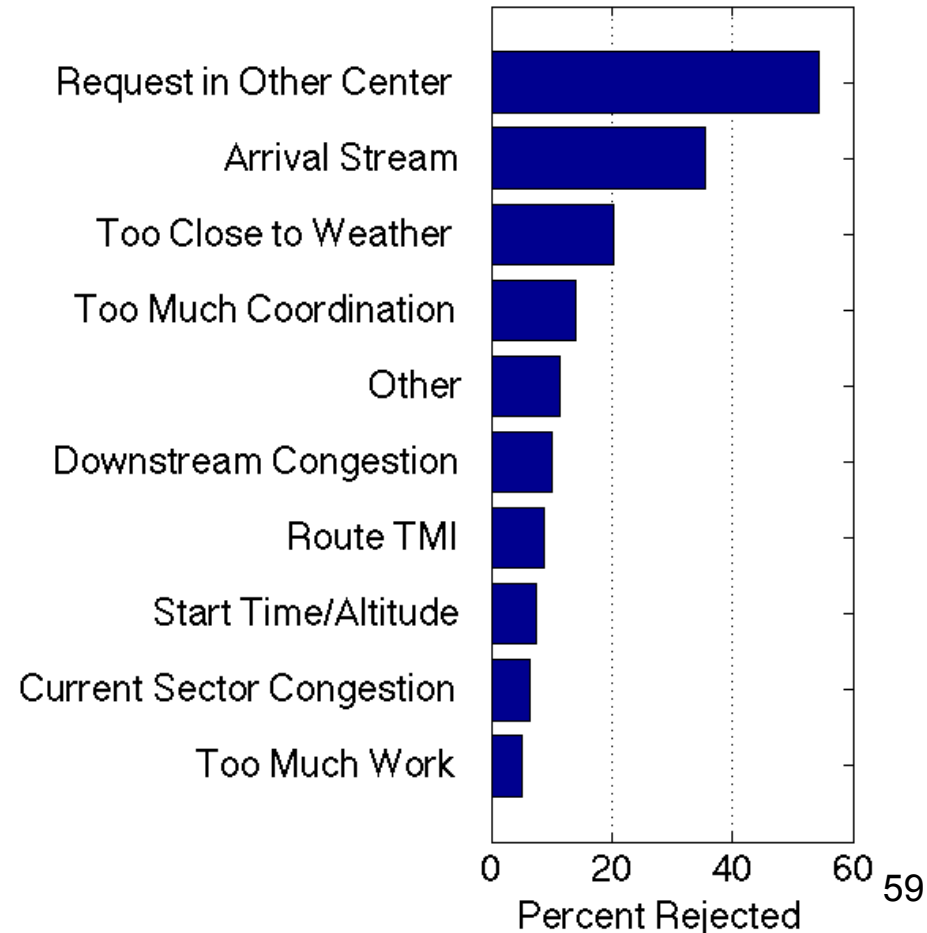


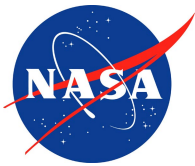
# TMC Evaluation of AA DWRs

Six recently retired ZFW Traffic Management Coordinators and Area Supervisors evaluated 39 actual DWR routes rated “Accept” by AA users

- 62% of AA routes approved
- 57% (151 minutes) of DWR savings
- Rejects primarily due to Airspace configuration
  - Center boundaries
  - Arrival stream/sector

## Reasons for Rejected DWRs

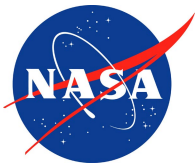




# Outline

- Building Blocks
- DWR Concept, Tool, Functional Components
- Operational Trial at American Airlines
- Analysis Results
  - Potential Benefits all Fort Worth Center Flights
  - American Airlines Test Results
  - Sector Congestion Analysis
- Software Architecture and Required Inputs
- How to Acquire DWR Software
- Next Steps

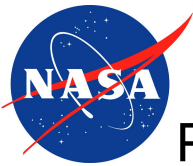




# Sector Congestion Analysis

- How many DWR flights encounter congestion?  
How much travel time in sectors with congestion?
- What happens if all flights are granted DWRs?

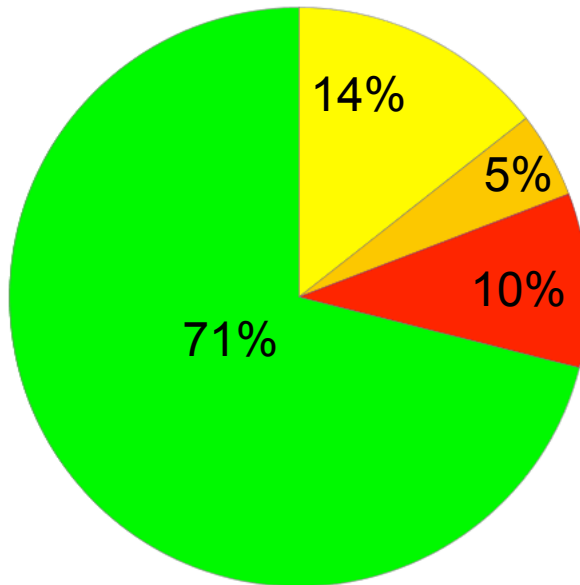




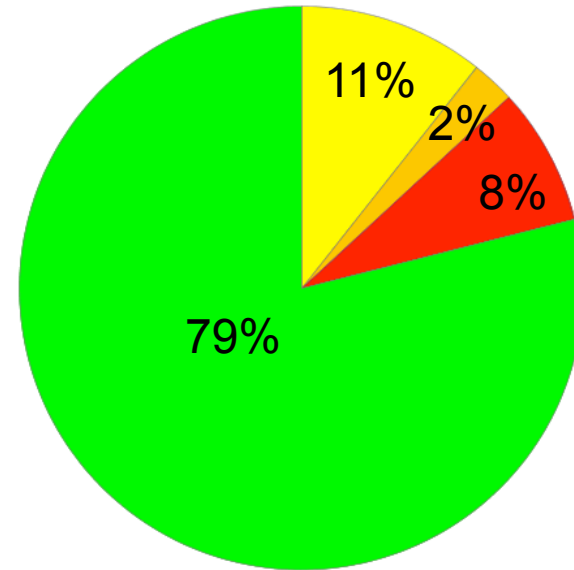
# How Many DWR Flights Enter Congested Sectors?

Proposed DWRs for 4,327 ZFW Flights, Top 24 days 2013/2014

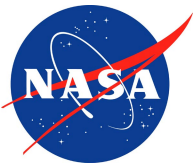
Congestion on Flight Plan



Congestion on DWR

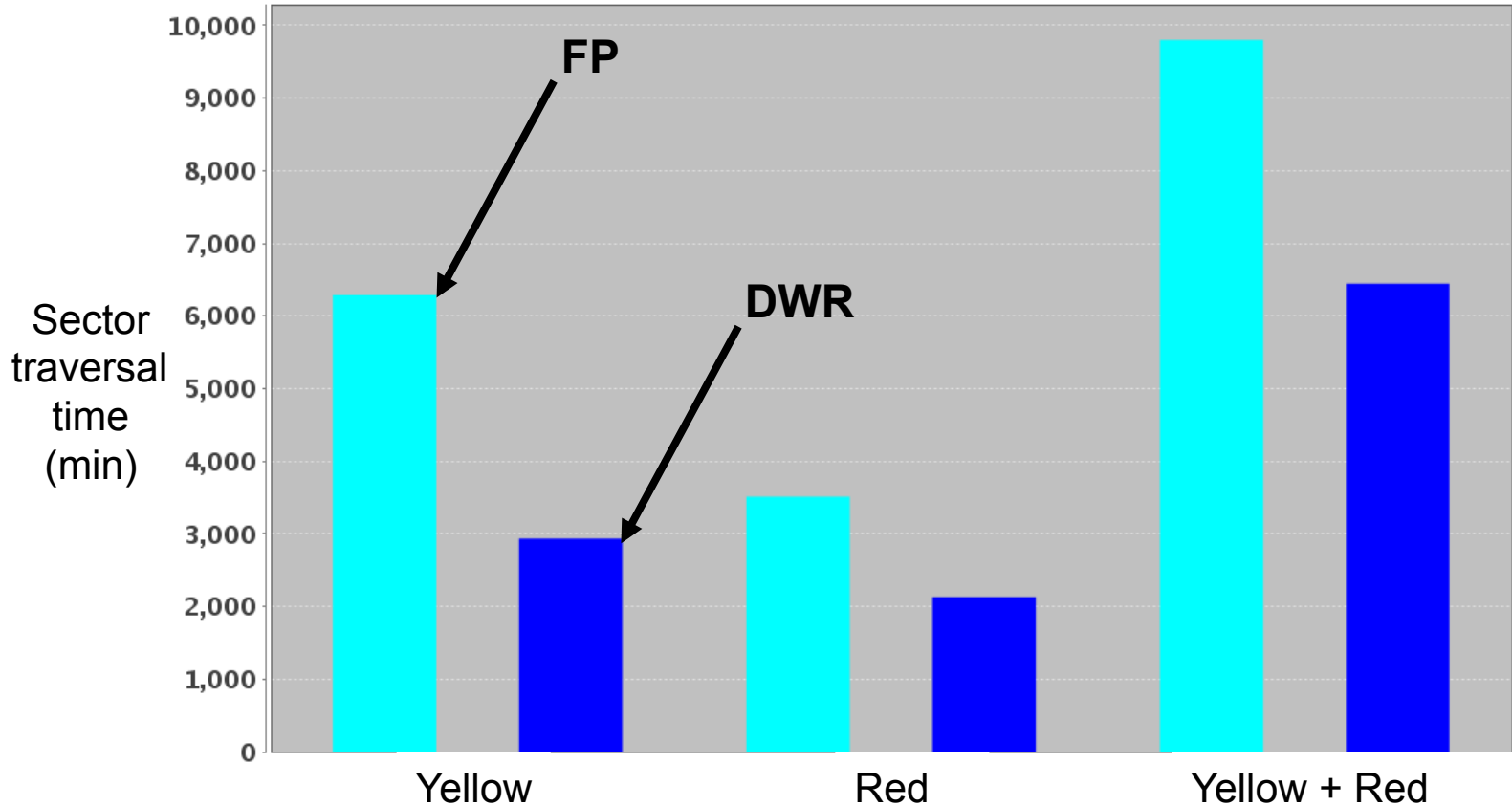


Flights fare better with DWRs for congested sector encounters

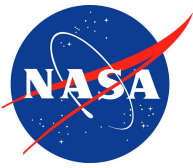


# Time Spent in Congested Sectors

Proposed DWRs for 4,327 ZFW Flights, Top 24 days 2013/2014

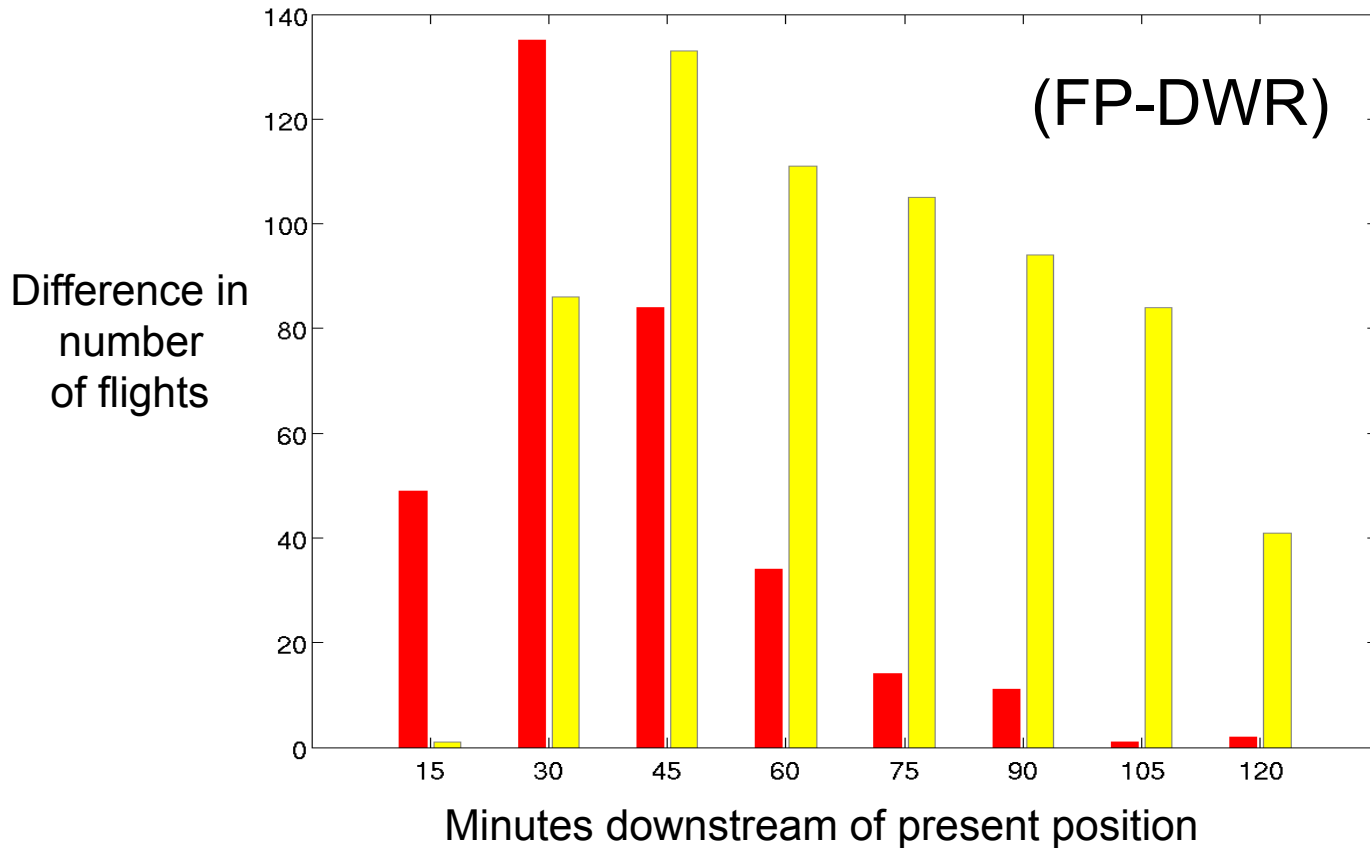


DWR trajectories spend less time in congested sectors  
(39% fewer min in red sectors, 53% fewer min in yellow sectors)

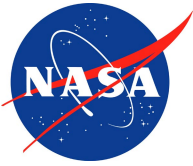


# Congestion vs. Congestion Look-Ahead Time

Proposed DWRs for 4,327 ZFW Flights, Top 24 days 2013/2014

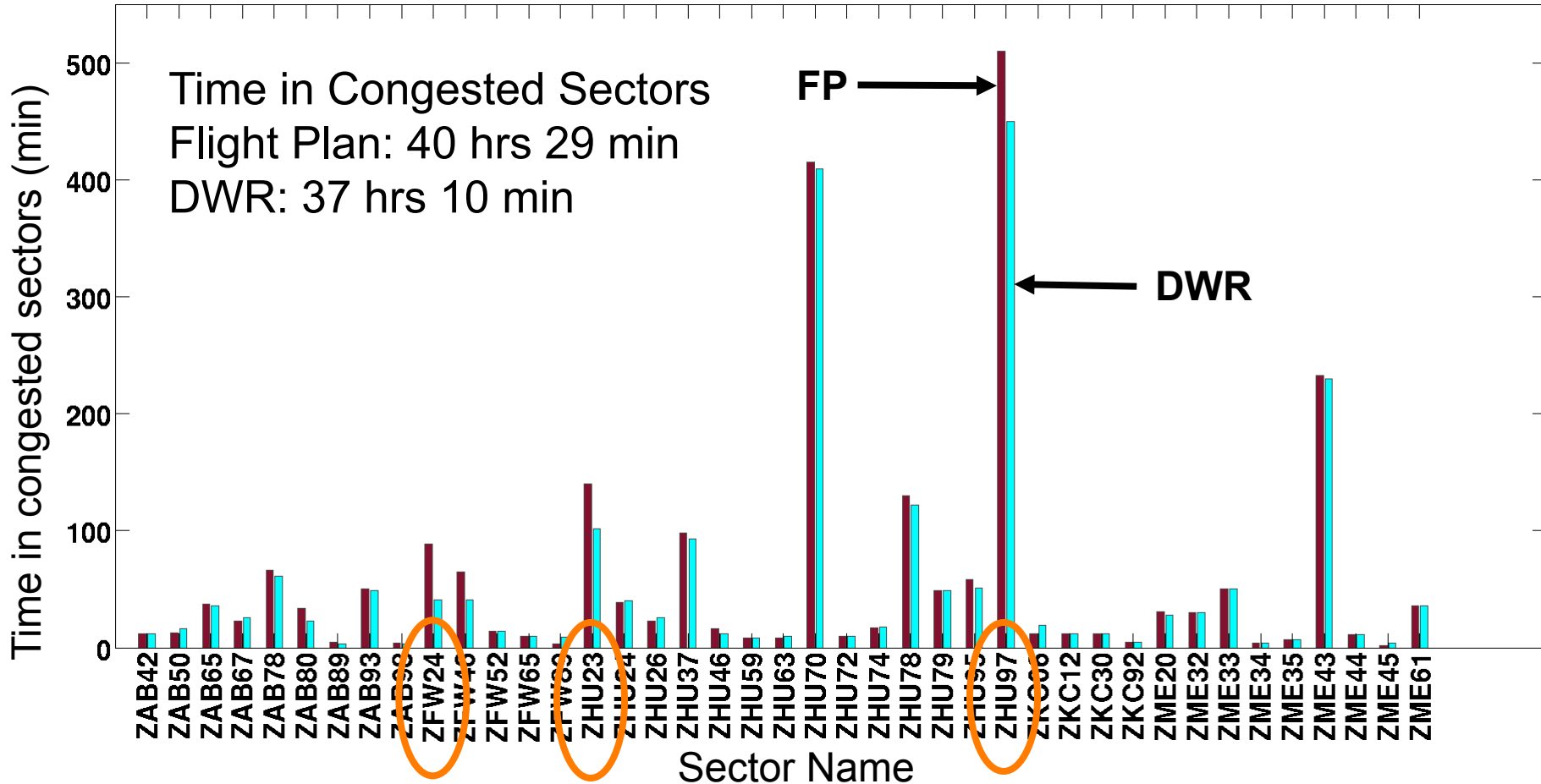


In the first 45 min flights on flight plan routes encounter more congestion than flights on DWR routes

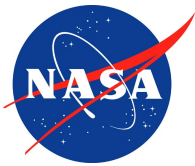


# What if all DWRs are Granted?

Proposed DWRs for 4,327 ZFW Flights, Top 24 days 2013/2014



DWRs reduce congestion 8 percent overall  
Most savings occur over 5 days in 3 sectors



# Outline

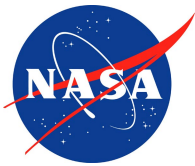
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## Software Architecture and Required Inputs

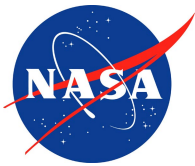
- How to Acquire DWR Software
- Next Steps





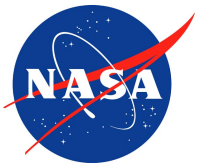
# External Live Data Sources

<b>Data Type</b>	<b>Source</b>	<b>Update Rate</b>
<b>Host/ERAM data (Flight plan, Track, etc.).</b>	<b>Direct from FAA</b>	<b>12 sec</b>
<b>ASDI - Aircraft Situation Display For Industry data.</b>	<b>Direct from FAA</b>	<b>1 min</b>
<b>CIWS - Corridor Integrated Weather System Convective Forecasts</b>	<b>Direct from FAA</b>	<b>5 Min, 120 min forecast</b>
<b>RR – Rapid Refresh Weather information</b>	<b>Direct from NOAA ftp site</b>	<b>60 min, 60 min forecast</b>
<b>TFMDI - Traffic Flow Management Data to Industry for route traffic management initiative information</b>	<b>Raw data from FAA, stored locally in a database</b>	<b>5 min</b>
<b>SUA - Special Use Airspace data</b>	<b>From FAA public website</b>	<b>5 min</b>



# Derived and Static Input Data

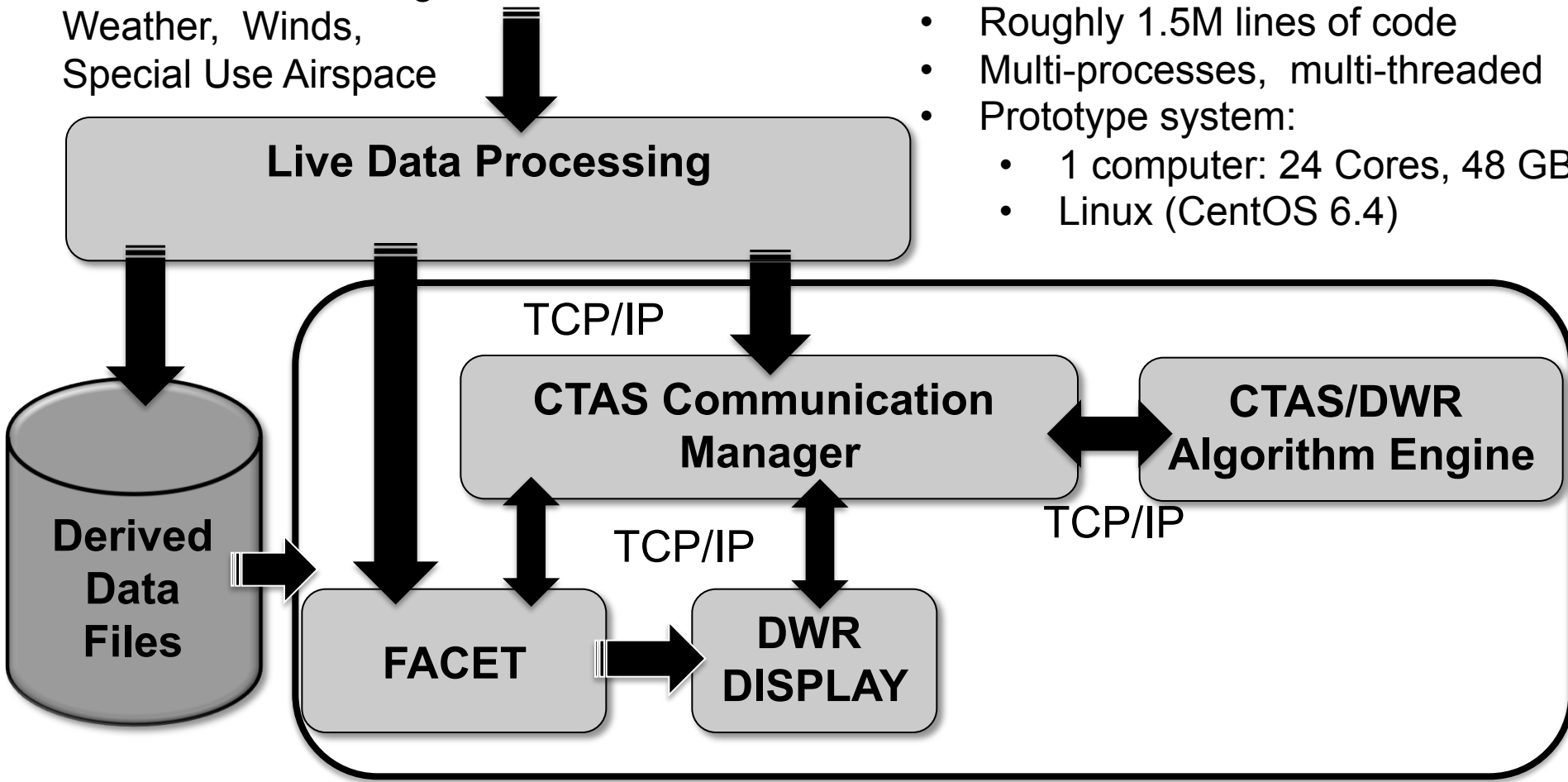
<b>Data Type</b>	<b>Source</b>	<b>Update Rate</b>
<b>CWAM - Convective Weather Avoidance Contours</b>	<b>Derived from CIWS by DWR weather processing scripts</b>	<b>5 min, 120 min forecast, 5 min time step</b>
<b>Adaptation - NAS configuration Chart Change Update</b>	<b>Direct from FAA</b>	<b>56 days</b>
<b>Aircraft performance data</b>	<b>Internal to DWR software, used to generate trajectories</b>	<b>N/A, Static</b>

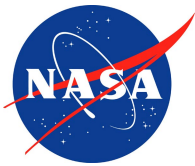


# DWR Software Architecture

Live Data: Track, Flight Plan,  
Weather, Winds,  
Special Use Airspace

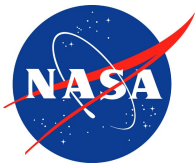
- Mixture of C, C++, Java, scripts
- Roughly 1.5M lines of code
- Multi-processes, multi-threaded
- Prototype system:
  - 1 computer: 24 Cores, 48 GB
  - Linux (CentOS 6.4)





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# How Do I Get the DWR Software?

- DWR is available for licensing on a non-exclusive basis both for commercial purposes as well as for internal evaluation.
- Details on licensing and NASA license request requirements can be accessed at

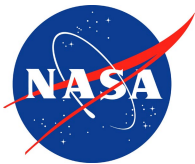
<http://www.nasa.gov/ames-partnerships/opportunities/licensing>

- Point of Contact for Licensing:

Trupti Sanghani, Technology Partnerships Division  
NASA Ames Research Center  
Telephone: (650) 604-6889  
Email: [Trupti.D.Sanghani@nasa.gov](mailto:Trupti.D.Sanghani@nasa.gov)

- Technical Point of Contact:

Dave McNally, Flight Trajectory Dynamics and Controls Branch  
NASA Ames Research Center  
Telephone: (650) 604-5440  
Email: [dave.mcnally@nasa.gov](mailto:dave.mcnally@nasa.gov)



# Next Steps

- Adjacent center traffic for more coordination time, more benefit, better analysis of merging arrival streams
- Smart filtering and route adjustment to avoid merging arrival streams – separate DWRs from traffic not airspace
- Support commercialization of DWR technology
- Streamline evaluation and coordination, faster delivery to dispatcher display, web-based DWR advisories
- Leverage DWR technology for groups of flights, identify and correct stale weather avoidance routing restrictions