Analysis of AIRE Continuous Descent Arrival Operations at Atlanta and Miami

JPDO EWG Ops SC Meeting

Georgia Tech, Nov 17-18, 2008

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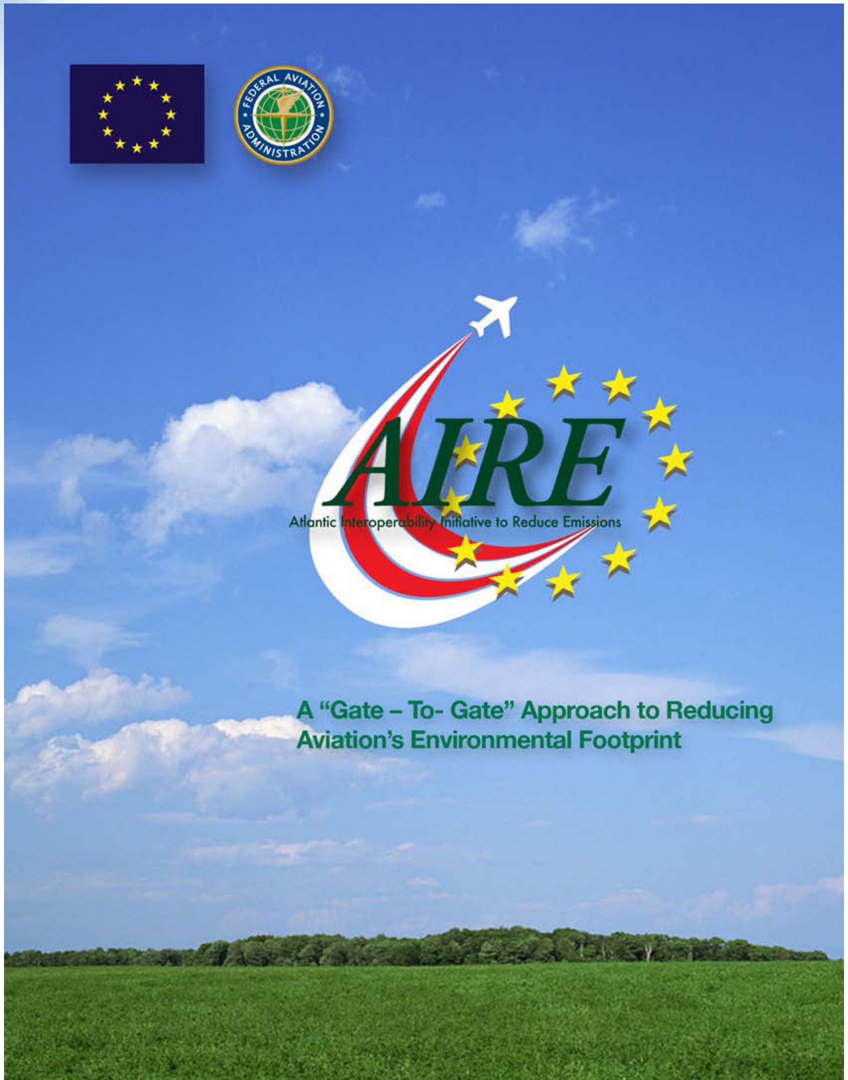
F083-B08-101

Overview

- AIRE Background
- FY08 AIRE CDA/OPD Activities
  - FY08 AIRE CDA/OPD Demonstration Recap
  - Benefit Analysis of AIRE CDA Demonstration Flights
  - AIRE CDA Human-In-The-Loop (HITL) Simulations
  - AIRE CDA Airspace and Airport Impacts
- Future Plans

AIRE Background



- Atlantic Interoperability Initiative to Reduce Emissions (AIRE)
- Reduce aviation’s environmental footprint via environmentally friendly procedures
- Not inventing new technologies
- All flight segments (gate-to-gate)
  - Surface
  - Oceanic
  - Arrival
    - CDA/OPD
    - Tailored Arrivals
- FY08 AIRE program goals
  - Coordinate operational demonstrations
  - Validate environmental improvements

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FY08 AIRE CDA/OPD Demonstration Recap

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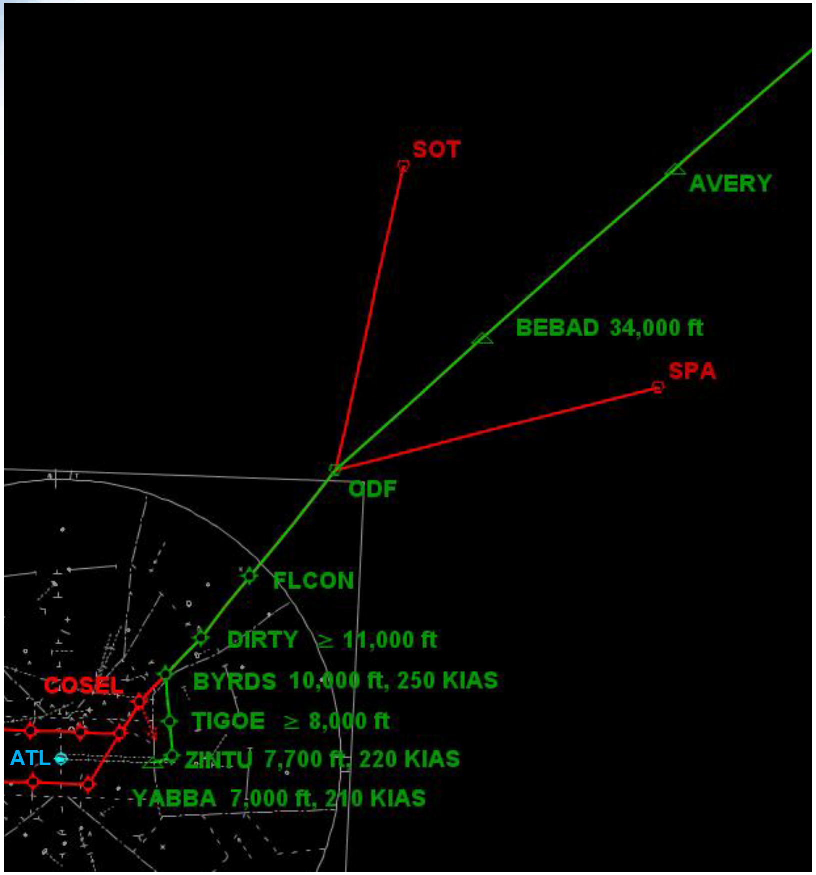
AIRE OPD Procedure Development

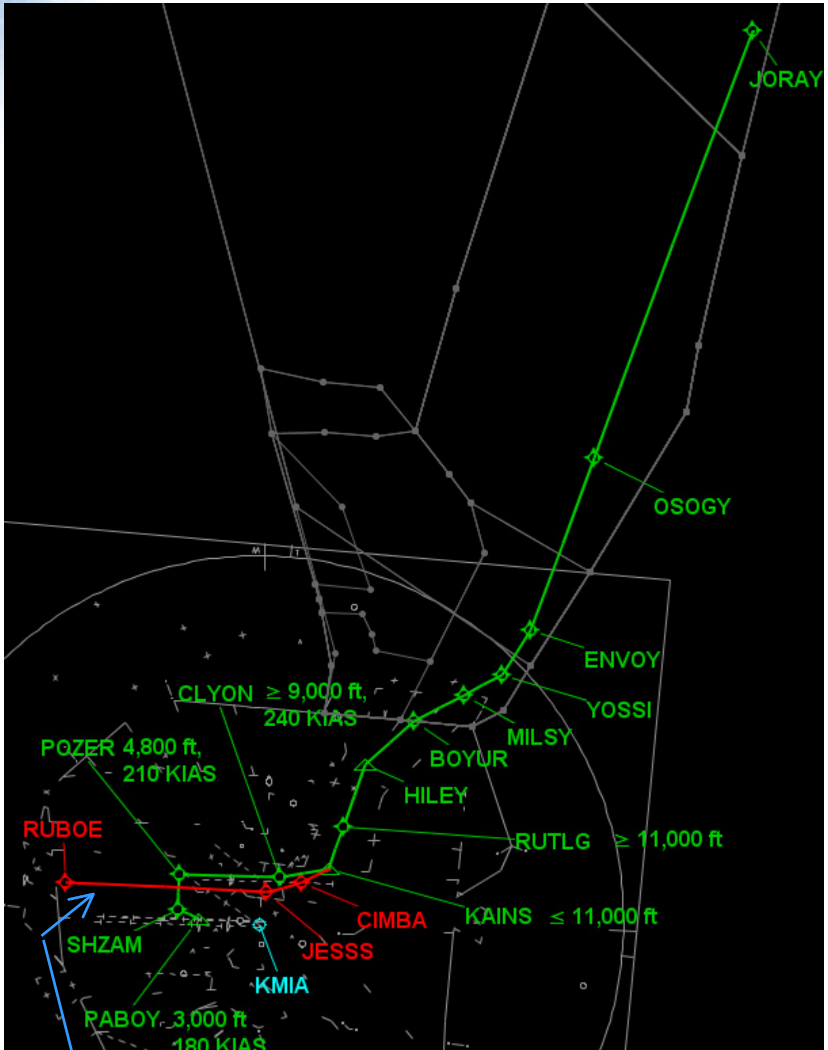
DIRTY (OPD) Compared To FLCON (Non-OPD)



DIRTY	Waypoint		FLCON
	MOL		
	JOINN		
	AVERY		
34,000 ft	BEBAD		Expect to cross at 34,000 ft
	ODF		
	FLCON		
≥ 11,000 ft	DIRTY		Typically cross at 13,000
10,000 ft, 250 KIAS	BYRDS		
≥ 8,000 ft	TIGOE	COSEL	250 KIAS
7,700 ft, 220 KIAS	ZINTU	---	Landing West: Expect radar vectors to final approach course
7,000 ft, 210 KIAS	YABBA	---	
DIRTY		FLCON	

AIRE OPD Procedure Development

RUTLG (OPD) Compared To HILEY (Non-OPD)



HILEY downwind

RUTLG	Waypoint		HILEY
	JORAY		Typically at cruise altitude and given a descent to FL360
	OSOGY		Typically told to cross at FL240
	ENVOY		
	YOSSI		
	MILSY		Expect 16,000 ft, 250 kts
	BOYUR		Descended to 10,000 ft once in TRACON airspace
	HILEY		
≥ 11,000 ft	RUTLG		Descended to 8000 ft abeam Ft. Lauderdale Airport
≤ 11,000 ft	KAINS		
≥ 9000 ft, 240 KIAS	CLYON	CIMBA	
4800 ft, 210 KIAS	POZER	JESSS	Descended to 3000 ft abeam Miami Airport
	SHZAM	RUBOE	
3000 ft, 180 KIAS	PABOY	-	
RUTLG		HILEY	

FL – Flight Level
kts - knots

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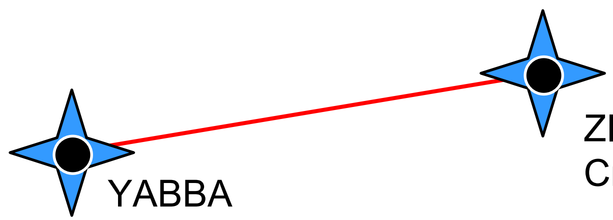
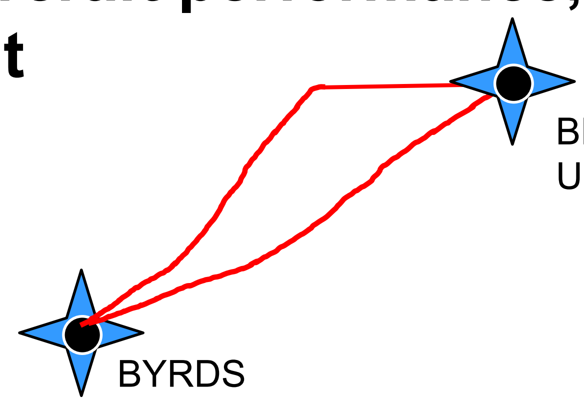
FMS VNAV Path Construction

- **Geometric Path – a constant angle glide path driven by hard-altitude constrained waypoints**

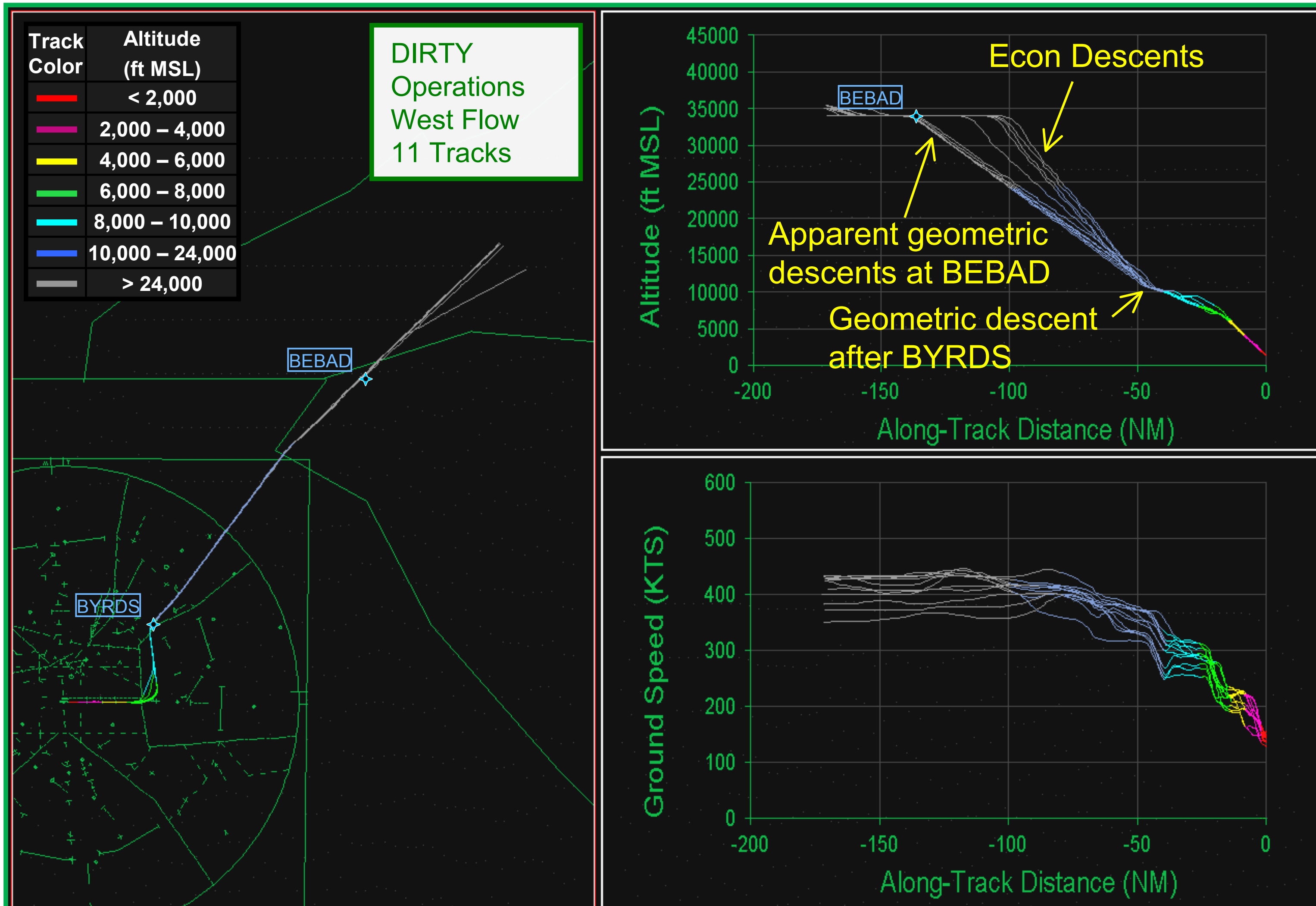


- **Econ, or Performance, Path – an idle-throttle path driven by aircraft performance, flight parameters, and environment**



AIRE CDA Demonstration Flights

Atlanta DIRTY Radar Tracks



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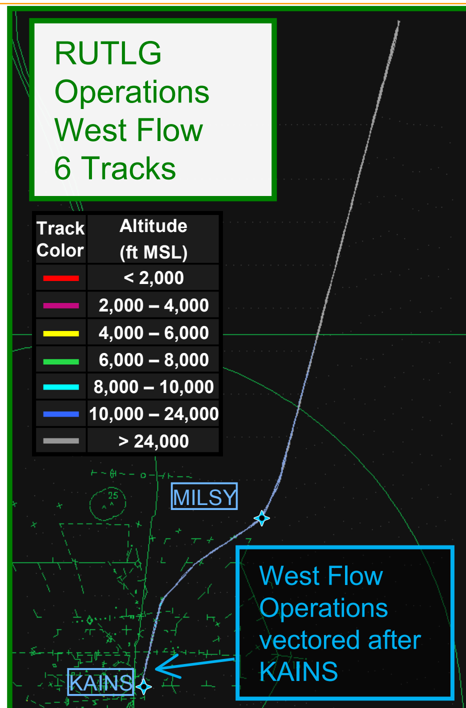
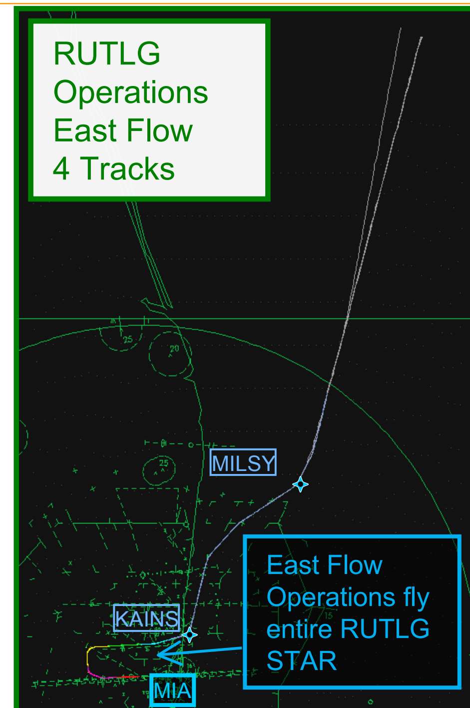
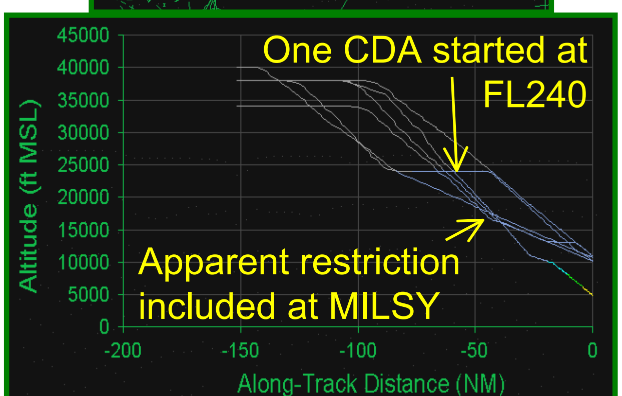
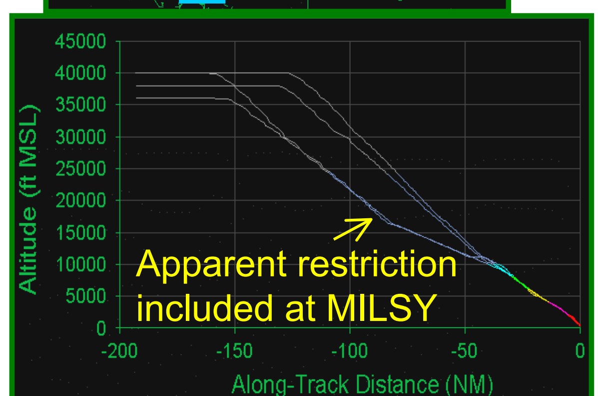
AIRE CDA Demonstration Flights
Miami RUTLG Radar Tracks









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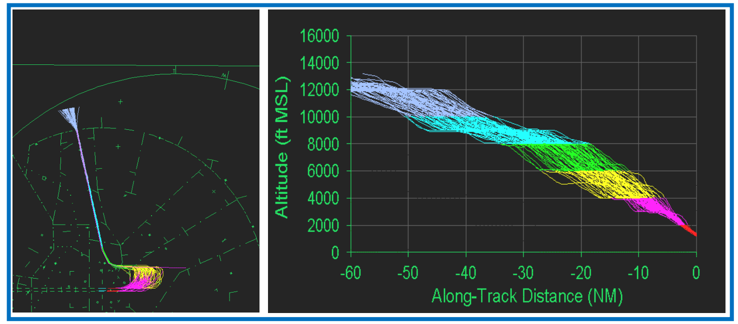
Benefit Analysis of CDA Demonstration Flights

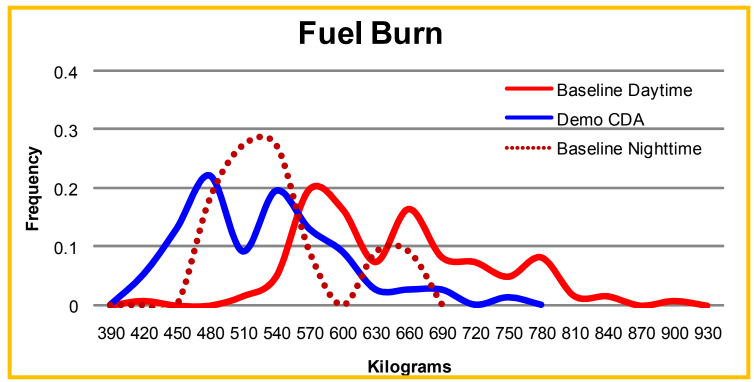
Fuel and Emissions Modeling Process

Aircraft Trajectories



Apply BADA

Computed Fuel Burn



Apply Emissions Model

Computed Emissions

$EI(CO_2) = 3155$ g/kg

$EI(H_2O) = 1237$ g/kg

$EI(SO_x) = 0.8$ g/kg

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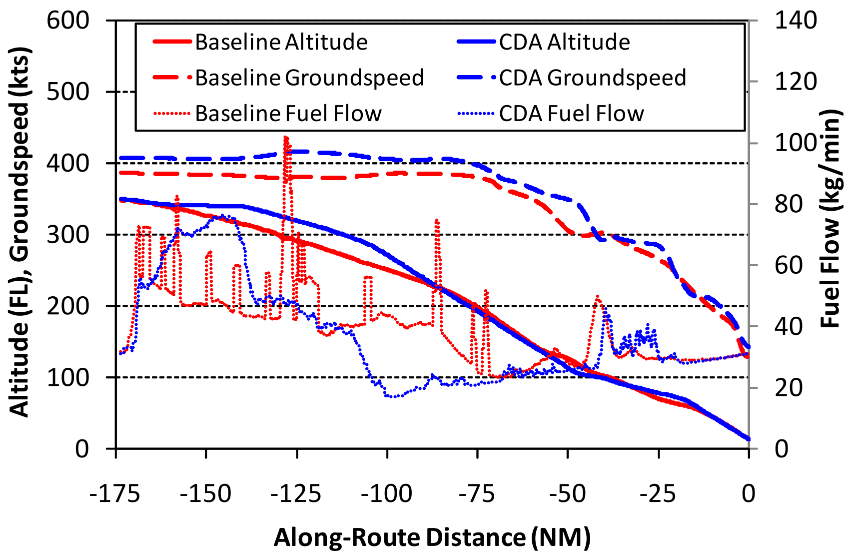
Atlanta CDA Benefits Analysis Results

Metric	Baseline Average Per Flight	Average CDA Difference from Baseline
Fuel Burn (gal)	393	-38 (-10%)
CO_2 emissions (kg)	3780	-360 (-10%)
Time Flown (min)	31.5	- 0.8 (-3%)



- Estimated fuel burn reductions of 38 gallons per flight
- Estimated CO_2 emissions reductions of 360 kilograms per flight
- Observed time savings of 0.8 minutes per flight
  - Consistent with higher average groundspeeds for CDA flights

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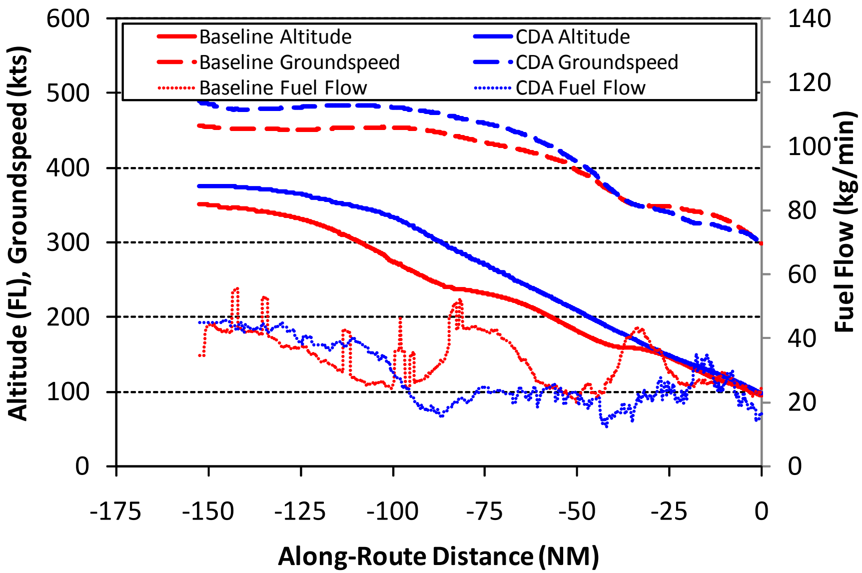
Miami CDA Benefits Analysis Results

West Flow

Metric	Baseline Average per Flight	Average CDA Difference from Baseline per Flight
Fuel Burn (gal)	233	- 48 (-21%)
CO_2 emissions (kg)	2241	- 460 (-21%)
Time Flown (min)	22.7	- 0.75 (-3%)



- **Estimated fuel burn reduction of 48 gallons per flight**
- **Estimated CO_2 emissions reductions of 460 kilograms per flight**
- **Fuel efficiency gains are most noticeable where baseline flights level off at FL240 and 16000 ft MSL**

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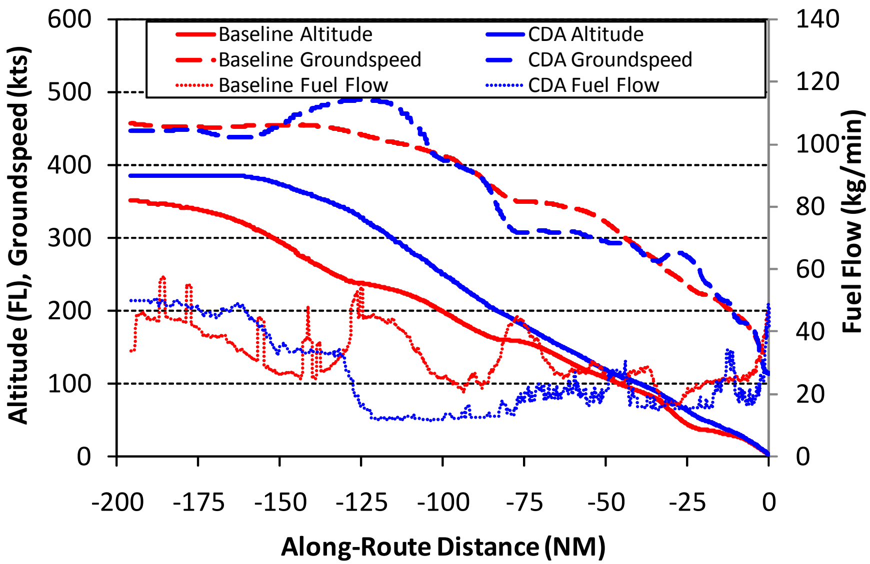
Miami CDA Benefits Analysis Results
East Flow

Metric	Baseline Average	Average CDA Difference from Baseline
Fuel Burn (gal)	324	- 52 (-16%)
CO_2 emissions (kg)	3121	-497 (-16%)
Time Flown (min)	31.6	+ 2.4 (+8%)



- **Estimated fuel burn reduction of 52 gallons per flight**
- **Estimated CO_2 emissions reductions of 497 kilograms per flight**
- **Observed flight time increase of 2.4 min/flight**
  - **Consistent with increased route distance on the RUTLG in the terminal area**
- **Fuel efficiency gains are most noticeable where baseline flights level off at FL240 and 16000 ft MSL**

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Human-In-The-Loop (HITL) Simulations

HITL Recap

- Miami HITL simulations occurred at ZMA the week of July 14th, 2008
  - Two scenarios involving the RUTLG OPD
  - ZMA and MIA TRACON participation
- Atlanta HITL simulations occurred at ZTL the week of October 27th, 2008
  - Four scenarios involving the DIRTY OPD as well as CDA operations from SOT and SPA
  - ZTL and A80 TRACON participation

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HITL Objectives

- **Identify issues and possible mitigation strategies for performing CDA flights during peak traffic operations**
  - **Identify factors involved in deciding which aircraft could be cleared to the CDA**
  - **Investigate impact of CDA on surrounding traffic**
    - Under what circumstances must the CDA be discontinued?
    - Identify methods for mitigating these impacts
  - **Increase understanding of necessary inter-facility communications**

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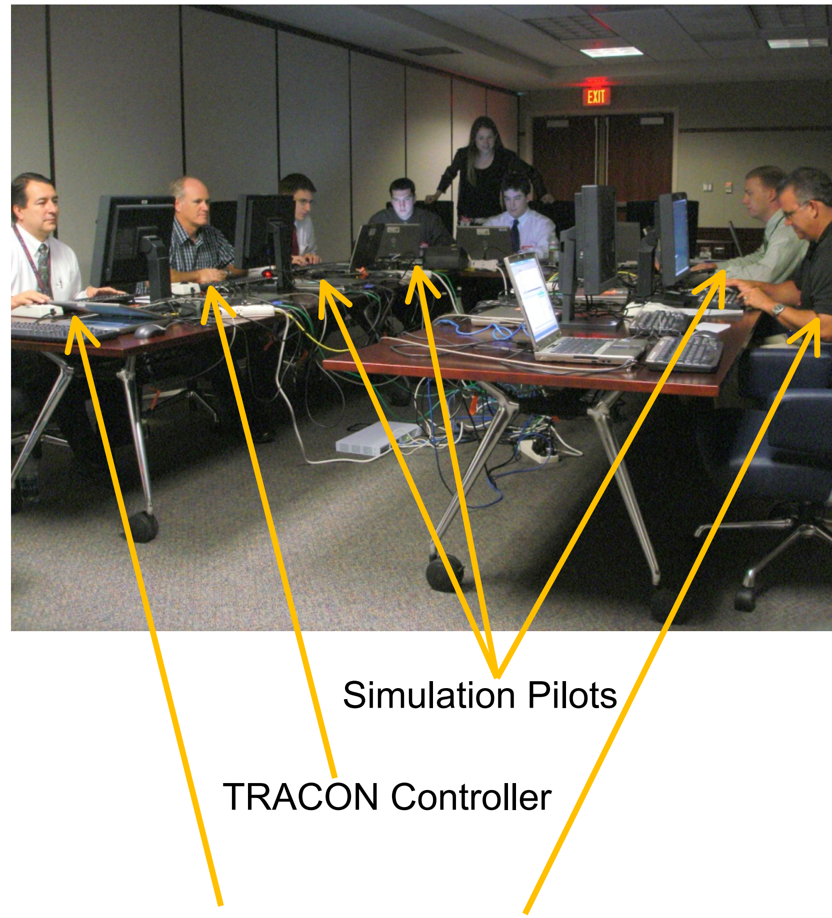
HITL Simulation Setup
TARGETS HITL Platform

- **Controllers worked the simulated traffic at a radar situation display in MITRE's TARGETS platform**
  - **2 views (en route and TRACON), with look and feel similar to HOST and STARS**
- **Aircraft were flown by "simulation pilots"**
  - **Entered controller commands into a pilot interface**



Miami HITL Scenarios

Identification of Peak Traffic CDA Issues

- **First Miami scenario**
  - **RUTLG STAR as published**
  - **Peak traffic operations**
  - **Identify operational issues**
- **The primary issues identified by the ZMA participants included:**
  - **Crossing traffic through the CDA descent area**
  - **Departures from Palm Beach (PBI) and Orlando (MCO)**
  - **Additional point-outs to other sectors**

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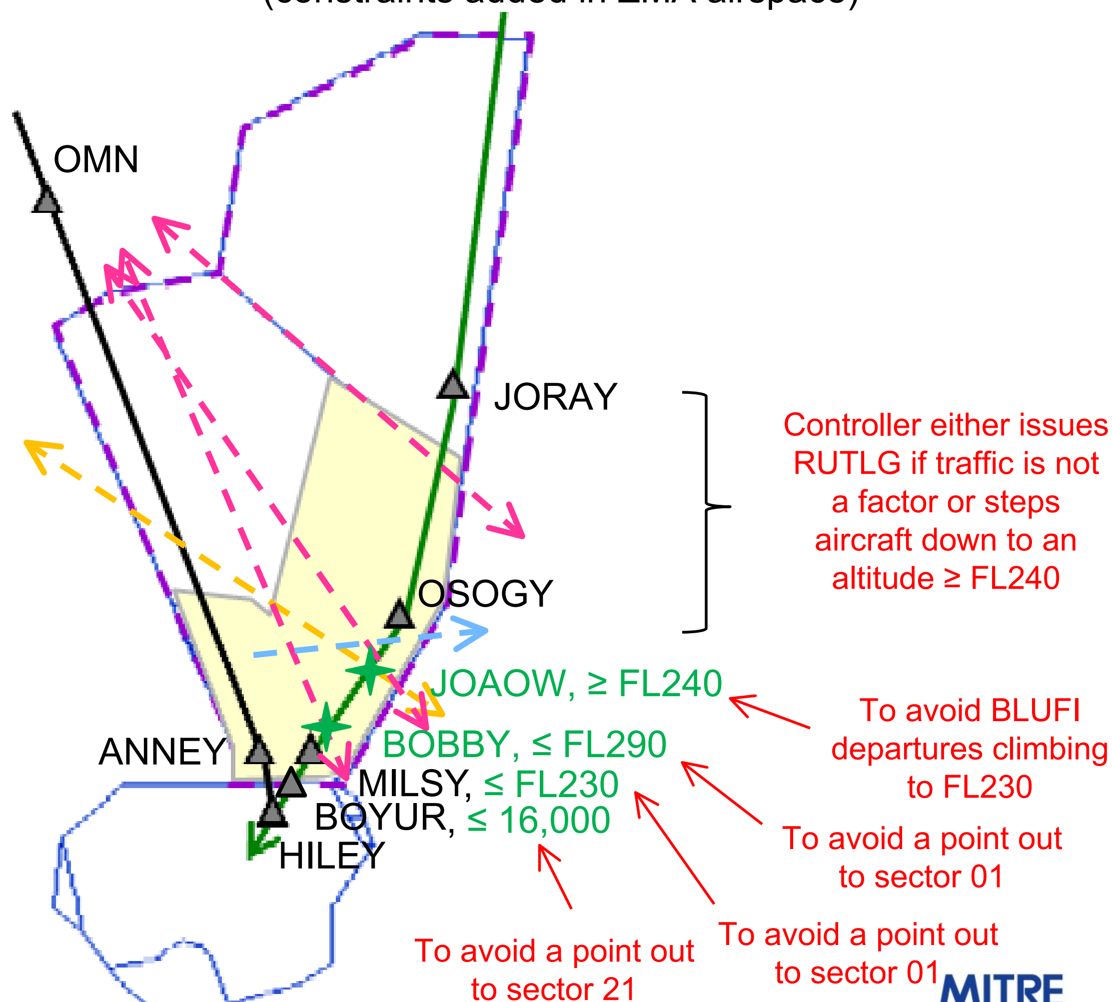
RUTLG
HILEY (western leg)

ATL to/from Mexico/Caribbean (northbound FL370 and above, southbound FL340, FL360, FL380)
MCO to Mexico/Caribbean (generally vectored to avoid and get above the FLL and MIA flows at FL240)
PBI departures climbing to FL230

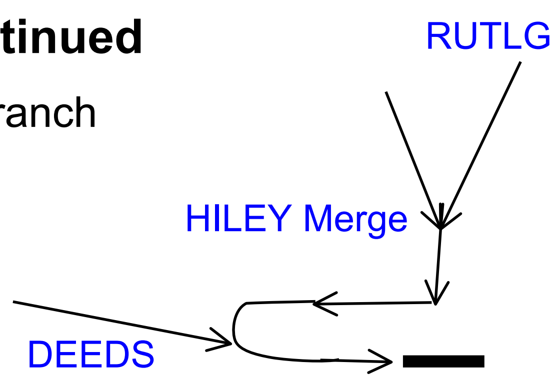
Second Miami HITL scenario incorporated modifications to the RUTLG procedure to mitigate the issues mentioned above

Proposed Modified CDA Route: RUTLG2
(constraints added in ZMA airspace)



MIA HITL Feedback
CDA Workability

- **Center Perspective**
  - **New restriction at JOAOW really helped with PBI/BLUFI departures**
  - **Ensuring no point-outs along the CDA path is critical**
- **TRACON Perspective**
  - **CDAs to the downwind are doable almost every time provided there is not a tie at HILEY**
  - **Potential issues that may cause CDA to be discontinued**
    - Ties at HILEY with MIA arrivals coming down the west branch
    - Final merge with the "straight-in" DEEDS arrivals
  - **Possible resolutions**
    - A merging tool may be useful to aid the controller
    - Exposure and familiarity
    - Move DEEDS arrivals to south runway if available



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MIA HITL Feedback
Coordination Issues

- **Electronic Coordination**
  - Scratch pad was used to identify the CDA flights in the simulation
  - The controllers agreed it would be best if there was some sort of electronic coordination
- **Advanced Coordination**
  - The TRACON controller will likely need "advanced coordination" for the CDA flights
- **Workload**
  - Participants noted that it is important that the coordination does not require too much workload since that can lead to operational errors

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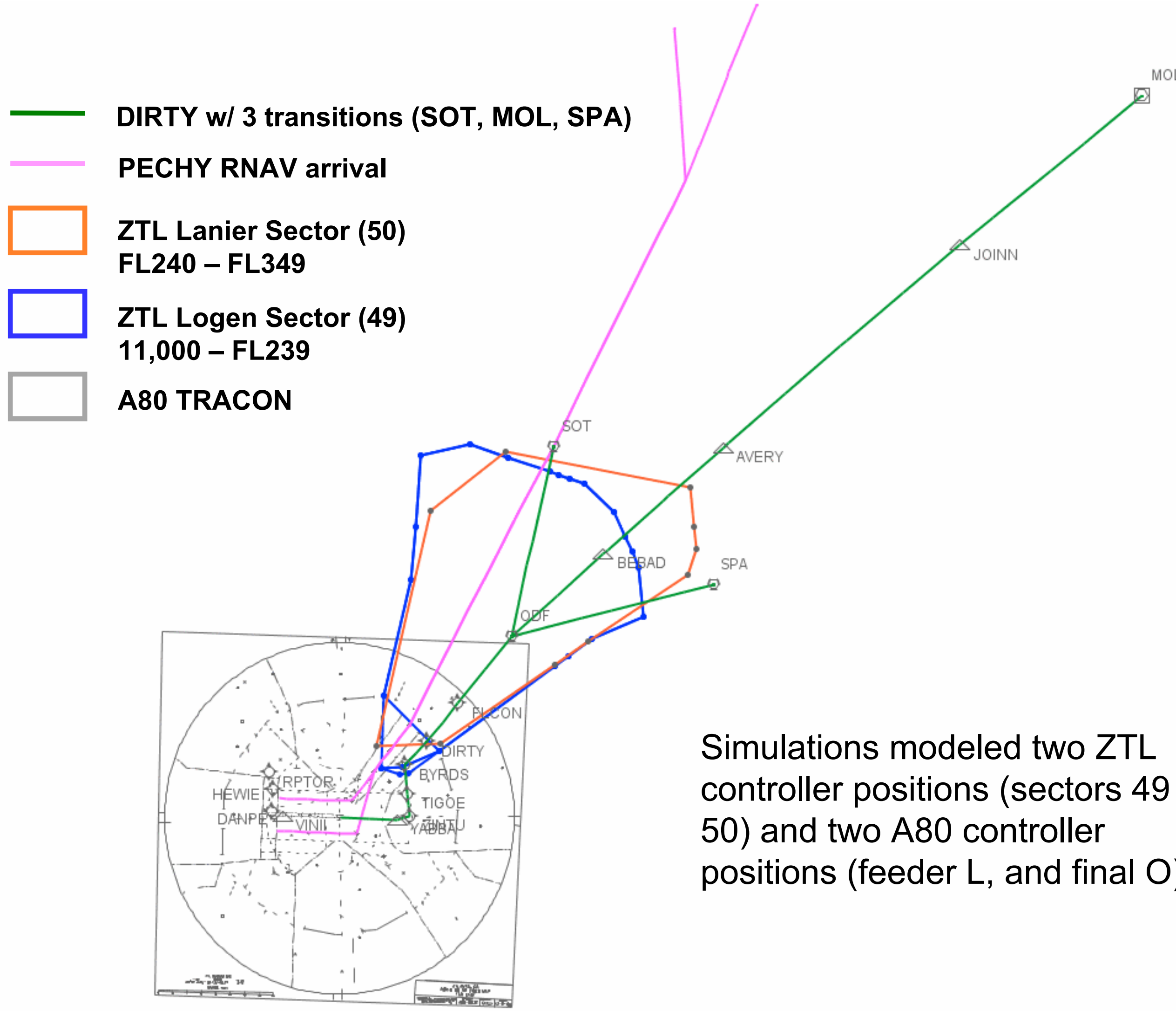
ATL HITL Simulation Setup

Modeled Airspace



Simulations modeled two ZTL controller positions (sectors 49 & 50) and two A80 controller positions (feeder L, and final O)

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Summary of Observations

OPD Workability

- **Uncertainty of aircraft performance made the operation more difficult to manage**
- **In moderate to low traffic levels, controllers felt OPD operations were feasible, safe, and orderly, but not always expeditious due to some reduction in efficiency**
- **Controllers felt OPD operations during the busiest traffic periods would not be feasible at ATL – too much efficiency would be lost**
- **A form of electronic coordination is needed between Center and TRACON to manage OPD flights**
- **Controllers needed to retain the ability to shortcut flights direct to DIRTY for airspace flexibility (illustrated on following slide)**

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OPD Issues Identified During Simulation

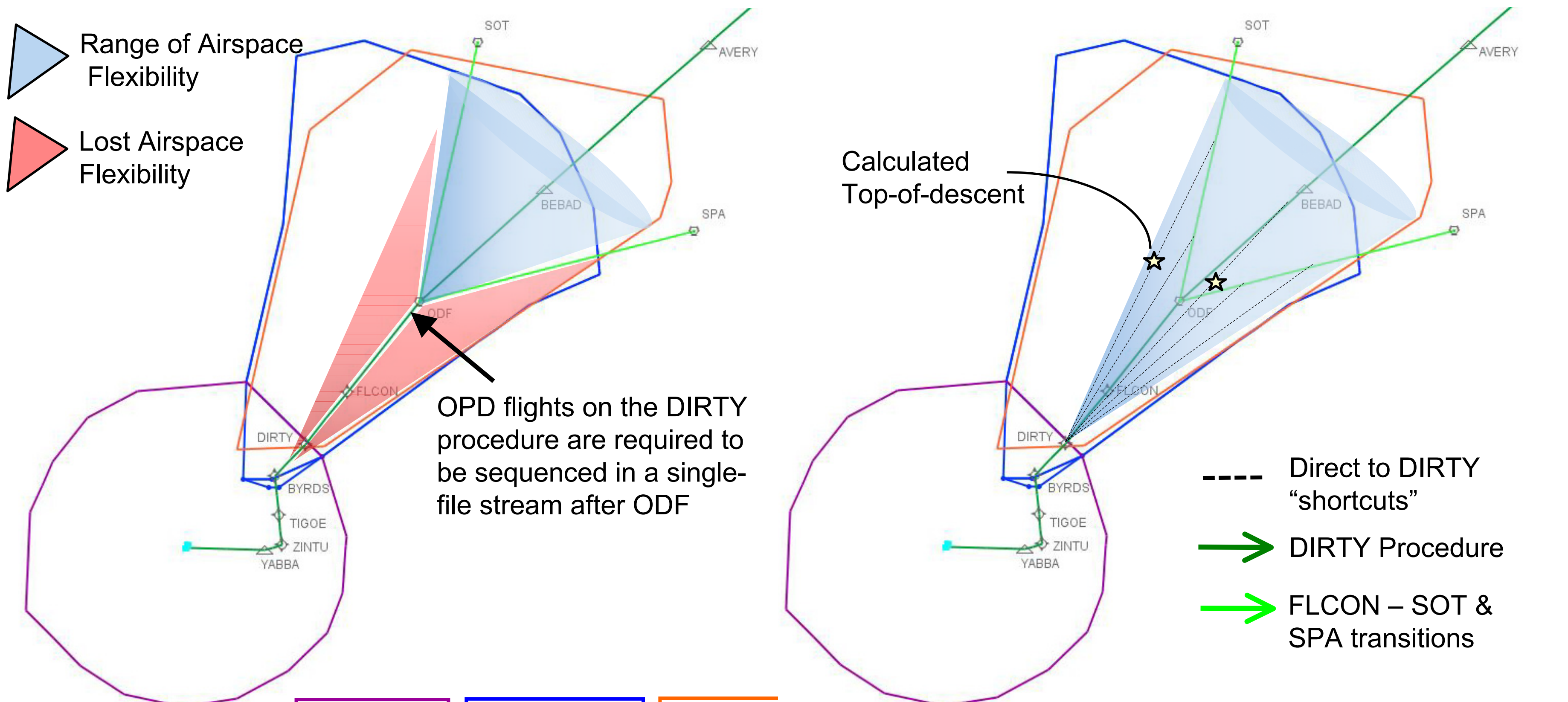
Merging and Spacing in ZTL - Lost Flexibility

Issue:

In today's operations, Logen sector and Lanier sector controllers issue flights a "direct to DIRTY" clearance as a method to improve efficiency, shorten flight paths, and set up appropriate sequencing for the handoff to the TRACON (at DIRTY). The DIRTY procedure, as designed, requires flights to begin a single-file stream at ODF. The amount of airspace that controllers have to work with is essentially reduced when the "funnel" is moved back to ODF.

Resolution:

If flights could be given "direct to DIRTY", then cleared for the OPD (either at cruise or a lower altitude like FL240), airspace flexibility would be retained with the "funnel" shifting back to DIRTY. Flights could still fly an OPD (from ToD to DIRTY, then as designed), since there are no intermediate restrictions until DIRTY ≥ 11,000 ft.



A80 0-11,000	Logen (49) 11,000-FL239	Lanier (50) FL240-FL349

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Summary of Observations

OPD Workability (concluded)

- **Assigning a speed profile for each aircraft to fly the OPD procedure would likely help with spacing and separation**
  - **(Ex. "AAL101 descend via the DIRTY, with a 310kt profile")**
- **Merges in the TRACON can be problematic for OPD operations, particularly if ZTL has offloaded many flights to the PECHY arrival**
  - **Explore the use of controller tools to assist with merging and sequencing**
- **Having the lower en route sector (Logen) issue the OPD clearance instead of the high sector (Lanier) seemed to improve workability**
  - **Lanier was able to use early speed control to begin setting up OPD sequencing prior to the OPD clearance from Logen**
  - **Crossing traffic had less impact on the ability to issue OPD clearances to aircraft**
  - **Lanier was no longer concerned about airspace violations from an OPD aircraft descending into Logen's airspace prior to handoff**

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Airspace and Airport Impacts

Impacts of CDA on En Route and Terminal Operations

- **Unique characteristics of aircraft conducting CDA impact sector operations**
  - Once aircraft are executing a CDA, altitudes below are typically not usable by other aircraft
  - Little to no intervention once CDA begins
- **Airspace impacts can result from**
  - Sector geometries
  - Traffic flows in sector
  - Top-of-descent location
  - Delivery options to TRACON

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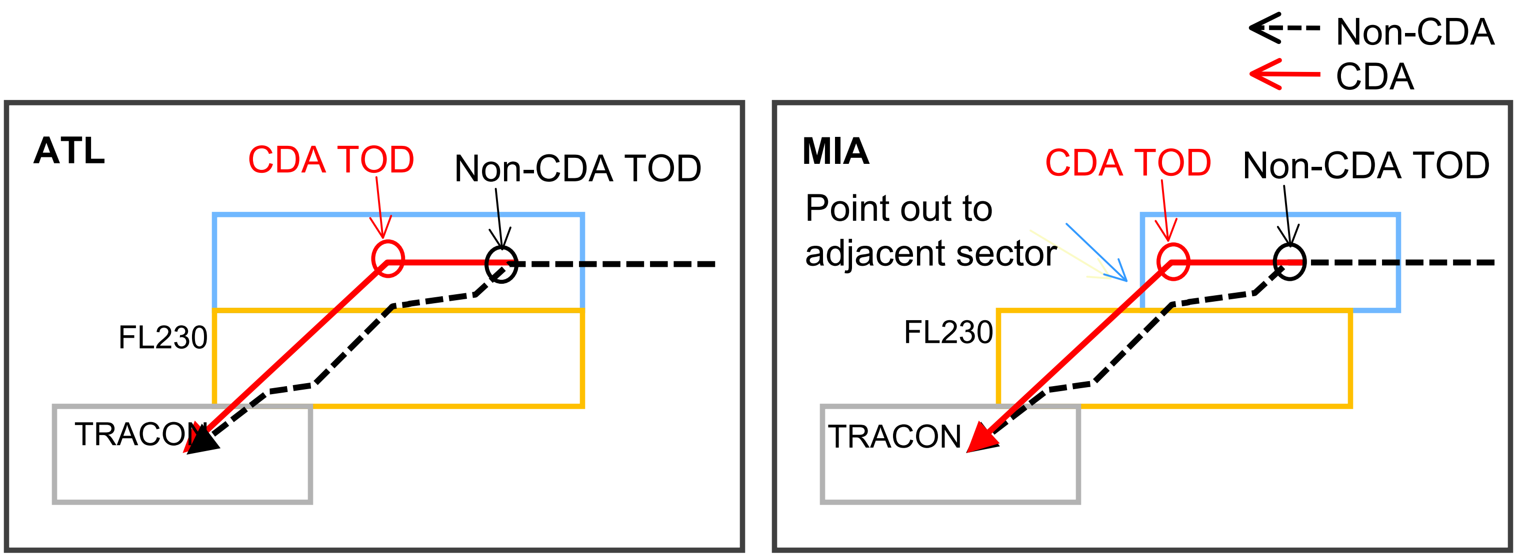
Sector Geometries

- **ATL sector geometry allows TOD to occur closer to the airport**
- **MIA sector geometry generates point-outs to adjacent sector**

Resulted in a modified HITL CDA flight profile



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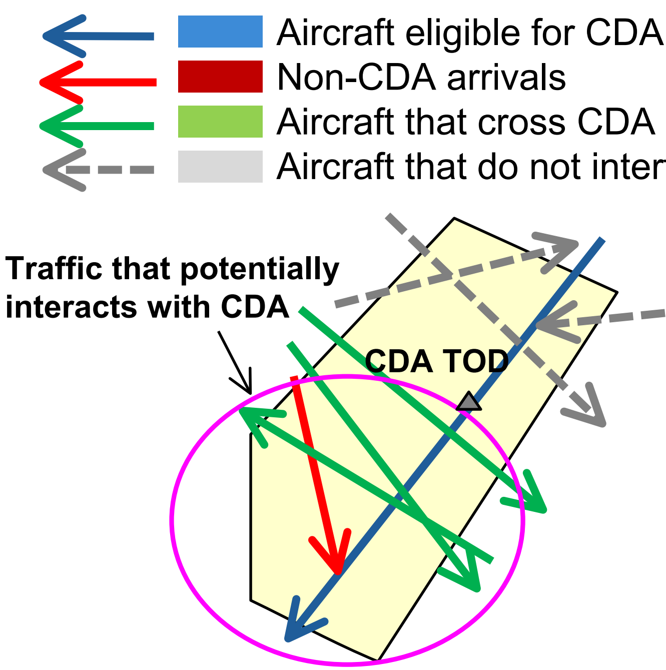
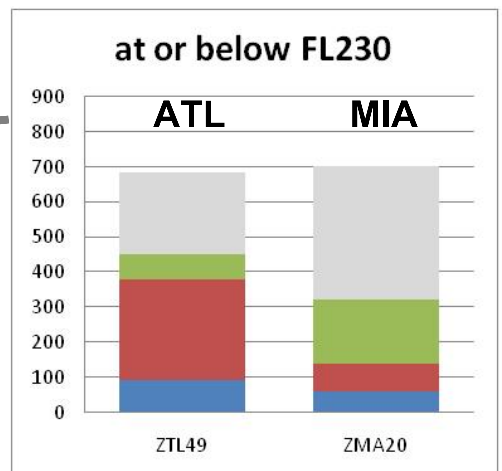
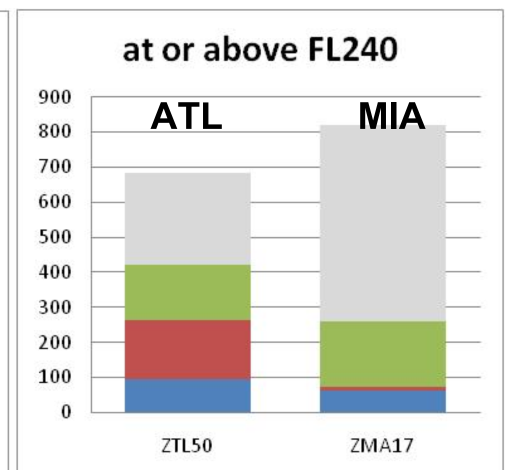
Traffic Flows in Sector

- **Number of aircraft that potentially interact with CDA aircraft were counted on a sample day***
  - **ATL sectors have higher ratio of merging traffic**
  - **MIA sectors have higher ratio of crossing traffic**

Identified during HITL simulation and resulted in proposal for modifying CDA flight profile





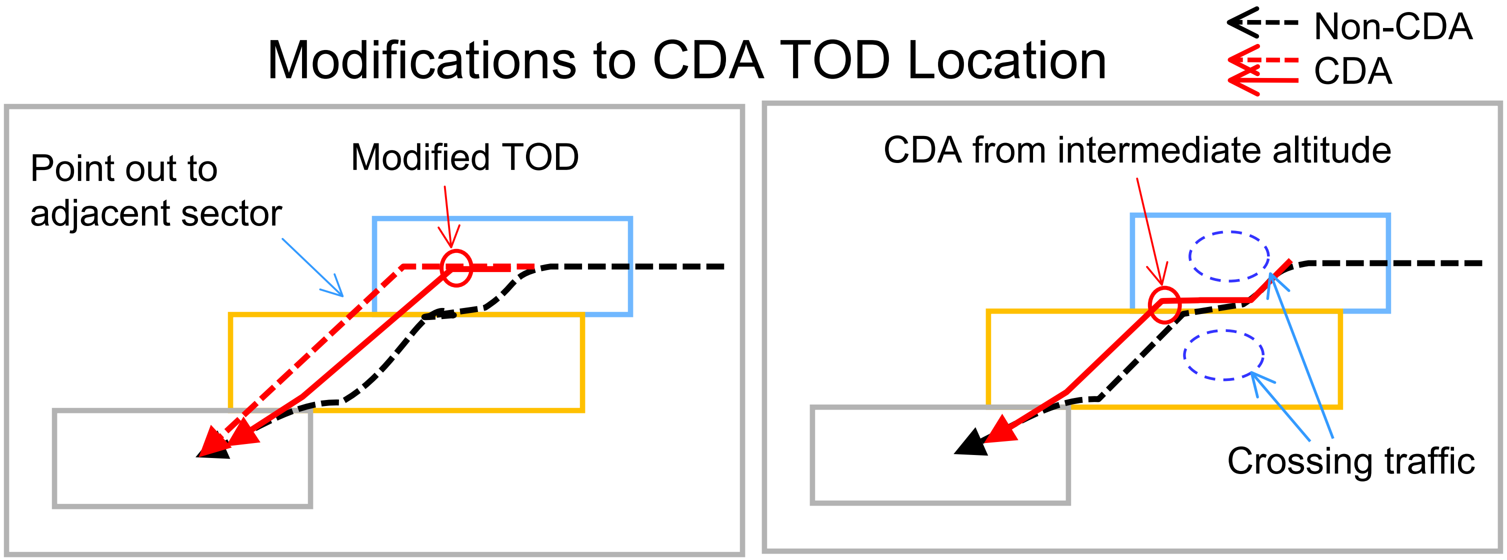


* Based on the route of flight , using ETMS track data on March 13, 2008 for MIA, July 12, 2007 for ATL

Top-of-Descent Location

- TOD location may need to be explicitly specified depending on sector geometries and sector traffic
- This may result in a less than fuel-optimal TOD point
- Various CDA TOD locations impact sector differently

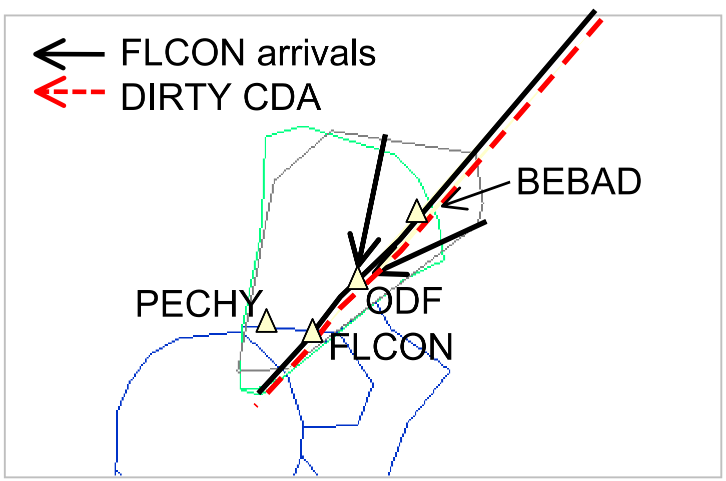
Modifications to CDA TOD Location



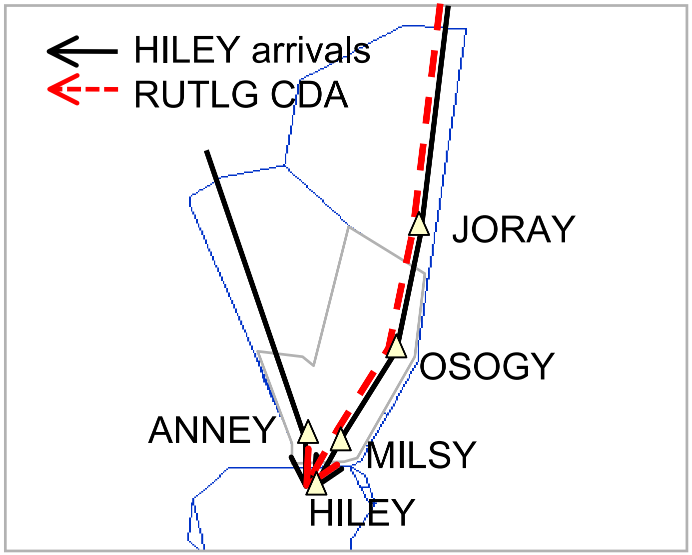
Comparison of CDA Delivery Options to TRACON

ATL and MIA

- **ATL arrivals are in-trail when handed off to TRACON**
- **PECHY is available for offloading traffic in order to provide additional spacing for CDA**



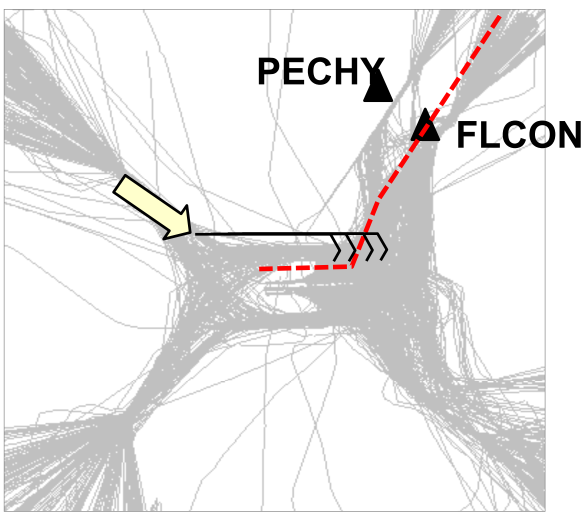
- **MIA arrival flows (ANNEY and MILSY) are delivered at different altitudes**
- **TRACON is required to merge and sequence**



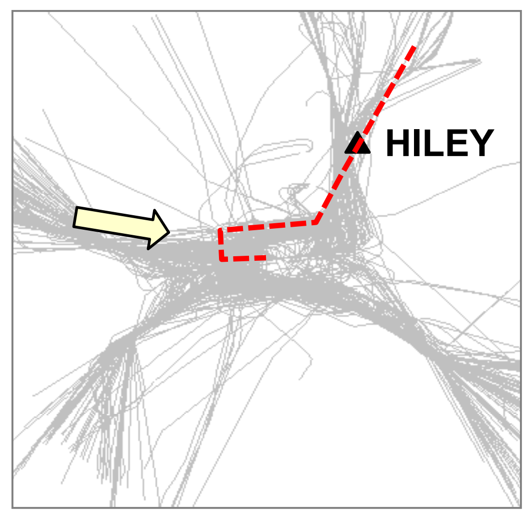
Comparison of CDA Delivery Options to TRACON

ATL and MIA

- **ATL OPD is designed to land from the base leg**
- **Merging traffic from west has an option to fly a longer/shorter downwind to facilitate merge**
- **MIA OPD is designed with a downwind leg**
- **Limited vectoring area for arrivals from west to merge with RUTLG arrivals**



ETMS track data of arrivals to ATL 07/12/07



ETMS track data of arrivals to MIA 03/13/08

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Conclusions

- AIRE CDA benefits demonstrated at ATL and MIA
  - ATL: Estimated fuel burn reductions of approximately 38 gallons per flight, CO_2 reductions of approximately 360 kg per flight
  - MIA: Estimated fuel burn reductions of approximately 48-52 gallons per flight, CO_2 reductions of approximately 460-500 kg per flight
- Operational CDA impacts identified through HITLs at ATL and MIA
  - Crossing traffic
  - Departure traffic
  - Sector point-outs
  - Inter-facility coordination
- Airspace and airport impacts of CDA
  - Sector geometries
  - Traffic flows in sector
  - CDA top-of-descent location

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CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT

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Backup Slides

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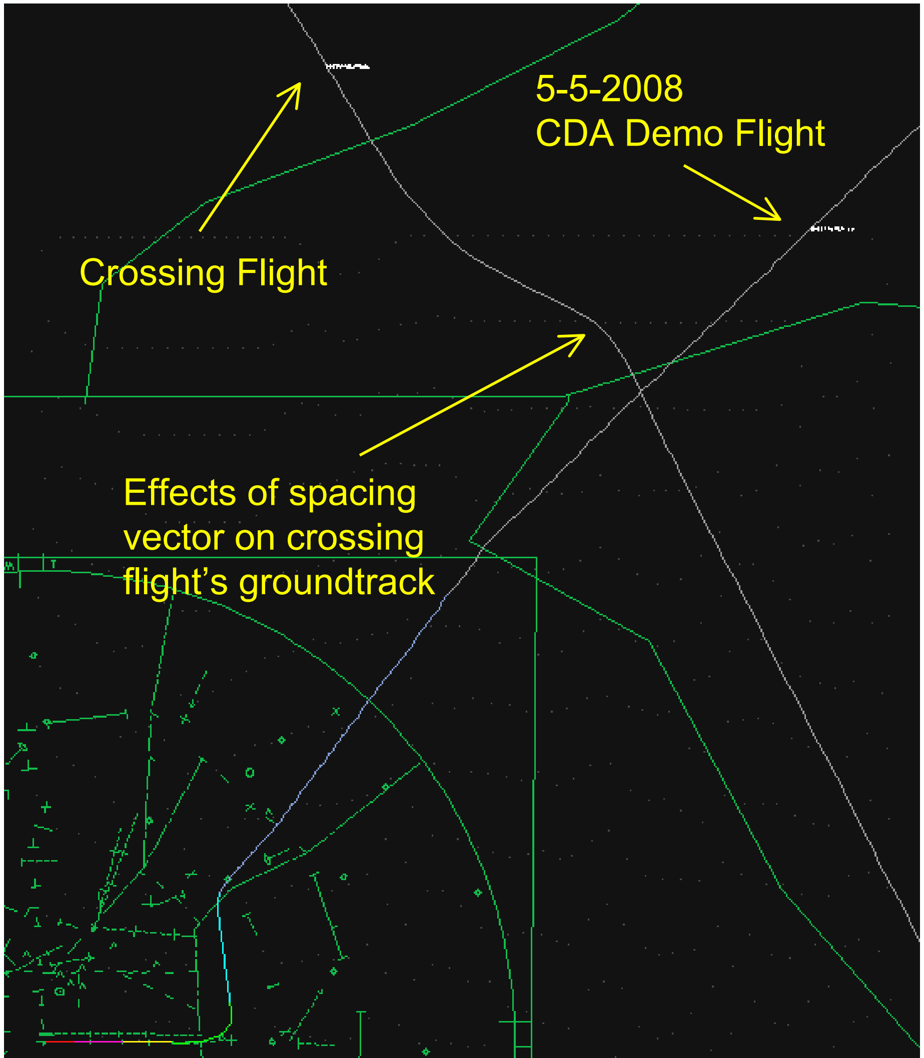
Atlanta Analysis Results
Examples of CDA Impacts on Other Traffic



- **Crossing flight was anticipated to conflict with CDA aircraft and was vectored**
- **Spacing vector increased distance flown by ~3.2 NM**
- **Approximately 12 additional gallons of fuel was burned by the crossing flight to accommodate the CDA**

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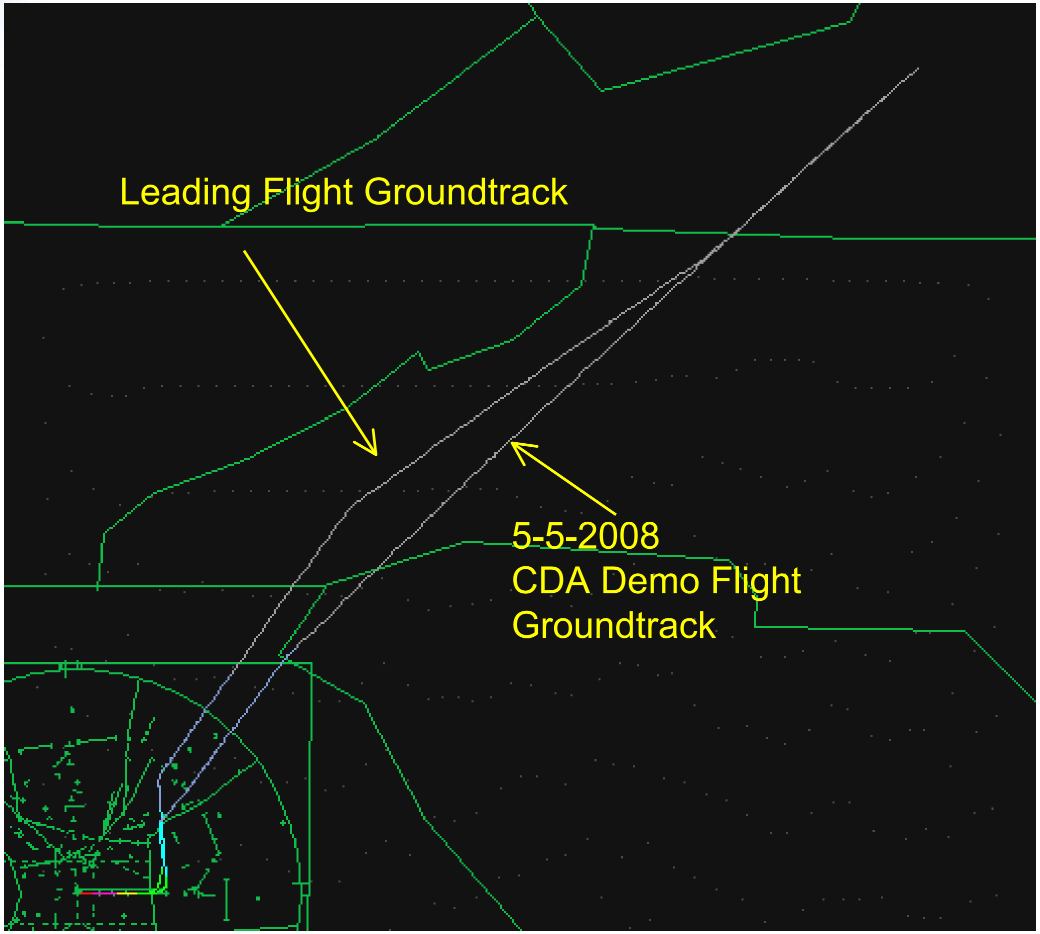
Atlanta Analysis Results

Examples of CDA Impacts on Other Traffic



- **Leading flight aircraft was cruising in front of the trailing CDA aircraft**
- **Leading flight was offloaded to PECHY RNAV STAR in order to make room for (presumably faster) CDA**
- **Leading flight flew an additional 8 NM as a result**

Benefit Analysis Methodology

Data Source

- **Pre- and post-demonstration benefits analysis conducted using historical recorded radar tracks of ATL and MIA arrival traffic**
- **Recorded radar track data provided by the FAA Air Traffic Airspace Laboratory (ATALAB)**
  - **Provides position, speed, and time information**
- **Uncompressed data from terminal automation (Automated Radar Tracking System (ARTS) or Standard Terminal Automation Replacement System (STARS)) as well as en route host automation (HOST)**
  - **Uncompressed data provided directly by ATALAB**
    - Each track is recorded by a single sensor (e.g., the primary terminal sensor)
    - 4.66 second update rate on terminal targets; 12 second update on en route targets
    - Decimal time values
    - Groundspeed data provided by automation
    - This is the standard data CAASD uses in RNAV operational evaluations

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Benefit Analysis Methodology

Data Collection and Analysis Considerations

- **Baseline data collection assumptions and methodology**
  - **Multiple days of baseline recorded radar track data collected for each airport**
    - **ATL Baseline Days – 2007: October 10, 11, 12. 2008 : January 14, 15, 20**
    - **MIA: 2007*:* October 22, 27, 28, November 4, 6, 11, 17, 28, 29, 30, December 1. 2008*:* January 5, 6, 7, 8, 9**
  - **All recorded baseline radar track data were collected while the respective airports were in Visual Meteorological Conditions (VMC)**
  - **Selected days of baseline recorded radar track data where the respective arrival airport remained in the appropriate CDA runway configuration throughout the day**
  - **Collected days of baseline recorded radar track data where a typical level of arrival traffic was observed**
  - **Turbojet aircraft only selected for analysis**
  - **Aircraft associated with the appropriate non-CDA arrival procedure selected for analysis**
  - **Tracks with significant data anomalies are not considered in the analysis**
- **Analysis assumptions and notes**
  - **Wind data was not considered in the analysis; winds may impact observed groundspeed values**
- **Fuel flow and emissions modeling notes**
  - **Fuel flow is modeled, based on Eurocontrol's Base of Aircraft Data (BADA)***
  - **Emission results are computed as a linear function of estimated fuel burn****

* Eurocontrol, 2004, Base of Aircraft Data (BADA 3.5), The EUROCONTROL Experimental Centre, Brétigny, France. http://www.eurocontrol.fr/projects/bada
** Sutkus, Donald J., et al., 2001, Scheduled Civil Aircraft Emission Inventories for 1999: Database Development and Analysis, NASA Contractor Report-2001-211216, National Aeronautics and Space Administration, Washington, DC.

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Benefit Analysis Methodology

Analysis Tools and Methods

- **Analysis Platform: integrated Terminal Research, Analysis, and Evaluation Capabilities (iTRAEC)***
  - **The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) analysis capability written in Simulation Language with eXtensibility (SLX)**
- **Simulation, operational analysis, and visualization capabilities**
  - **Operational Analysis**
    - Reading, processing, and metrics analysis (e.g., time in level flight, track length) of recorded radar track data
    - Visualization and animation of operations
    - Fuel and emissions modeling based on recorded radar tracks

* Mayer, Ralf H., "Estimating Operational Benefits of Aircraft Navigation and Air Traffic Control Procedures Using an Integrated Aviation Modeling and Evaluation Platform", Conference Proceedings, Winter Simulation Conference, Monterey, CA, December 2006.

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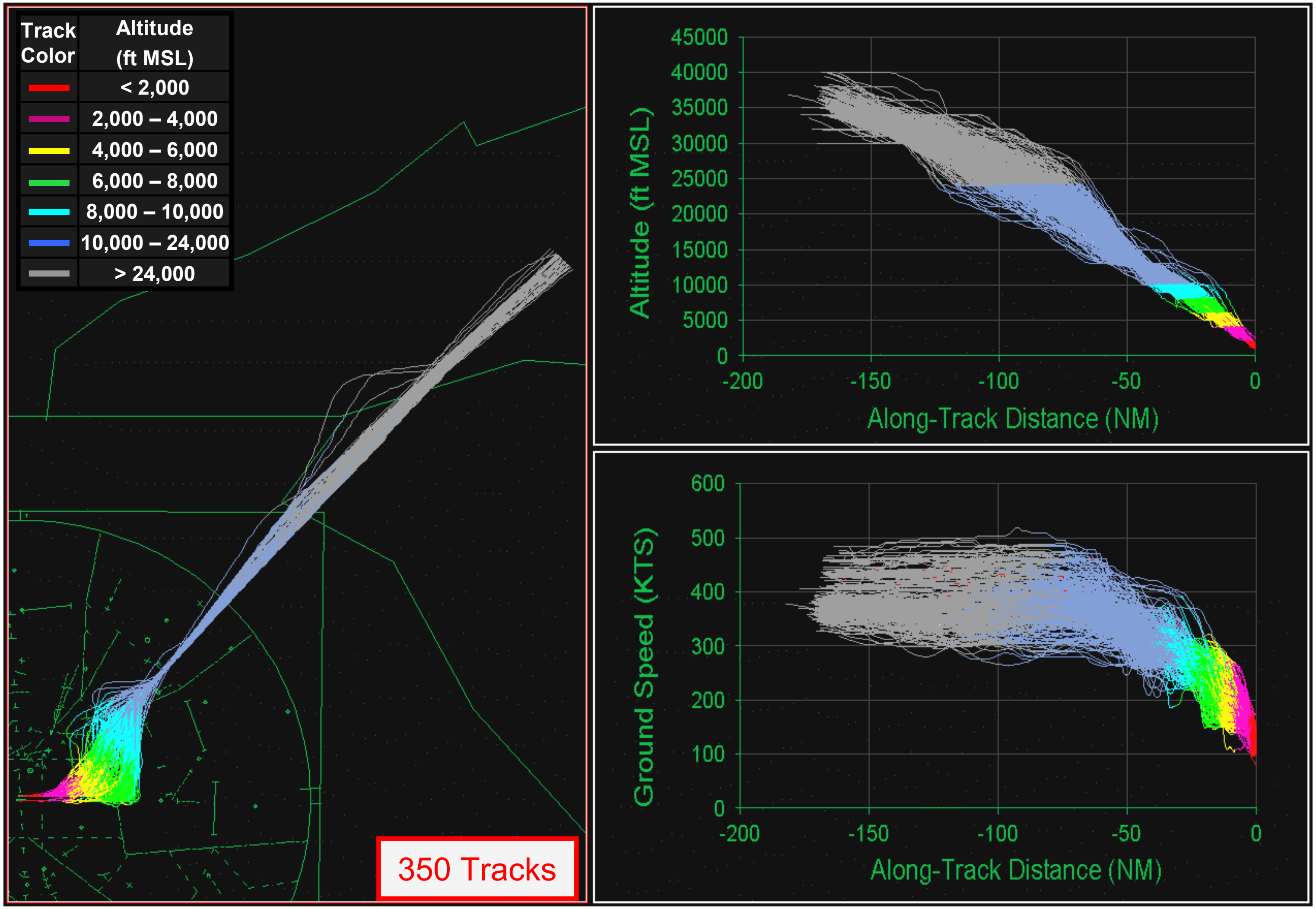
Data Analyzed

Atlanta Baseline Operations

Northeast Corner Post Arrivals over BEBAD/FLCON



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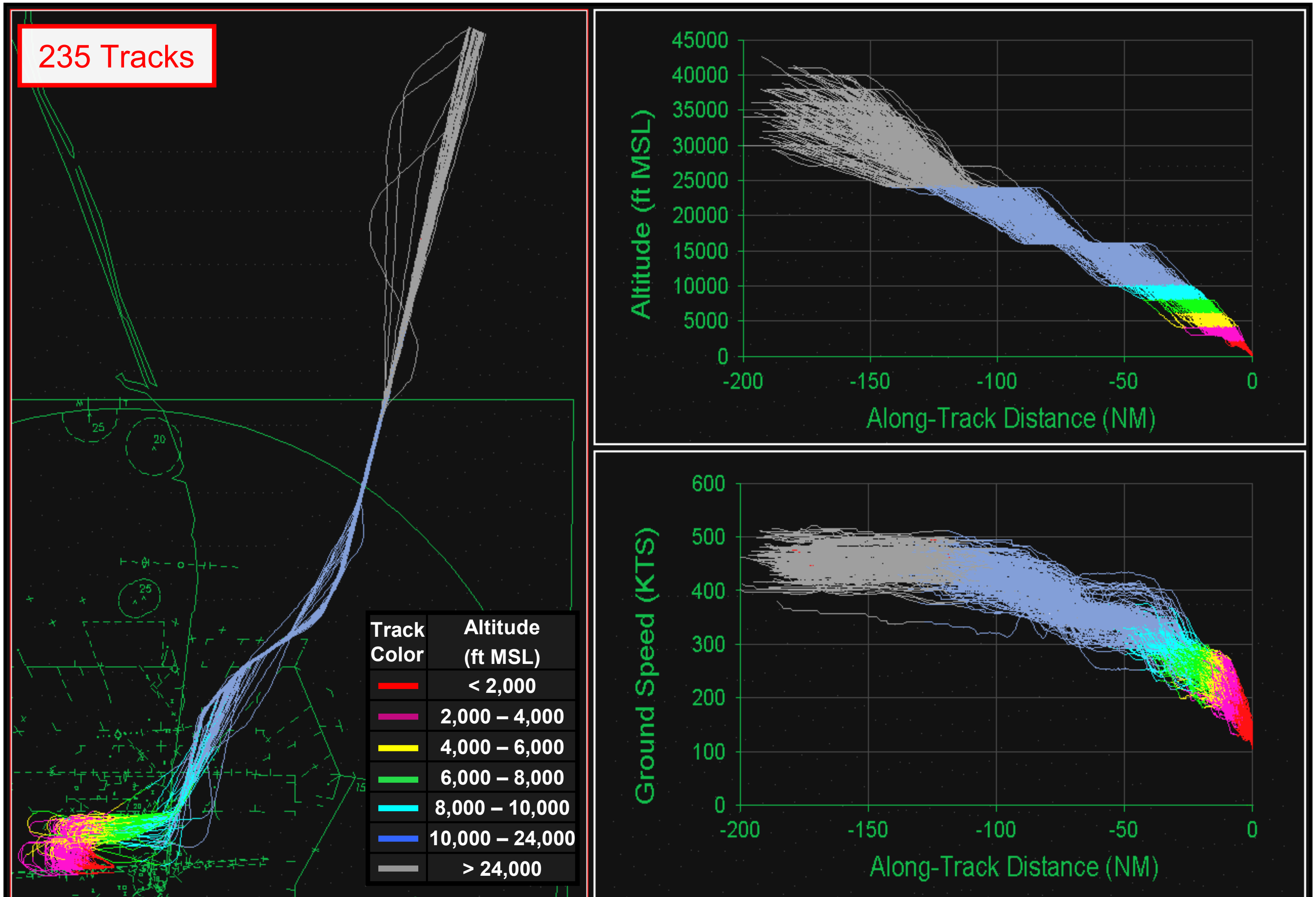
F083-B08-067

Data Analyzed

Miami Baseline Operations

Northeast Corner Post Arrivals over JORAY



MSL – Mean Sea Level

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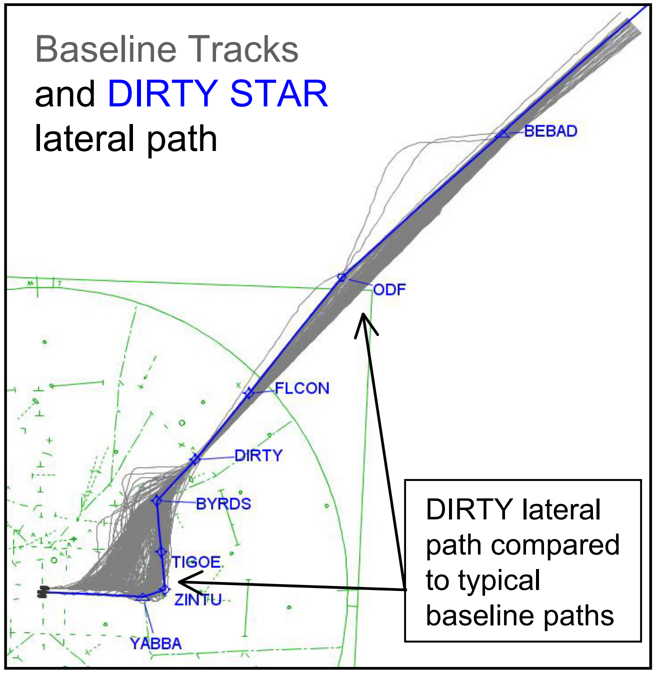
Atlanta Benefits Analysis Results

Indicator Metrics

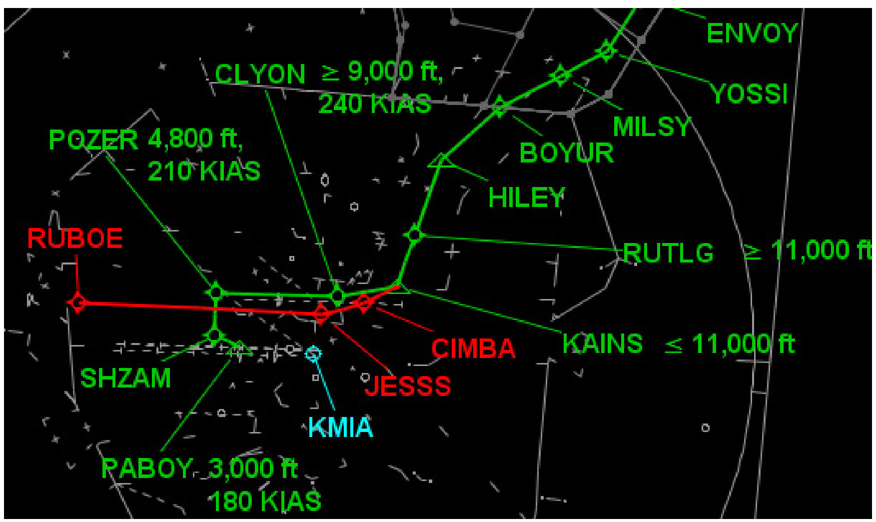
Metric	Baseline Average Per Flight	Average CDA Difference from Baseline per Flight
Distance Flown (NM)	166.1	+ 5 (+3%)
Time in Level Flight (s)	241	- 222 (-92%)
Average Groundspeed (kts)	319	+ 15 (+5%)



- **Results show longer track distances associated with adherence to the lateral track of the DIRTY procedure compared to shortcuts applied via radar vectors, particularly at low altitudes**
- **Groundspeed profiles were observed to be faster for the CDA demonstration flights**
- **Consistent with the design of the vertical constraints, time in level flight was significantly reduced for CDA demonstration flights. Note that ATL baseline flights spent a shorter amount of time in level flight than MIA baseline flights; this is consistent with the ATL baseline flights occurring as "short side" flights (flights arriving over an arrival fix to the east while ATL is operating in west flow configuration – the lack of a downwind, by necessity, leads to fewer low altitude level flight segments)**

Miami Analysis Results
Indicator Metrics

Metric	East Flow Baseline Average per Flight	West Flow Baseline Average per Flight	East Flow Average CDA Δ from Baseline per Flight	West Flow Average CDA Δ from Baseline per Flight
Distance Flown (NM)	184.1	151.7	+ 8.85 (+5%)	- 0.2 (-0.1%)
Time in Level Flight (s)	384	307	- 367 (-96%)	- 234 (-76%)
Average Groundspeed (kts)	348	399	- 9 (-3%)	+ 12 (+3%)



- **Results show essentially equivalent baseline and CDA demonstration track distances from en route until the KAINS waypoint, but increased track distance for CDA flights from KAINS until Runway 08L. This is consistent with the longer downwind and base leg built into the RUTLG procedure (in green at left) versus the HILEY (in red at left)**
- **Groundspeed profiles were also observed to be slower for CDA demonstration flights after the KAINS waypoint, despite being faster from en route until KAINS, consistent with the speed restrictions built into the RUTLG procedure**
- **Consistent with the design of the vertical constraints, time in level flight was significantly reduced for CDA demonstration flights on all segments of the procedure**