



CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Collection and Processing of 4D Intent Data from Operational Flights

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Outline

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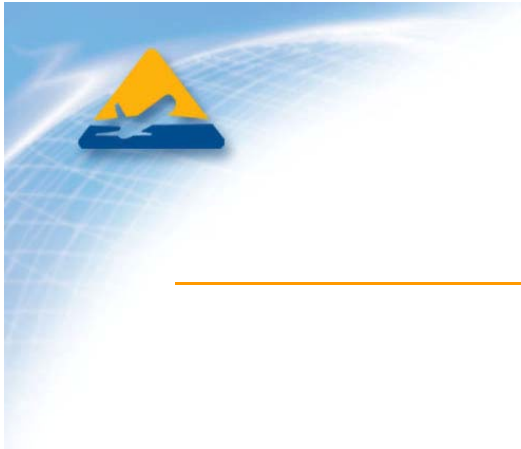
Project Goals

Phase 1

- **Gain experience decoding ARINC 702A-1 Intent Downlink Messages.**
- **Determine the characteristics of intent information, particularly FMS generated ETAs within the operational environment of today's NAS.**

Phase 2

- **Develop operational concepts and decision support tools for ATC/AOC applications which make use of down-linked intent data.**
- **Perform flight trials to gain operational experience in using intent data among air traffic specialists and airline operations personnel.**



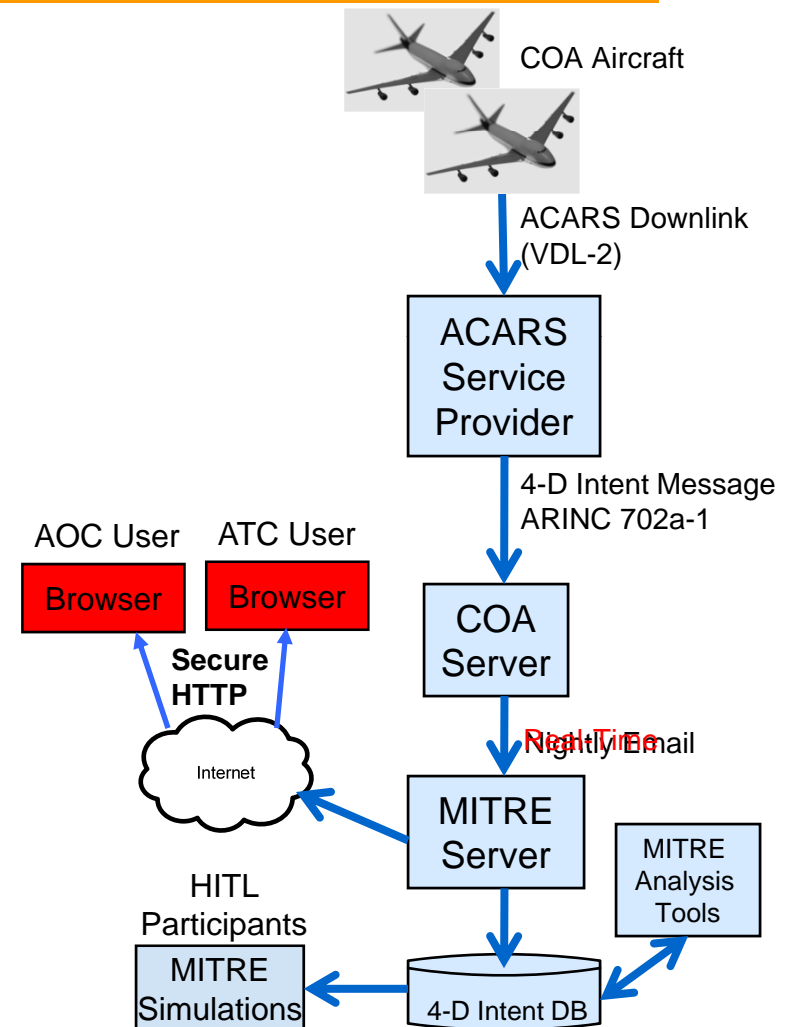
4D Intent Data

Collection/Description/Downlink Operations



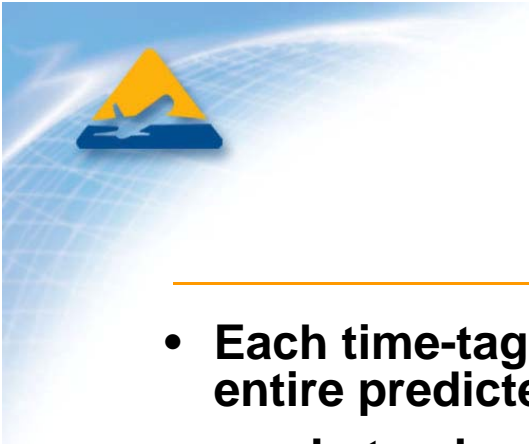
Intent Data Collection

- 53 COA 737-800 aircraft have been configured to provide Intent Downlink Messages (IDL).
- The messages are forwarded through a ground link from ARINC to Continental Airlines Airline Operations Center (AOC), where it is accumulated for each day.
- The data is then packaged, compressed and emailed to CAASD for processing and analysis.
- **For future demonstrations, it is expected that the downlink data will be sent on a real-time basis to CAASD.**



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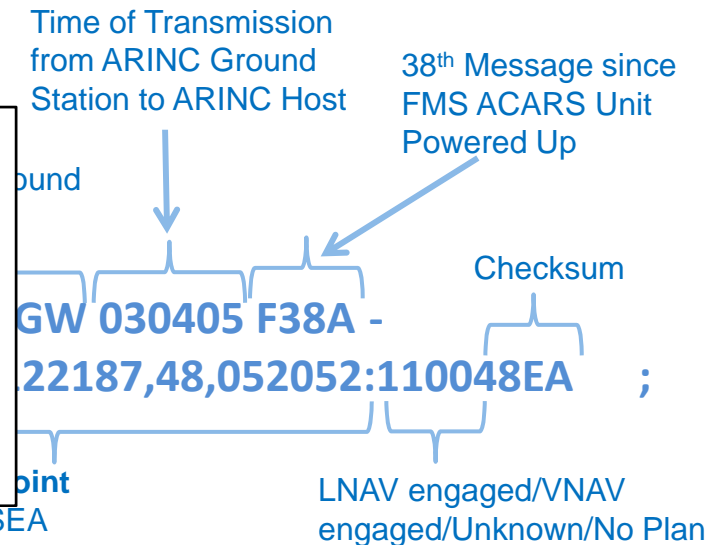


Intent Data Description

- Each time-tagged Intent Downlink (IDL) report consists of the entire predicted flight trajectory:
 - Lateral path
 - Vertical path
 - ETA at waypoints ← **4th Dimension**
- Whether LNAV/VNAV is engaged
- Status of the report

Time of Transmission from ARINC (200)

- **Position report downlinks sporadically available (1 report per flight)**
 - **Current position (time, lat/lon, altitude)**
 - **Previous, next and next+1 waypoints**
 - **Air temperature, actual winds, fuel remaining and target mach**



Indication of IDL Message

No Radius/Direction
 Lat: 47° 32.2'N/Lon: 122° 18.6' W
 Altitude: 1880 ft
 ETA: 05:19:13 UTC

Rwy 16C at KSEA
 Lat: 47° 27.8'N/Lon: 122° 18.7' W
 Altitude: 480 ft
 ETA: 05:19:13 UTC

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Intent Data

- Processed IDL data is stored for analysis at CAASD and viewable through a web server.



4D Trajectory Intent Project

Select a Flight

Airline Code	Flight Number	Departure Date and Time	Departure Airport	Arrival Date and Time	Arrival Airport
COA	1881	2008-03-30 22:34:00	EWR	2008-03-31 04:12:00	SEA
COA	233	2008-03-31 01:04:00	LGA	2008-03-31 04:16:00	IAH
COA	1491	2008-03-31 01:26:00	IAH	2008-03-31 03:56:00	DTW
COA	1457	2008-03-31 01:34:00	CLE	2008-03-31 06:09:00	SEA
COA	1789	2008-03-31 02:07:00	IAH	2008-03-31 06:15:00	OAK
COA	289	2008-03-31 02:23:00	IAH	2008-03-31 06:51:00	CYVR
COA	1427	2008-03-31 03:00:00	IAH	2008-03-31 06:23:00	ONT
COA	1547	2008-03-31 03:04:00	IAH	2008-03-31 05:57:00	SAN
COA	435	2008-03-31 03:14:00	IAH	2008-03-31 06:30:00	SAN
COA	1932	2008-03-31 03:20:00	SAN	2008-03-31 05:38:00	IAH
COA	748	2008-03-31 03:38:00	IAH	2008-03-31 05:33:00	FLL
COA	467	2008-03-31 03:55:00	IAH	2008-03-31 08:11:00	SEA
COA	595	2008-03-31 04:26:00	IAH	2008-03-31 07:56:00	LAX
COA	1416	2008-03-31 04:29:00	IAH	2008-03-31 05:16:00	MSY
COA	274	2008-03-31 06:35:00	SEA	2008-03-31 10:09:00	CLE
COA	767	2008-03-31 07:26:00	SEA	2008-03-31 10:48:00	IAH
COA	284	2008-03-31 07:40:00	OAK	2008-03-31 10:25:00	IAH
COA	766	2008-03-31 07:52:00	ONT	2008-03-31 10:08:00	IAH
COA	475	2008-03-31 10:17:00	TJSJ	2008-03-31 13:49:00	EWR
COA	1649	2008-03-31 10:26:00	FLL	2008-03-31 12:43:00	IAH



4D Trajectory Intent Project

- [Airlines](#)
- [Airports](#)
- [Flight List](#)
- [Total Fuel](#)
- [Trajectory Intent Report](#)
- [Waypoint Report](#)
- [Sector Management](#)





Intent Data

Intent data for flights in the database can be seen in tabular form.

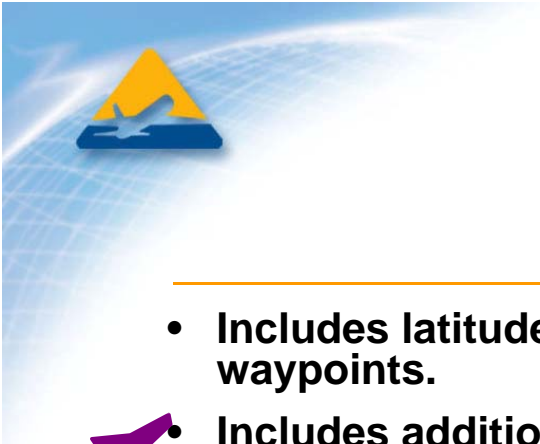
Airline	COA
Flight Number	1500
Departure Date and Time	2008-03-31 19:49:00
Departure Airport	FLL
Arrival Date and Time	2008-03-31 22:13:00
Arrival Airport	EWR

Note: Waypoints Names Are Not Part of 4D Downlink

Downlinks

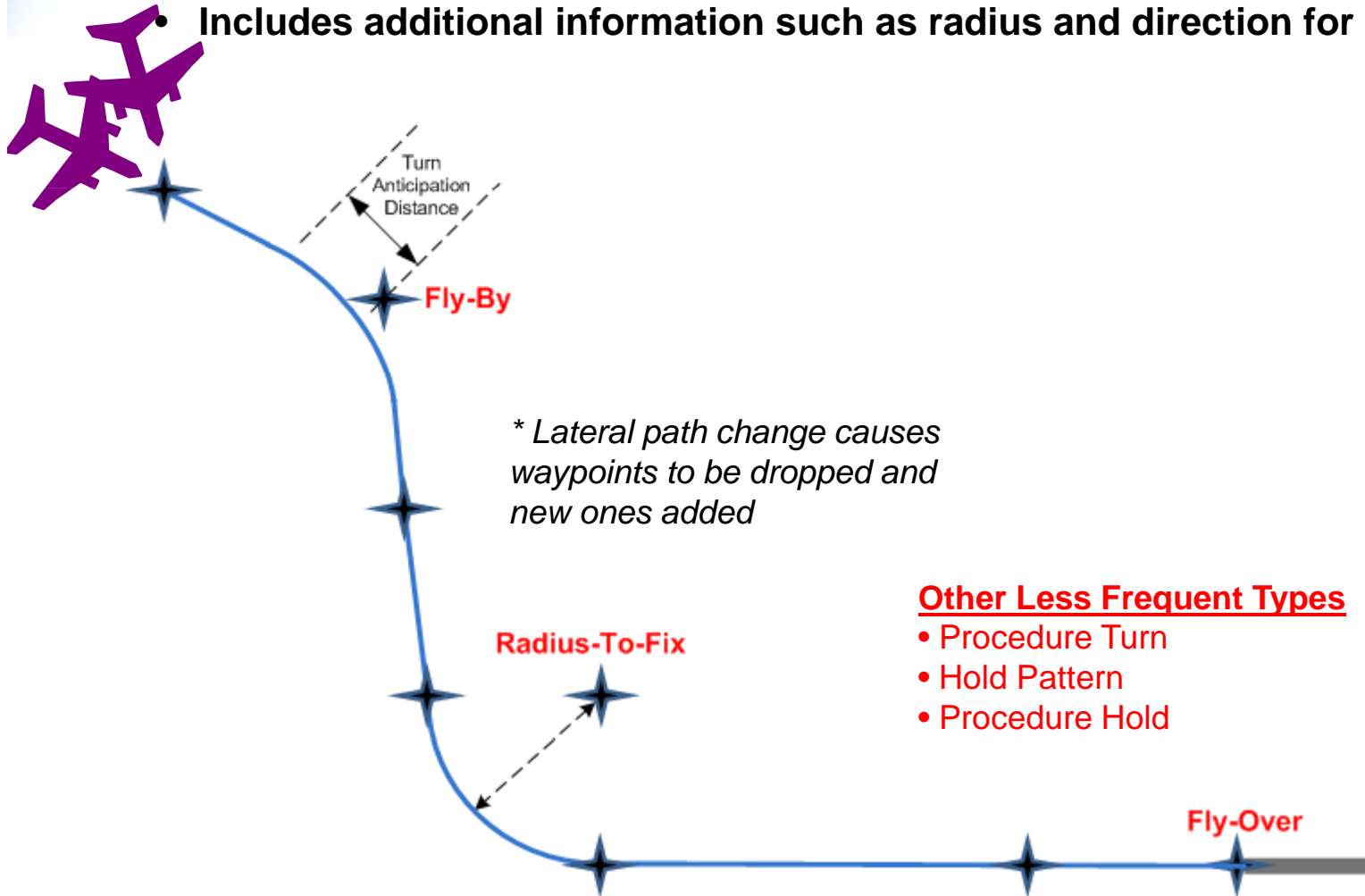


Waypoint	PERMT		LENS	SNABS	EMCEE	SEELO	ILM	RIC56	FAK	OTT			
Point Type	Fly By Waypoint	Top Of Climb	Fly By Waypoint	Fly By Waypoint	Fly By Waypoint	Fly By Waypoint	Fly By Waypoint	Fly By Waypoint	Fly By Waypoint	Fly By Waypoint	Top of Descent	Top of Descent	T D
Latitude	27.415	27.9067	29.3667	30.42	30.7933	32.0233	34.3517	36.6633	37.5283	38.7067	38.8867	38.8817	3
Longitude	-78.9467	-78.8783	-78.67	-78.52	-78.46	-78.2567	-77.875	-77.8417	-77.8283	-76.745	-76.5367	-76.5417	-
19:55:00Z													
20:05:00Z	20:06:21Z 33,550	20:10:30Z 37,000	20:23:11Z 37,000	20:32:24Z 37,000	20:35:37Z 37,000	20:46:12Z 37,000	21:06:00Z 37,000	21:25:24Z 37,000	21:32:38Z 37,000	21:44:18Z 37,000	21:46:13Z 37,000		
20:15:00Z			20:23:27Z 37,000	20:32:38Z 37,000	20:35:51Z 37,000	20:46:22Z 37,000	21:06:03Z 37,000	21:25:21Z 37,000	21:32:33Z 37,000	21:44:09Z 37,000	21:46:04Z 37,000		
20:25:00Z			20:23:32Z 37,000	20:32:45Z 37,000	20:35:59Z 37,000	20:46:33Z 37,000	21:06:18Z 37,000	21:25:41Z 37,000	21:32:55Z 37,000	21:44:33Z 37,000		21:46:27Z 37,000	
20:35:00Z				20:32:39Z 37,000	20:35:51Z 37,000	20:46:26Z 37,000	21:06:10Z 37,000	21:25:32Z 37,000	21:32:45Z 37,000	21:44:23Z 37,000		21:46:16Z 37,000	
20:45:00Z					20:35:51Z 37,000	20:46:20Z 37,000	21:06:04Z 37,000	21:25:26Z 37,000	21:32:39Z 37,000	21:44:18Z 37,000		21:46:11Z 37,000	
20:55:00Z						20:46:20Z 37,000	21:06:10Z 37,000	21:25:37Z 37,000	21:32:51Z 37,000	21:44:32Z 37,000		21:46:26Z 37,000	
21:05:00Z						20:46:20Z 37,000	21:06:10Z 37,000	21:25:39Z 37,000	21:32:54Z 37,000	21:44:35Z 37,000		21:46:29Z 37,000	
21:15:00Z							21:06:10Z 37,000	21:25:46Z 37,000	21:33:02Z 37,000	21:44:44Z 37,000			2 3
21:25:00Z								21:26:01Z 37,000	21:33:31Z 37,000	21:45:34Z 37,000			
21:36:00Z										21:47:33Z 37,000			
21:45:00Z										21:47:27Z 29,510			
21:55:00Z													
22:06:00Z													



Lateral Waypoints

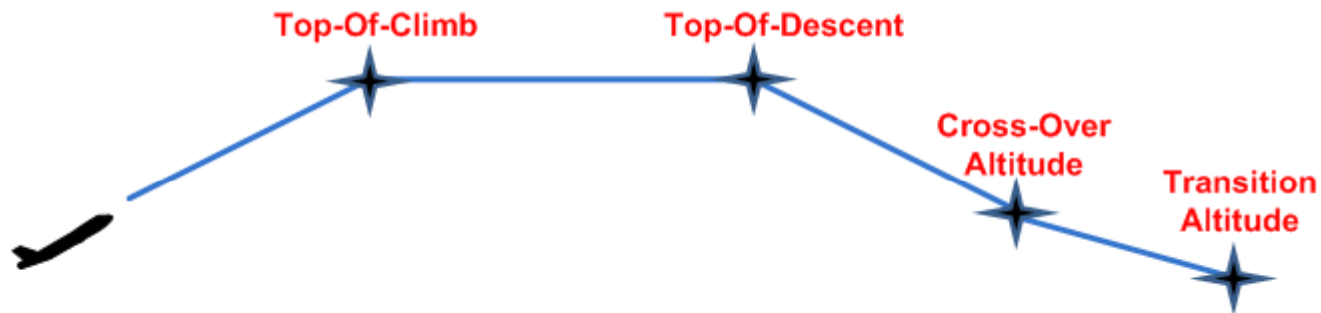
- Includes latitude, longitude, altitude, ETA for all downstream **lateral** waypoints.
- Includes additional information such as radius and direction for turns.





Vertical Waypoints

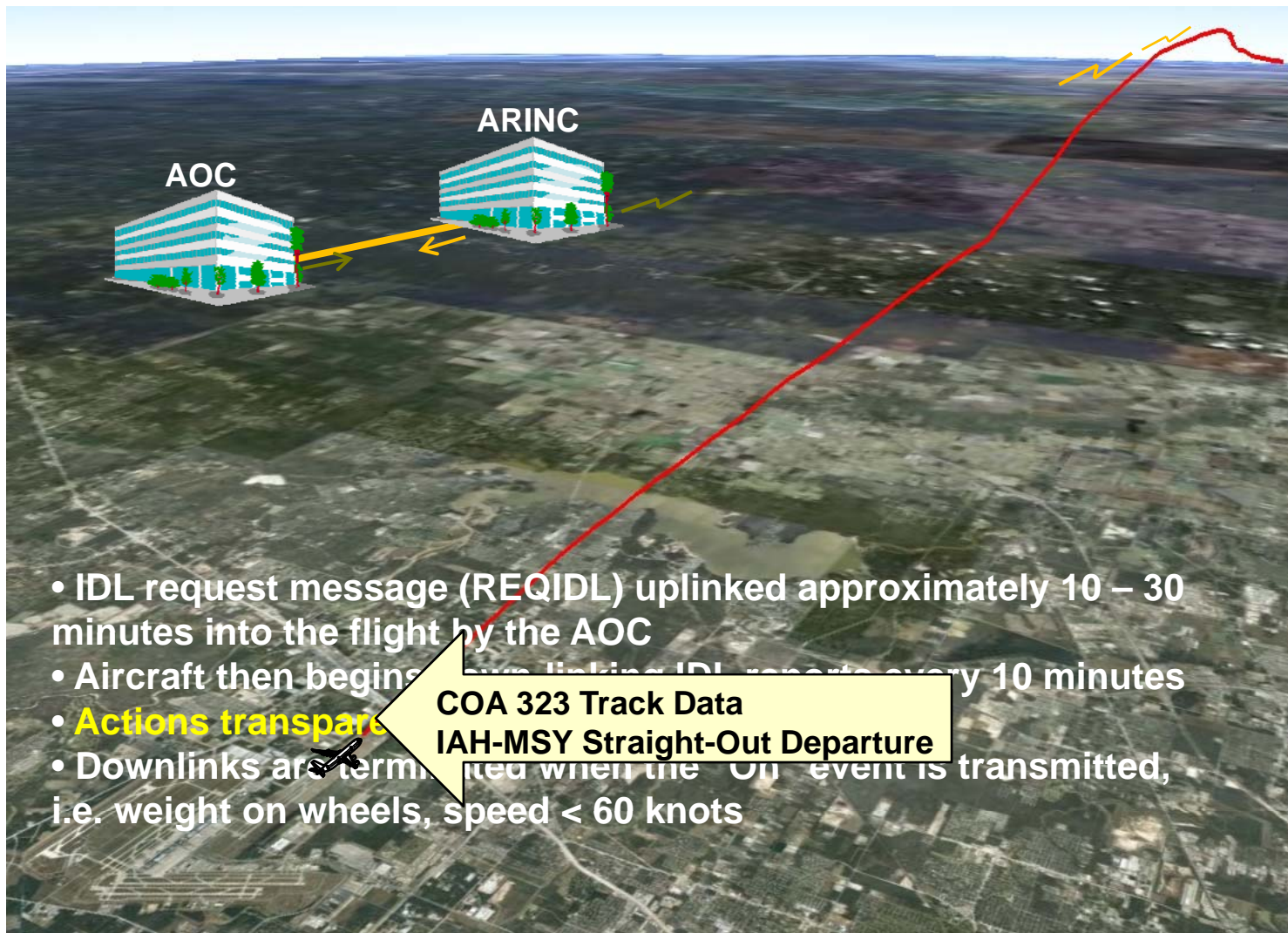
- Includes latitude, longitude, altitude, ETA for all downstream **vertical** waypoints.



* *Vertical path change causes vertical waypoints to move in time & location*



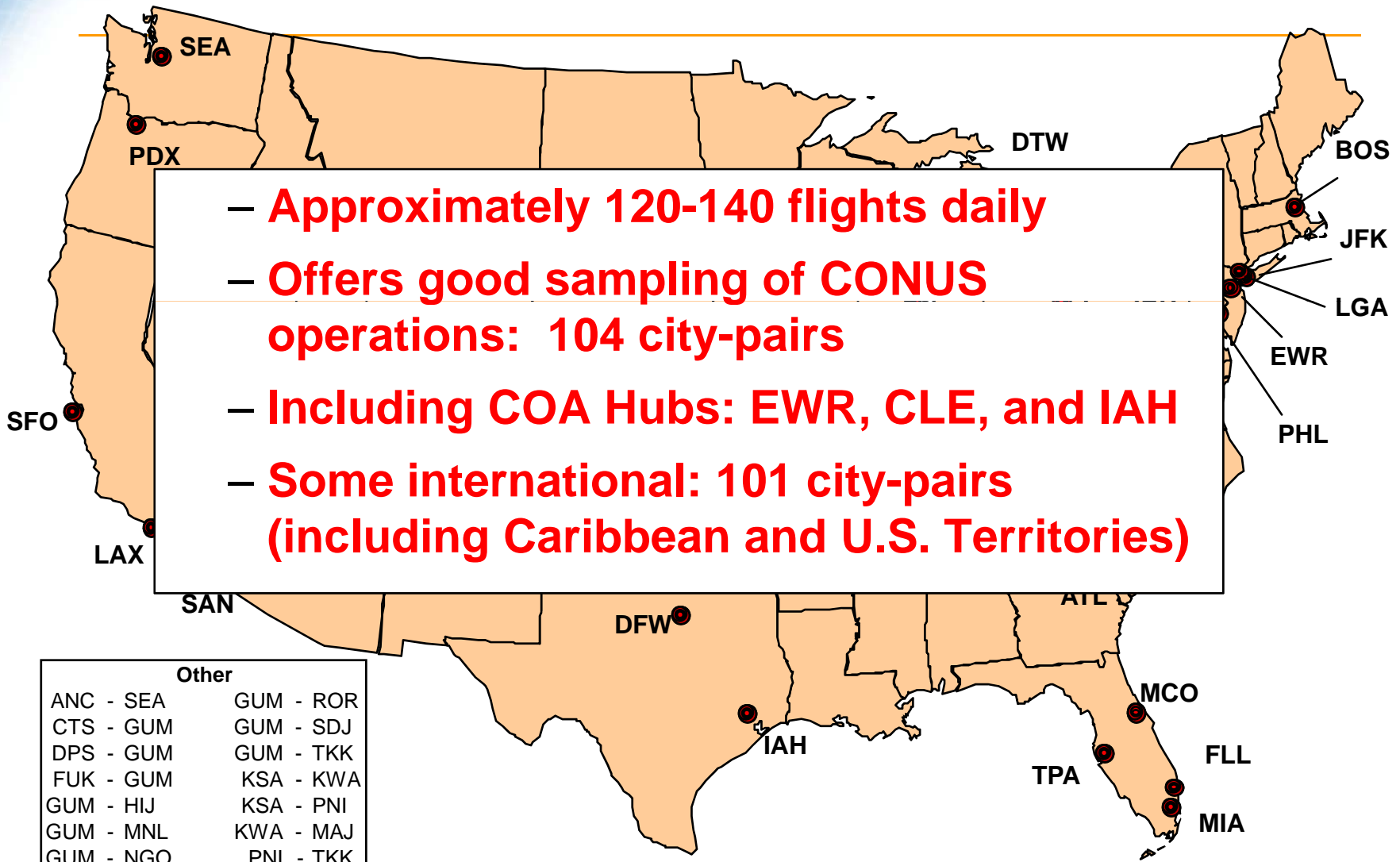
Intent Downlink Operations



- IDL request message (REQIDL) uplinked approximately 10 – 30 minutes into the flight by the AOC
- Aircraft then begins uplinking IDL reports every 10 minutes
- **Actions transparent**
- Downlinks are terminated when the "On" event is transmitted, i.e. weight on wheels, speed < 60 knots



COA 737-800 City Pairs



Other	
ANC - SEA	GUM - ROR
CTS - GUM	GUM - SDJ
DPS - GUM	GUM - TKK
FUK - GUM	KSA - KWA
GUM - HIJ	KSA - PNI
GUM - MNL	KWA - MAJ
GUM - NGO	PNI - TKK
GUM - NRT	



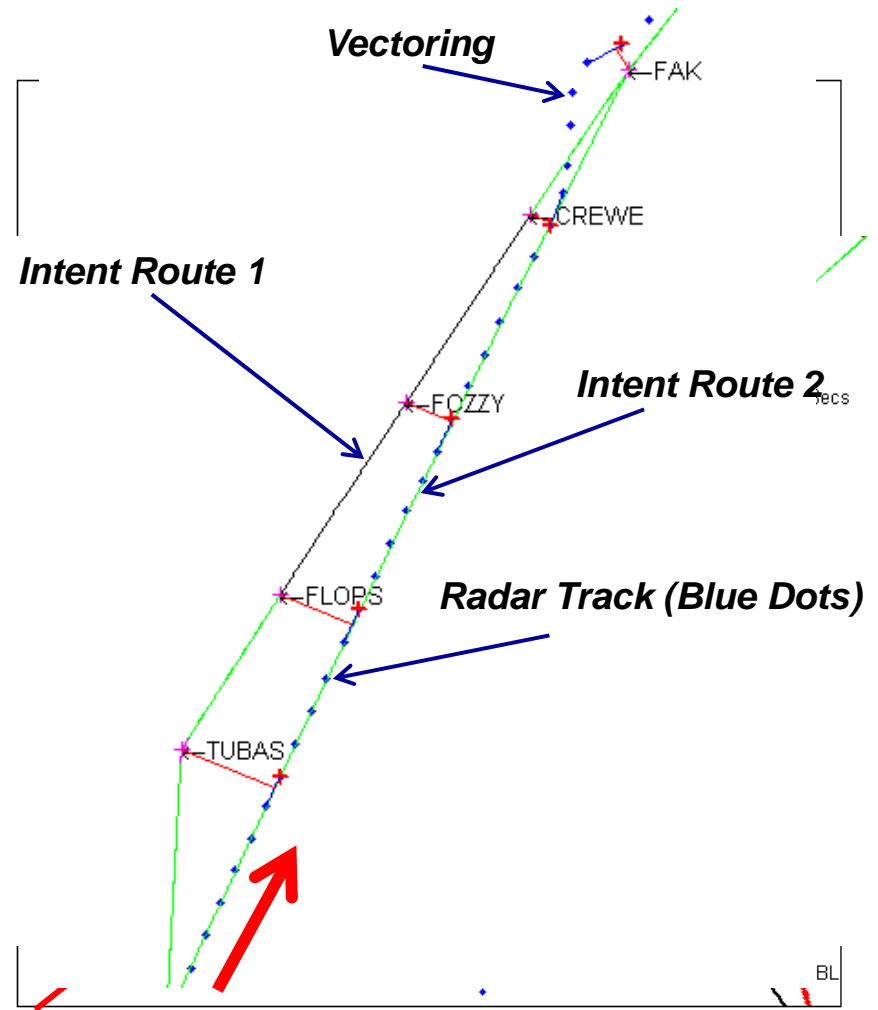
Current Activities

- **Data Analysis** – Aircraft intent data is being correlated with radar track data and flight plan data for each flight to gauge ETA variability and its causes under different conditions of NAS operations.
- **Data Visualization** – Down-linked trajectories are being interfaced to graphical tools to show progressions of downlinks as the flight moves from origin to destination.
 - These tools will be evolved to use “real” downlinks in the ATM lab environment to study various aspects of using the data.
 - These activities are expected be precursors to trials for 4D intent usage in AOC/ATC applications.



Intent Data Processing

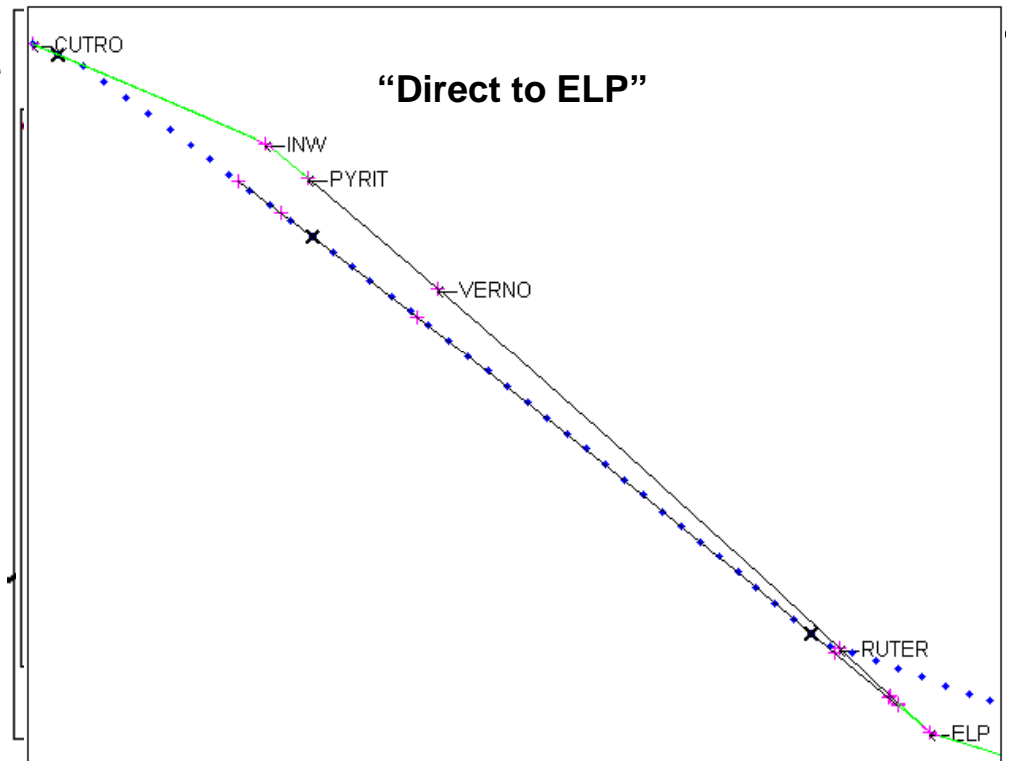
- An integrated picture for each flight is created:
 - FMS Intent routes
 - Actual flown routes (using track data).
 - Filed/amended flight plan; arr/dep airports; SIDs, STARs and IAPs flown by the aircraft
- For each down-linked waypoint, it is estimated:
 - Whether it was actually crossed
 - If so, the Actual Crossing Time (ATA).
 - This leads to:
 - **ETA Delta = ATA - ETA**
 - **Look-Ahead Time = ATA - Downlink Time**
- WGS84 projection is used for all geodetic calculations and plotting.
- The processes are automated to allow for batch processing of flights.





Intent Data Processing

- There are numerous situations in post-analysis where the FMS predicted ETAs are known to be inaccurate based on events that subsequently occurred.
- Cases include:
 - Route changes
 - Holding
 - Vectoring
- Data points impacted are flagged to allow for filtering or isolated to be looked at separately.





Initial Results/Next Steps



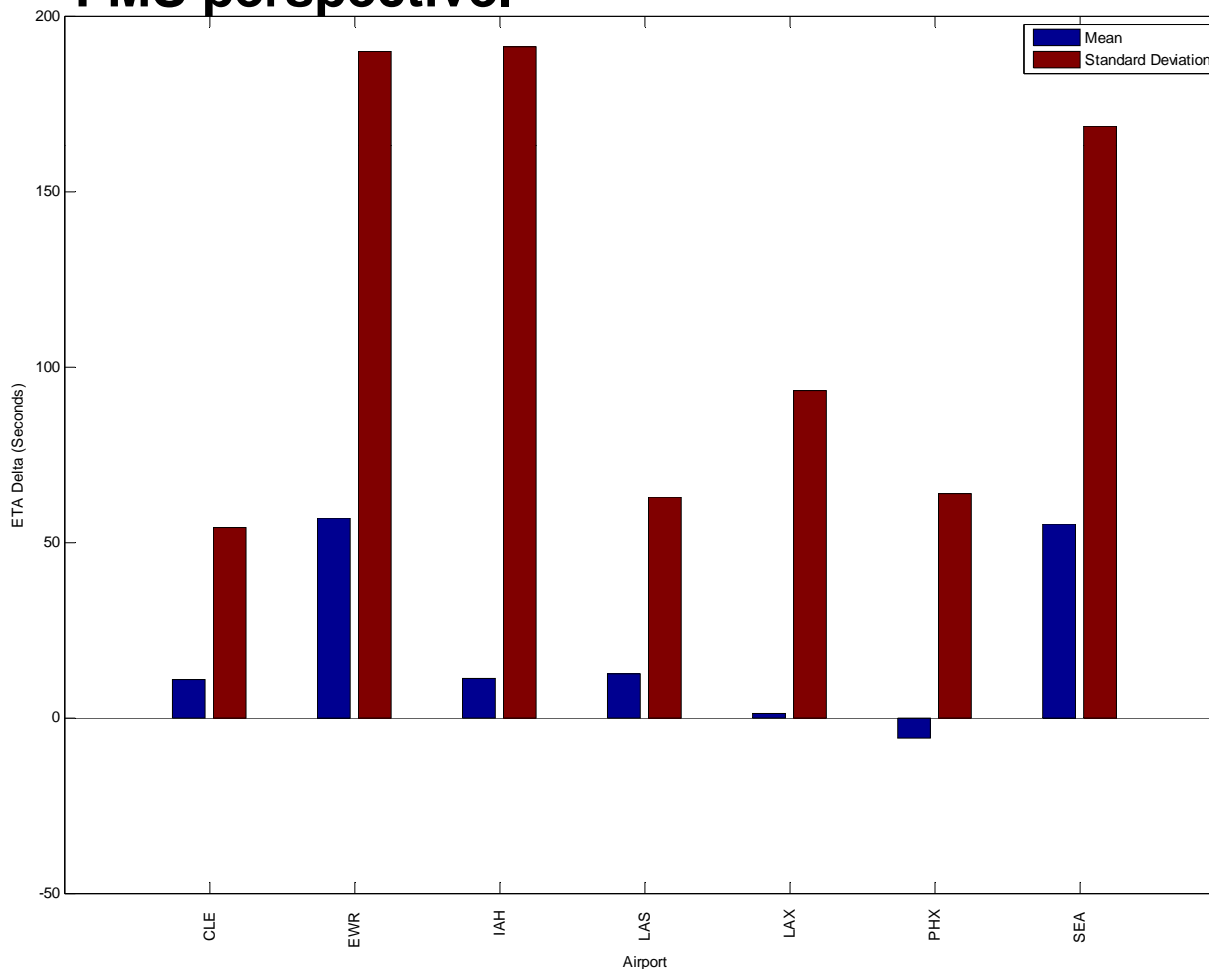
Initial Results

- **The processing and analysis is still ongoing.**
- **Approximately 5,500 flights have been processed thus far.**
 - **Less than 3% of the flights crossed every en route waypoint sequenced in the initial downlink.**
 - **In 8% of the cases during the en route phase, aircraft were found to be more that 4 nm off laterally from the straight line path between two crossed waypoints.**
 - **These interventions impact ETA stability.**
- **Initial observations from the ETA data:**
 - **En Route waypoint ETAs are the most stable of the three phases, but can be off over longer segments/look-ahead times – wind impacts are currently being studied.**
 - **Terminal waypoint ETAs are impacted by vectoring for merging and spacing.**
 - **IAP waypoints are generally not accurate till the aircraft is on final – mostly due to “expect vectors” at the end of STARs.**



Initial Results

- Looking at ETAs down-linked after TOD can be useful to see the level of intervention/vectoring at each airport from the FMS perspective.

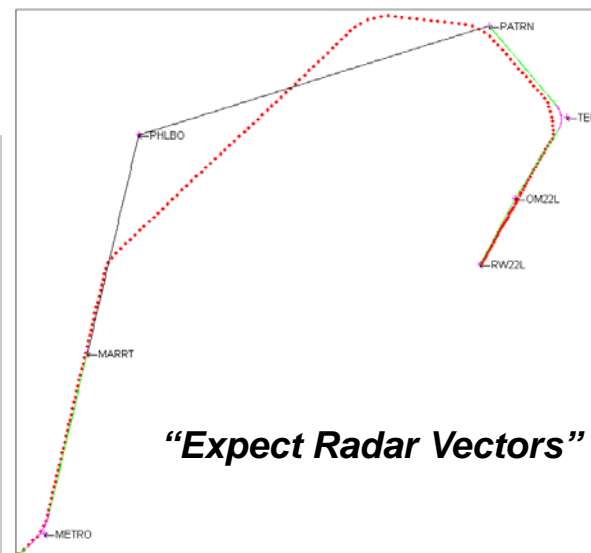
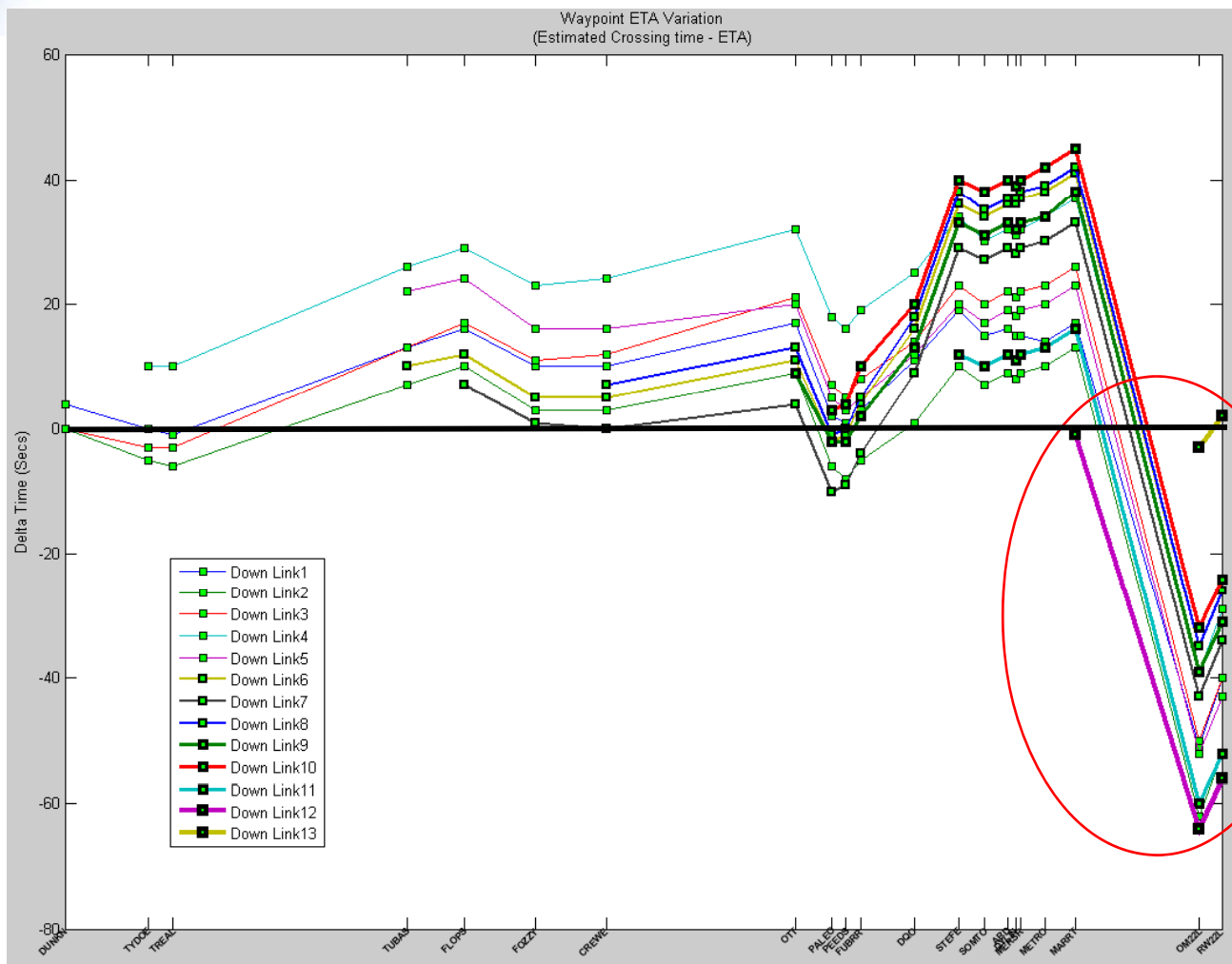


ETAs for STAR and IAP waypoints down-linked after the TOD for top airports.

(Arrival procedures using RNAV)



Initial Results – ETA Evolution for a Single Flight

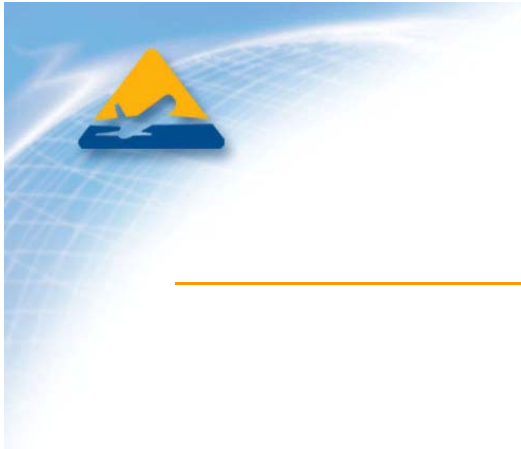


ETA deltas for this flight were under a minute for the whole flight except for the final approach waypoints.



Next Steps

- **Continue to become smarter about FMC generated ETAs**
 - Compare winds used by the FMS to RUC forecast winds.
 - Compare IDLs to ground generated trajectories.
 - Work with pilots and controllers to understand interventions & provide a log of their flight
 - Continue collaboration to understand message sequence events (predictions, recalculation triggers, clearing of data, old data).
- **Develop operational concepts for ATC/AOC decision support tools that make use of down-linked intent data.**
- **Perform flight trials to explore questions such as:**
 - Can FMS generated ETAs be used for merging and spacing?
 - What are the effects of RTA controls on ETAs?
 - How can intent data be used to improve AOC planning?



Story of COA796 (LAS - IAH)

Intent Data Playback in TARGETS



Flight Overview

LAS - IAH
(X1000 Fast Forward)

◇ KLAS

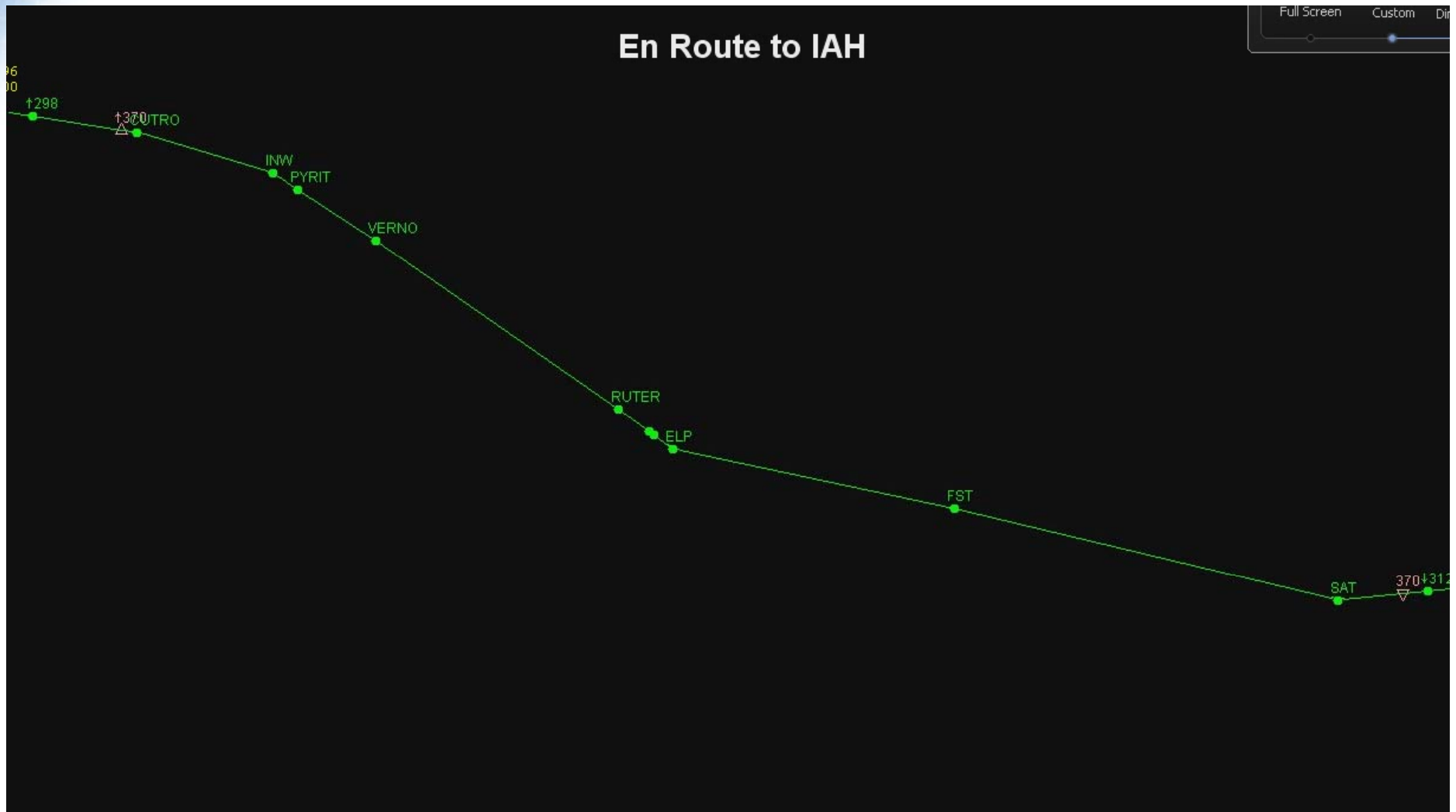
◇ KIAH

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“Direct-To”



TOD

Top of Descent to IAH

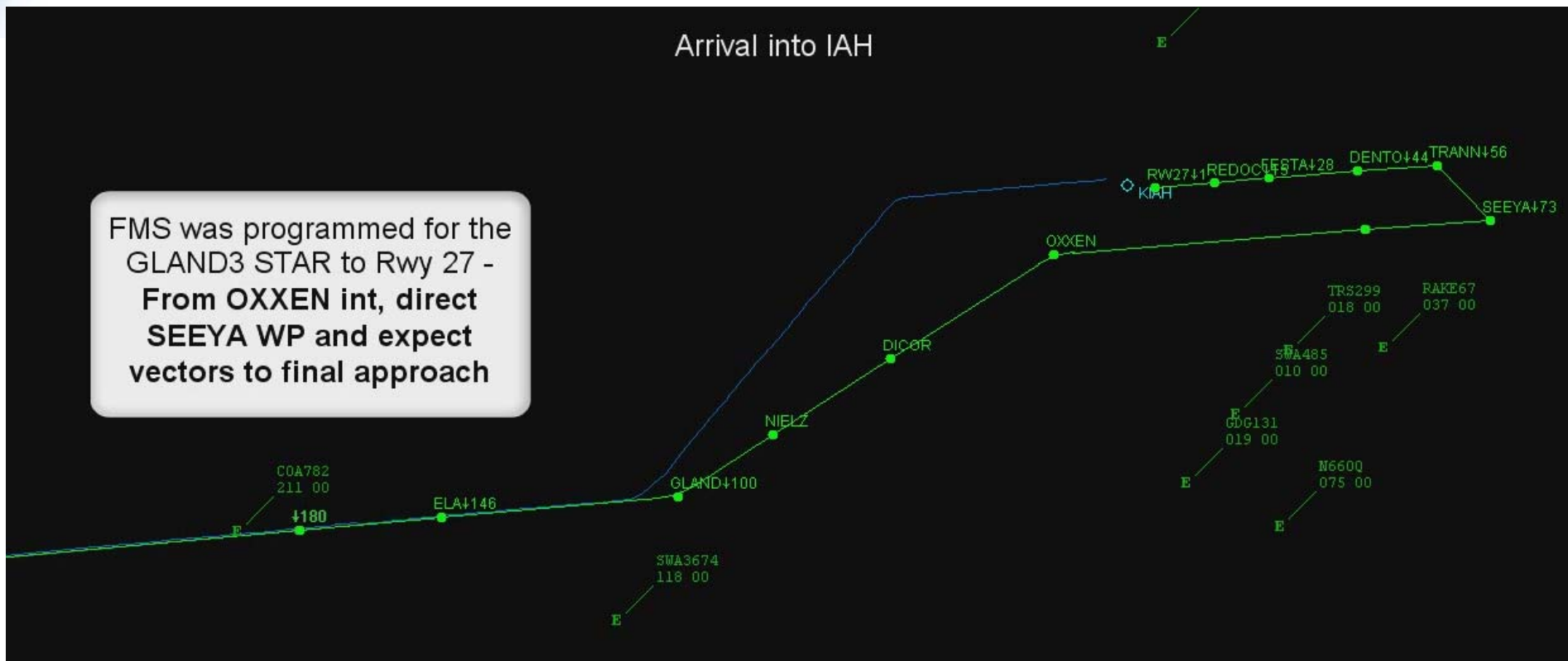
Full Screen Custom Dir



Runway Change

Arrival into IAH

FMS was programmed for the GLAND3 STAR to Rwy 27 -
From OXXEN int, direct
SEEYA WP and expect
vectors to final approach





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