Federal Aviation Administration

Optimization of Airspace and Procedures in the Metroplex (OAPM)

Study Team Final Report

Charlotte Metroplex

Table of Contents

1 Background 1

2 Purpose of the Charlotte OST Effort 1

3 OST Analysis Process 2

3.1 Five Step Process 2

3.2 OST Study Area Scope 2

3.3 Assumptions and Constraints 3

3.4 Assessment Methodology 3

3.4.1 Track Data Selected for Analyses 4

3.4.2 Determining the Modeled Fleet Mix 5

3.4.3 Profile Analysis 5

3.4.4 Analysis Tools 6

3.4.5 Universal Considerations 7

4 Identified Issues and Proposed Solutions 8

4.1 Arrival Issues 8

4.1.1 Identified Issues for Corner Post STAR Procedure Designs 9

4.1.1.1 En Route Airspace Level-Offs 9

4.1.1.2 En Route Airspace Delay Vectoring 10

4.1.1.3 Terminal Airspace Level-Offs 11

4.1.1.4 Single Downwind on RNAV STARs 12

4.1.2 OST Recommendations: Dual RNAV STARs with OPDs 13

4.1.2.1 General Considerations for the Conceptual RNAV STARs 15

4.1.2.2 Impact of Raising the CLT Ceiling 16

4.1.2.3 Arrivals from the Northeast 18

4.1.2.4 Arrivals from the Southeast 22

4.1.2.4.1 Option 1 for the Southeast Arrivals 23

4.1.2.4.2 Option 2 for the Southeast Arrivals 27

4.1.2.5 Arrivals from the Southwest 30

4.1.2.6 Arrivals from the Northwest 34

4.1.2.6.1 Option 1 for the Northwest Arrivals 35

4.1.2.6.2 Option 2 for the Northwest Arrivals 40

4.1.3 Identified Issue: KCLT Re-Routes over HUSTN 43

4.1.4 OST Recommendation: Implement Proposed RNAV STARs 43

4.2 Departure Issues 45

4.2.1 Identified Issues for SID Procedure Designs 45
4.2.1.1 Terminal Airspace Level-Offs 45
4.2.1.2 En Route Airspace Level-Offs 47
4.2.1.3 Increased Initial In-Trail Spacing Due to SID Design 48
4.2.1.4 Width of Final Sector Impacts SID Leg Lengths 49
4.2.1.5 Less-Efficient Routings to En Route Structure 50
4.2.1.6 Need for Additional En Route Transitions and/or New SIDs 51
4.2.2 OST Recommendations: Optimize Current and Add New RNAV SIDs 52
4.2.2.1 General Considerations for the Conceptual RNAV SIDs 54
4.2.2.2 Impact of Increased Divergence 55
4.2.2.3 Departures to the East 56
4.2.2.4 Departures to the South 61
4.2.2.5 Departures to the West 66
4.2.2.6 Departures to the North 71
4.2.2.6.1 Option 1 for the North Departures 72
4.2.2.6.2 Option 2 for the North Departures 76
4.2.3 Alternate KCLT Arrival and Departure Leg Concepts 80
4.2.4 Charlotte Satellite Airport Arrivals 83
4.2.5 T-Routes 85
4.2.6 Charlotte Adjacent Airport Operations 87
4.2.6.1 KCAE Arrivals and Departures 88
4.2.6.2 KGSP Arrivals and Departures 89
4.2.6.3 KRDU Departures 90
4.2.6.4 KGSO Departures 91
4.2.7 Military Activity Issues in ZJX Airspace 92
4.2.8 Early Morning Arrival Issues 93
5 Issues Not Analyzed by Charlotte OAPM Study Team 94
6 Summary 95

1 Background

In September 2009, the Federal Aviation Administration (FAA) received the RTCA's Task Force 5 Final Report on Mid-Term NextGen Implementation containing recommendations concerning the top priorities for the implementation of NextGen initiatives. A key component of the RTCA recommendations is the formation of teams leveraging FAA and Industry Performance Based Navigation (PBN) expertise and experience to expedite implementation of optimized airspace and procedures.

Optimization of Airspace and Procedures in the Metroplex (OAPM) is a systematic, integrated, and expedited approach to implementing PBN procedures and associated airspace changes. OAPM was developed in direct response to the recommendations from RTCA's Task Force 5 on the quality, timeliness, and scope of metroplex solutions.

OAPM focuses on a geographic area, rather than a single airport. This approach considers multiple airports and the airspace surrounding a metropolitan area, including all types of operations, as well as connectivity with other metroplexes. OAPM projects will have an expedited life-cycle of approximately three years from planning to implementation.

The expedited timeline of OAPM projects centers on two types of collaborative teams: Study Teams will provide a comprehensive but expeditious front-end strategic look at each major metroplex. Using the results of the Study Teams, Design and Implementation (D&I) Teams will provide a systematic, effective approach to the design, evaluation and implementation of PBN-optimized airspace and procedures. The Charlotte OAPM Study Team (OST) was one of the first OAPM Study Teams formed.

2 Purpose of the Charlotte OST Effort

The principle objective of the OST was to identify operational issues and propose PBN procedures and/or airspace modifications in order to address them. This OAPM project for the Charlotte Metroplex seeks to optimize and add efficiency to the operations of the area. These efficiencies include making better use of existing aircraft equipage by adding Area Navigation (RNAV) procedures, optimizing descent and climb profiles to eliminate or reduce the requirement to level-off, creating diverging departure paths that will get aircraft off the ground and heading toward their destination faster, and adding more direct high-altitude RNAV routes between two or more metroplexes, among others.

The OST effort is intended as a scoping function. The products of the OST will be used to scope future detailed design efforts and to inform FAA decision-making processes concerning commencement of such design efforts.

3 OST Analysis Process

3.1 Five Step Process

The Charlotte OST followed a five-step analysis process:

1. Collaboratively identify and characterize existing issues: review current operations and solicit input to obtain an understanding of the broad view of operational challenges in the metroplex.
2. Propose conceptual designs and airspace changes that will address the issues and optimize the operation: using an integrated airspace and PBN "toolbox" and technical input from operational stakeholders to explore potential solutions and the identified issues.
3. Identify expected benefit, quantitatively and qualitatively, of the conceptual designs: assess the rough-order-of-magnitude impacts of conceptual designs, to the extent possible use objective, quantitative assessments.
4. Identify considerations and risks associated with proposed changes: describe, at a high-level, considerations (e.g., if additional feasibility assessments are needed) and/or risks (e.g., if waivers may be needed).
5. Document the results from the above steps.

Steps 1 and 2 are worked collaboratively with local facilities and operators through a series of outreach meetings. Step 3 is supported by the OAPM National Analysis Team (NAT). The analysis methodology used for the quantitative approach is described in Section 3.4. The NAT is a centralized analysis and modeling capability that is responsible for data collection, visualization, analysis, simulation, and modeling. Step 4 is conducted with the support of the OAPM Specialized Expertise Cadre (SEC). The SEC provides "on-call" expertise from multiple FAA lines of business, including environmental, safety management, airports, and specific programs, like Traffic Management Advisor (TMA).

Assessments at this stage in the OAPM process are expected to be high-level, as detailed specific designs (procedural and/or airspace) have not yet been developed. More accurate assessments of benefits, impacts, costs and risks are expected after the Design phase has been completed.

3.2 OST Study Area Scope

The Charlotte Metroplex consists of those facilities and airspace that contain the primary flows of traffic serving Charlotte Douglas International (KCLT) airport along with associated satellite and adjacent airports. The principle Air Traffic Control (ATC) facilities serving the Charlotte Metroplex are Charlotte Terminal Radar Approach Control (TRACON) (CLT), Atlanta Air Route Traffic Control Center (ARTCC) (ZTL), Washington ARTCC (ZDC), Jacksonville ARTCC (ZJX), and Indianapolis ARTCC (ZID).

3.3 Assumptions and Constraints

OAPM is an optimized approach to integrated airspace and procedures projects, thus the process is centered on airspace redesign or procedurally-based, most probably PBN, solutions. The Study Teams are expected to document those issues that cannot or should not be addressed by airspace and procedures solutions, as these will be shared with other appropriate program offices. These issues are described at the end of this report.

The OAPM expedited timeline and focused scope bound airspace and procedures solutions to those that can be achieved without requiring an Environmental Impact Statement (EIS) (e.g., only requiring an Environmental Assessment (EA) or qualifying for a Categorical Exclusion (CATEX) and within current infrastructure and operating criteria. The Study Team results may also identify airspace and procedures solutions that do not fit within the environmental and criteria boundaries of an OAPM project. These other recommendations then become candidates for other integrated airspace and procedures efforts.

3.4 Assessment Methodology

Both qualitative and quantitative assessments were made to gauge the potential benefits of proposed solutions.

The qualitative assessments are those that the OST could not measure, but would certainly result from the implementation of the proposed solution. These assessments included:

- Impact on ATC task complexity
- Ability to apply procedural separation (e.g., laterally or vertically segregated flows)
- Ability to enhance safety
- Improved connectivity to en route structure
- Improvements to security (avoiding restricted airspace)
- Reduction in communications (cockpit and controller)
- Reduction in need for Traffic Management Initiatives (TMIs)
- Improved track predictability and repeatability
- Reduced reliance on ground-based navigational aids (NAVAIDS)

Task complexity, for example can be lessened through the application of structured PBN procedures versus the use of radar vectors, but quantifying that impact is difficult. Reduced communications between pilot and controller, as well as reduced potential for operational errors, are examples of metrics associated with controller task complexity that were not quantified.

For the quantitative assessments, the OST relied in identifying changes in track lengths, flight times, and fuel burn. Most of these potential benefits were measured by comparing a baseline case with a proposed change using both a flight simulator (to establish a relationship between simulator fuel burn results and the European Organization for the Safety of Air Navigation Base

of Aircraft Data (BADA) fuel burn model and The MITRE Corporation's Center for Advanced Aviation System Development's (CAASD) Java-based Monte Carlo Flight Management System (FMS) Aircraft Simulation Tool (JMFAST).

To determine the fuel burn benefit for users from any proposed lateral path change, proposed procedures were compared to actual flown tracks. The reduction in distance between proposed and current procedures also results in a decrease of the amount of fuel load (lbs) required/planned for each aircraft. This reduced fuel load results in lighter aircraft that burn less fuel and is reflected as a cost-to-carry savings, which was estimated to be 6% of the incremental fuel loading cost (based on industry findings). For example, a fuel savings of 100 gallons due to a shorter route would result in a cost-to-carry savings of 6 gallons.

3.4.1 Track Data Selected for Analyses

During the study process, a standard set of radar traffic data was utilized in order to maintain a standardized operational reference point.

For determining the number, length, and location of level-offs for the baseline of operational traffic, thirty 90th-percentile traffic days in calendar year (CY) 2010 were utilized. These days were selected using the Airport Specific Analysis Page (ASAP) operational counts matched with Meteorological Aviation Report (METAR) weather data. These days were also used as input for examining sector load analyses for notional sector boundary re-designs.

The following days were utilized by the Charlotte OST and the NAT:

- January 2, 3, 4, 5, 6, and 31
- March 3 and 31
- April 1
- May 27
- June 7, 10, 17, 18, 19, 20, 21, and 22
- July 30
- August 17 and 26
- October 6, 11, 12, and 29
- November 1, 10, 12, 14, and 15

For these traffic days, historical radar track data was used to allow the OST to visualize the flows and identify where shortcuts were routinely applied as well as where flight planned routes were more rigorously followed. The track data was also used as a baseline for the development of several conceptual solutions including PBN routes and procedures. In many cases, the OST generally overlaid the historical radar tracks with PBN routes or procedures to minimize the risk of significant noise impact and an associated EIS. The conceptual arrival procedures contain runway transitions and the conceptual departure procedures are designed as RNAV "off-the-ground" procedures. The determination as whether to include runway transitions and RNAV

"off the ground" departure procedures in the proposed design will need to be made during the Design and Implementation process.

3.4.2 Determining the Modeled Fleet Mix

Due to the compressed schedule associated with this study effort, there was not sufficient time to model the entire fleet mix that services the Charlotte Metroplex airspace. As a result, the analyzed fleet mix had to be reduced to a manageable number of aircraft types. The OST determined that regional jets (CRJ-series and Embraer-series), B73X-series, and A319/A320s accounted for over 80% of the aircraft types operating in the area. The remaining fleet is comprised of multiple aircraft types individually representing no more than 1% of the total fleet.

The fleet mix was queried from the FAA's Enhanced Traffic Management System (ETMS) reporting of aircraft operations in 2010.

AC Type	# Ops	% Ops
CRJ-series	187,775	34.4%
Embraer-series	68,794	12.6%
B73X-series	58,888	10.8%
A319/A320-series	121,629	22.3%
Other	109,195	19.9%
Total	**546,281**	**100%**

3.4.3 Profile Analysis

To establish a baseline, the OST examined track data using the FAA's Graphical Airspace Design Environment (GRADE) tool to identify and measure level-off characteristics: altitude, along-track distance from runway to the start of the level-off, and length of the level-off.

For comparison, the concepts proposed by the OST were modeled using CAASD's JMFAST assessing the same characteristics as the baseline: altitude, along-track distance from runway to the start of the level-off, and length of the level-off. The results were then reviewed by OST Subject Matter Experts to ensure continuity with intent of the design. The OST then applied the BADA fuel flow model and flight simulations to determine a range of fuel burn.

Flight simulations were also conducted on an actual arrival as well as the proposed conceptual design during the Washington, D.C. Metroplex prototype study team effort. The flight simulator values were obtained through a US Airways A320 flight simulator fuel burn analysis for two transitions on a proposed versus baseline arrival procedure. Derived values for fuel burn per minute in level flight, idle descent, and less-efficient descent were then used to determine and validate the relationship between the flight simulator fuel saving estimates and the BADA-based fuel burn estimates (calculated in gallons per nautical mile). This established a variable range between BADA's conservative aircraft performance numbers and high-fidelity flight simulator evaluations. This same relationship was applied to the Charlotte study to determine a maximum

fuel savings per flight. Applying both the flight simulator and BADA methods provides for a range of potential benefits:

- BADA numbers (speed/fuel burn – lower bound for potential benefit)
- Flight simulation numbers (speed/fuel burn – upper bound for potential benefit)

3.4.4 Analysis Tools

The following tools were employed by the OST in the process of studying Charlotte OAPM:

- PDARS (Performance Data Reporting and Analysis System)
  - Historical traffic flow analysis using merged datasets to analyze multi-facility operations (CLT, ZTL, ZJX, ZDC, Greensboro [KGSO], Raleigh-Durham [KRDU], Columbia [KCAE], Greenville-Spartanburg [KGSP])
  - Developed customized reports to measure performance and air traffic operations (i.e., fix loading, hourly breakdowns, origin-destination counts, etc.)
  - Identification and analysis of level flight segments for KCLT arrivals and departures
  - Graphical replays to understand and visualize air traffic operations
  - Verify level segments in ZTL, ZDC, and ZJX airspace
- TARGETS (Terminal Area Route Generation Evaluation and Traffic Simulation)
  - Compare actual flown routes to proposed routes when developing cost/benefit estimates
  - Conceptual airspace and procedure design
- SDAT (Sector Design Analysis Tool)
  - Identify impact of altitude stratification on airspace sectorization
- *runway*Simulator
  - Simulation tool that estimates runway capacity for a system
  - Quantify increased throughput obtainable by increasing divergence
- iTRAEC (Integrated Terminal Research, Analysis and Evaluation Capabilities) tool
  - Identify location, altitude and magnitude of level-off segments
- ATA Lab (Air Traffic Airspace Lab) National Offload Program (NOP) data queries
  - Quantify traffic demand over time for specific segments of airspace
  - Identify runway usage over time
- NTML (National Traffic Management Log)
  - Identify occurrence and magnitude of TMIs

- ETMS (Enhanced Traffic Management System)
  - Traffic counts by aircraft group categories for annualizing benefits
  - Examine filed flight plans to determine impact of significant re-routes

3.4.5 Universal Considerations

The following issues were universal considerations employed by the Charlotte OST while designing the conceptual RNAV Standard Terminal Arrivals (STARs) and RNAV Standard Instrument Departures (SIDs):

- Additional controller and pilot training may be required
- An environmental screening will be required for all proposed procedures
- Typical RNAV benefits will be gained by implementing the new procedures. These may vary depending on the status of current procedures:
  - Reduced phraseology
  - Repeatable, predictable flight paths
  - Reduced pilot/ATC task complexity
- More than 95% of the aircraft are equipped to fly the proposed PBN procedures. Procedures for unequipped aircraft will need to be addressed.
- Safety Risk Management (SRM) process will be required for all new procedures
- Traffic Management Advisor (TMA) concerns
  - Adaptation requirements
  - Manageable feeds of traffic from multiple flows
- Expected Industry impacts
  - Dispatch flight planning
  - More direct paths due to the use of non-ground-based navigational aids and optimized flight profiles will lead to reduced mileage and fuel burn
  - Reduced fuel loading will also allow for a reduction in cost-to-carry
  - Timetable: shortened, more efficient routes may necessitate timetable adjustments, particularly as more metroplexes are optimized, impacting
  - Crew scheduling
  - Connecting information
  - Time on gates
  - Ramp scheduling

4 Identified Issues and Proposed Solutions

This section presents the findings and results of the Charlotte OST effort. It is organized beginning with arrivals for KCLT, then departures for KCLT, followed by issues for the surrounding satellite and adjacent airport facilities. Each issue is characterized and solutions are proposed. For all proposed solutions, expected benefits, considerations and risks are identified. Where applicable, the results of quantitative analyses are also presented.

4.1 Arrival Issues

The OST review and analysis of arrival procedures in the Charlotte Metroplex led to the conclusion that several opportunities existed for optimizing descent profiles. This included optimizations specific to the arrivals from each corner post of operations. The ATC facilities also expressed a need for the modification, addition, or removal of arrival transitions for existing STARs and the need for a new dual RNAV STAR to better support traffic from the Northwest corner post. Finally, the CLT airspace was identified as needing re-stratification, increasing the ceiling from 14,000 feet to 16,000 feet. Specifically, the solution proposals to increase arrival efficiency included the following:

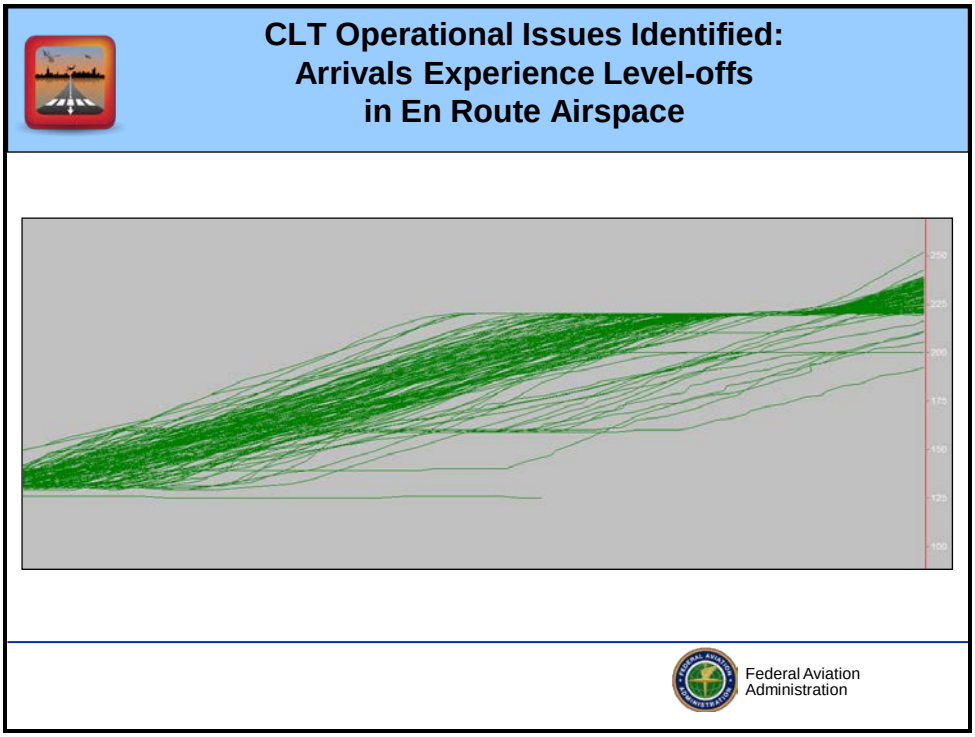
- Maximizing the use of Optimized Profile Descents (OPDs) on the current STARs
  - Arrivals from the Northeast
    - SUDSY
  - Arrivals from the Southeast
    - HUSTN
  - Arrivals from the Southwest
    - ADENA
  - Arrivals from the Northwest
    - JOHNS

4.1.1 Identified Issues for Corner Post STAR Procedure Designs

The Charlotte OST identified multiple issues affecting the arrival operations for KCLT resulting from level-offs and delay vectoring in both the en route and terminal airspace, and vectoring for non-published runway transitions.

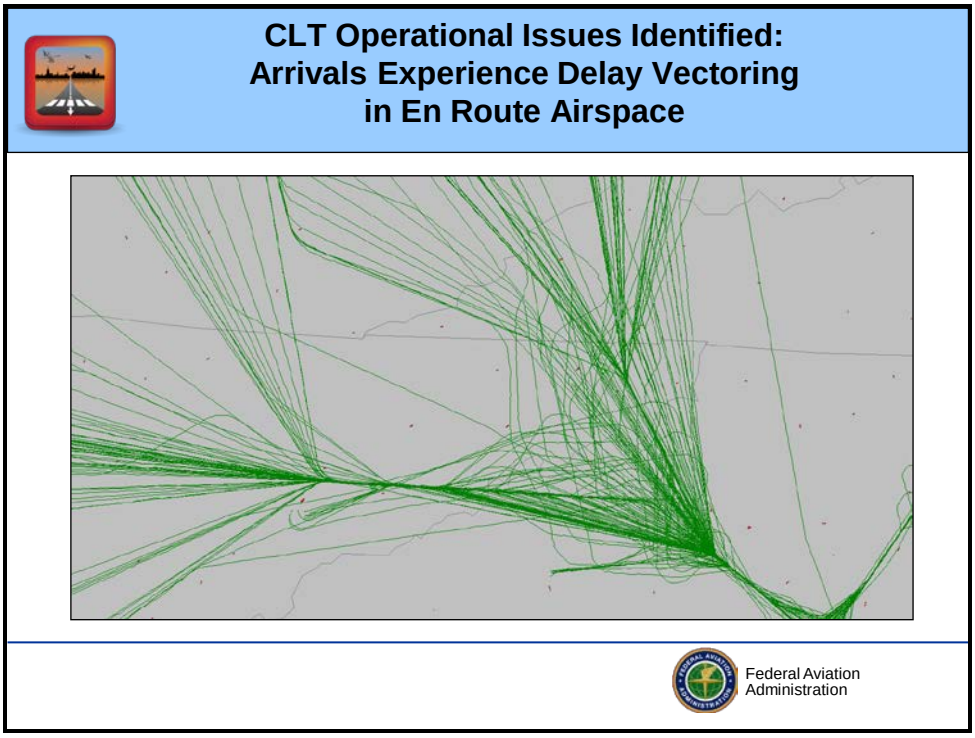
4.1.1.1 En Route Airspace Level-Offs

Charlotte arrivals in en route airspace are experiencing level-offs. The OST found several instances where aircraft were descended to an altitude to avoid airspace (rather than optimizing the flight path of the aircraft) or to avoid conflicting traffic. The graphic below shows traffic descending to FL220 over MAYOS intersection to avoid ZTL high altitude sectors. This is representative of all four corner posts.



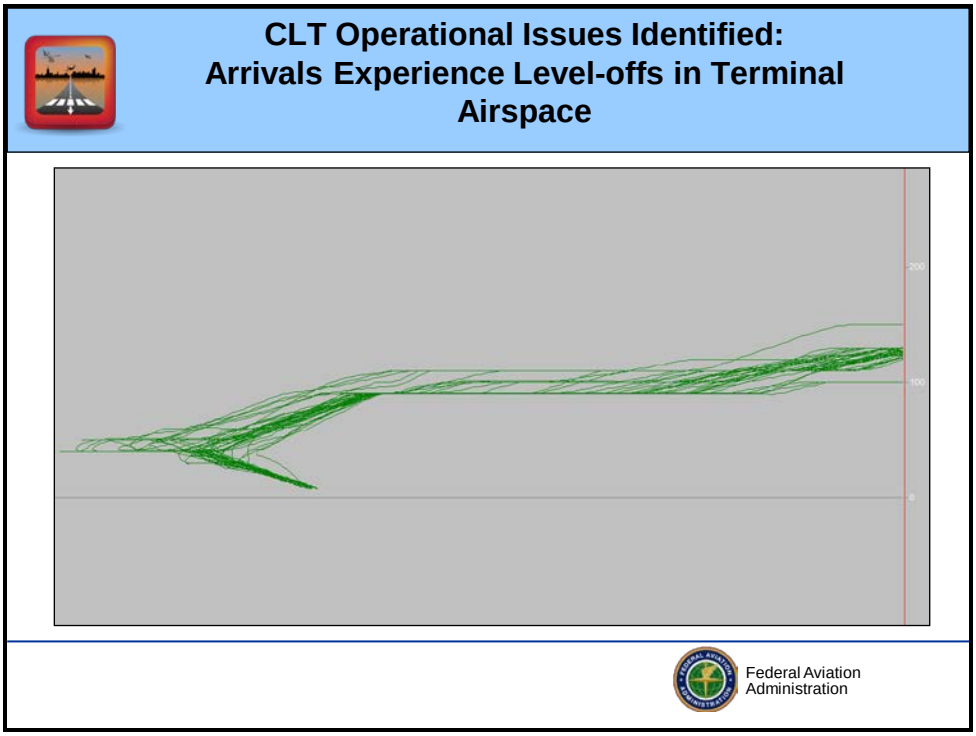
4.1.1.2 En Route Airspace Delay Vectoring

Charlotte arrivals in en route airspace are experiencing delay vectors. Different wind characteristics impacting multiple routes which must be merged into one stream can increase spacing needed to allow for compression of aircraft with dissimilar speeds. Also, aircraft are required to be merged from several streams into a single arrival stream at the CLT boundary, although these aircraft are routinely assigned to different runways. In addition, Letters of Agreement (LOA) and airspace limitations negate the ability to deliver more than one aircraft at a time over a fix, even when the demand and the TMA-expected throughput are higher.



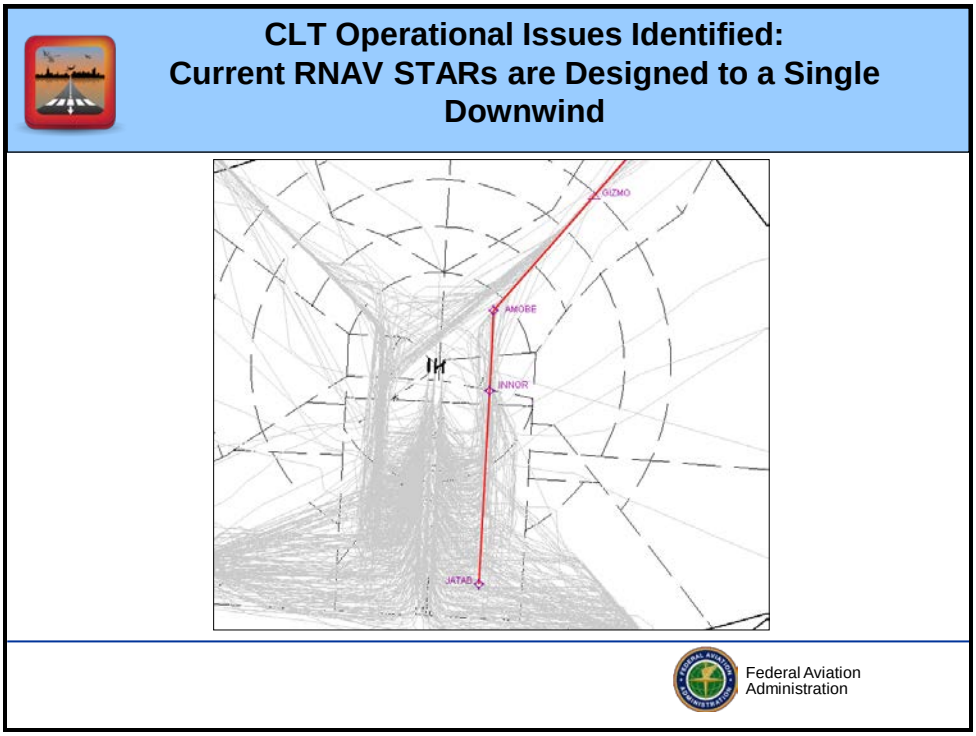
4.1.1.3 Terminal Airspace Level-Offs

The graphic below illustrates step down arrivals, rather than an optimal profile. Current LOAs require surrounding centers to deliver aircraft at level flight at the terminal boundary, regardless of landing direction and miles flown in terminal airspace. This causes non-optimal fuel burn and excessive carbon emissions, particularly during flows requiring downwind legs.



4.1.1.4 Single Downwind on RNAV STARs

To accomplish efficient runway load balancing, controllers at CLT routinely vector aircraft to runways other than the primary runway, resulting in increased flight crew and controller task complexity. This lack of published runway transitions results in increased voice communications and flight crew “heads down” time for Flight Management Computer (FMC) programming.



4.1.2 OST Recommendations: Dual RNAV STARs with OPDs

The Charlotte OST recommends the creation of dual RNAV OPD STARs to support all CLT arrival flows at the four corner posts, in order to make the arrivals' vertical profiles more efficient. The OPDs should begin in the en route airspace, and continue within the TRACON. In the specific case of the Northeast corner post, the offload RNAV STAR is suggested to be an ATC-assigned only procedure and would not necessarily support an optimized vertical profile.

The expected benefits associated with the introduction of OPDs on proposed RNAV STARs into CLT are described below, while more detail behind the proposed altitude windows along the proposed procedures is described in upcoming sections of the document.

The following table describes the qualitative benefits, impacts, and risks of the solution concept, in regard to operational and safety concerns.

Operational/Safety	
Benefits	**Impacts/Risks**
- Reduces sequencing of arrival flows for ZTL, ZJX, and ZDC - Increases opportunity to permit aircraft to fly OPDs by not having to merge multiple flows in en route airspace - Increases ability to react to asymmetrical demand by increasing throughput of CLT STARs - More predictable flight path and descent profiles - Reduces ATC task complexity - Enhances safety due to significant reduction of control instructions (reduces chance for controller/pilot read-back/hear-back errors) - Advances CLT's current PBN procedures - Segregates satellite and CLT traffic at SE corner post	- Airspace modifications - More coordination may be required during weather events - Opportunity to quickly overload CLT airspace - En route facilities providing CLT landing direction - Holding pattern design for dual STARs - Mixed equipage/type aircraft increases controller task complexity - Limited vectoring airspace and flexibility for CLT feeder controllers due to new proposed NW SID

In addition, the OST examined qualitative benefits, impacts, and risks of the solution concept, in regard to the Airspace Users.

Airspace User	
Benefits	**Impacts/Risks**
- Reduces vectoring for arrival flow sequencing - Reduces track miles - Reduces non-optimal fuel burn and high carbon emissions - Promotes more efficient use of CLT RNAV OPD STARs - Reduces pilot task complexity - Reduces departure level offs	- Increases flying distances for some arrival flows - Possibly increases track miles for aircraft departing/arriving adjacent airports

Finally, the Charlotte OST identified concerns regarding initial environmental screening, listed in the table below.

Initial Environmental Screening

- Environmental Assessment required
- All new routes that do no overlay current traffic are at or above 10,000ft except for one baseleg entry from the NW corner post. Routes do not appear to overlay any National Parks or Wilderness Areas.

The following graphic describes the total estimated annual benefit to be achieved from implementing the OST recommendations at all corner posts.

Estimated Annual Fuel Savings^

Distance	1.1M gal	$3.1M
Cost to Carry Fuel	105K gal	$291K
Level-off	1.3 - 3.8M gal	$3.4-10.2M
Total	2.5-5.0M gal	$6.8 – 13.6M

^Proposed STAR vs. actual tracks

Estimated Carbon Savings 24 – 48K metric tons

Savings reflect SE option 2 and NW option 1

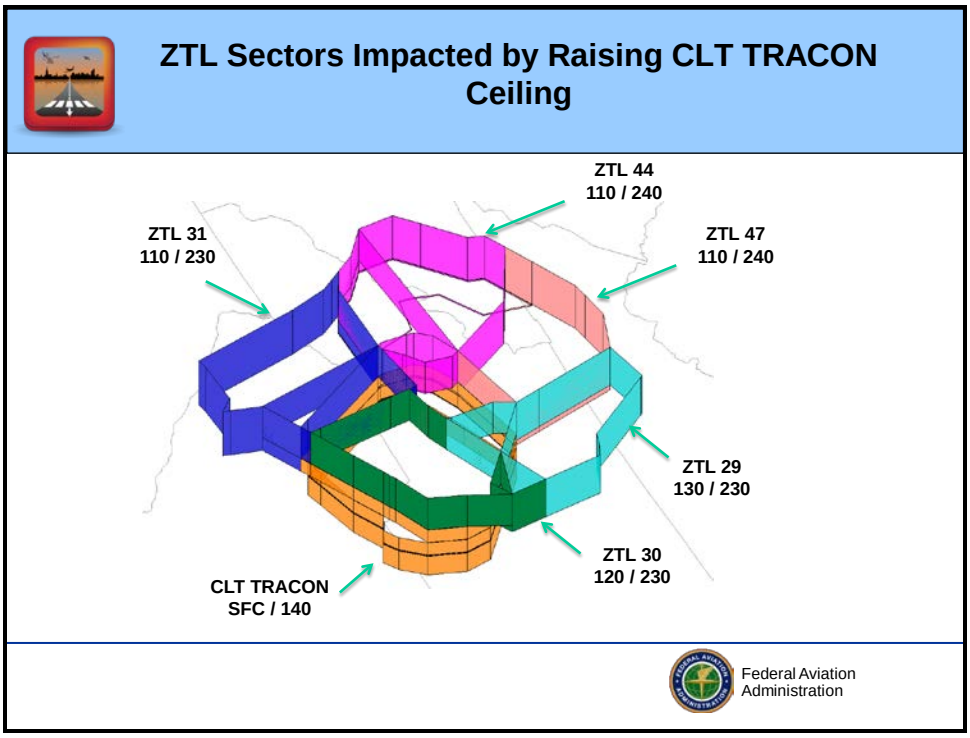
4.1.2.1 General Considerations for the Conceptual RNAV STARs

The following issues were general considerations employed by the Charlotte OST while designing the conceptual RNAV STARs for each of the corner posts:

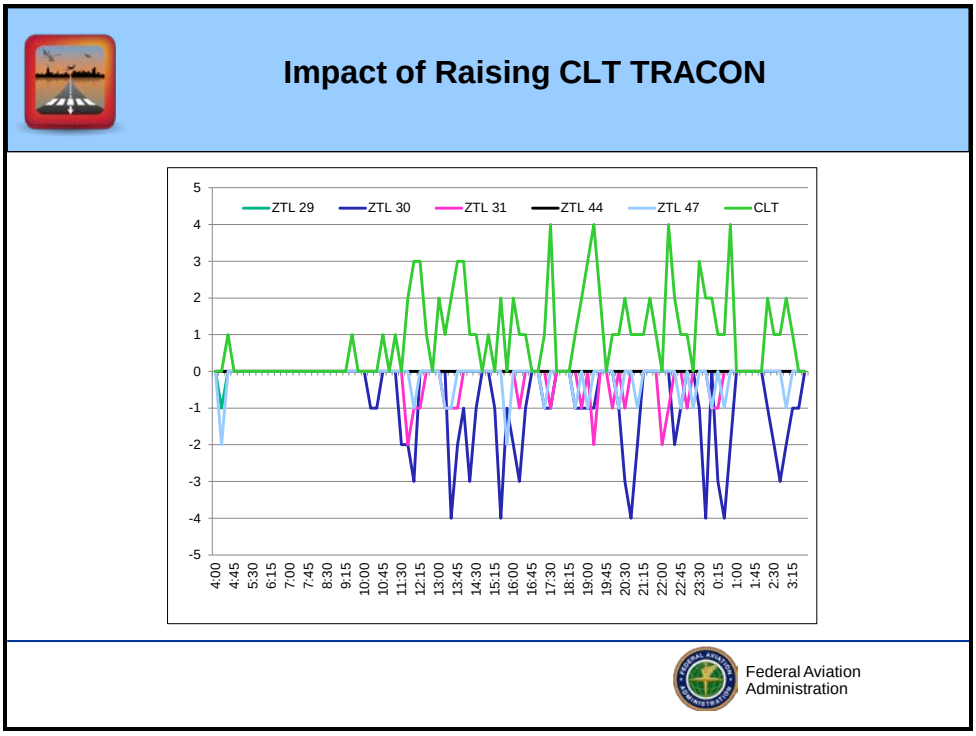
- CLT airspace vertical limits expanded up to 16,000 feet
- 11,000-16,000 feet at CLT/en route boundary enables an OPD from all corner posts
- All STARs terminate on a Heading-to-Fix (VM) leg. The D&I Team may consider adding approach transitions
- An Environmental Assessment is required. Consideration must be given to overflights over National Parks or Wilderness Areas where a quiet setting is a generally recognized purpose and attribute
- Non-RNAV STARs remain and may have to be redesigned. Non-RNAV STARs and turboprop arrival procedures were not considered by the Study Team
- Centers issue KCLT landing direction
- TMA will be updated to maximize efficiency of final routings
- A more optimized TMA feed may be achieved in the terminal environment using dual STARs when the majority of aircraft arrive over one corner post
- Dual STARs provide options for en route controllers when dealing with differing wind conditions, altitudes, or aircraft performance on a single stream
- KCLT appears to have the capacity to accept an increased arrival demand based on current airport arrival rates
- All STAR designs permit an initial climb to 9,000 feet except for MERIL departures on a south flow which permit an initial climb to 8,000 feet
- All STAR designs may require airspace changes

4.1.2.2 Impact of Raising the CLT Ceiling

Raising the CLT ceiling from 14,000 to 16,000 feet would affect sectors ZTL30, ZTL29, ZTL47, ZTL44, and ZTL33. The figure below illustrates those sectors and the current altitude stratification.

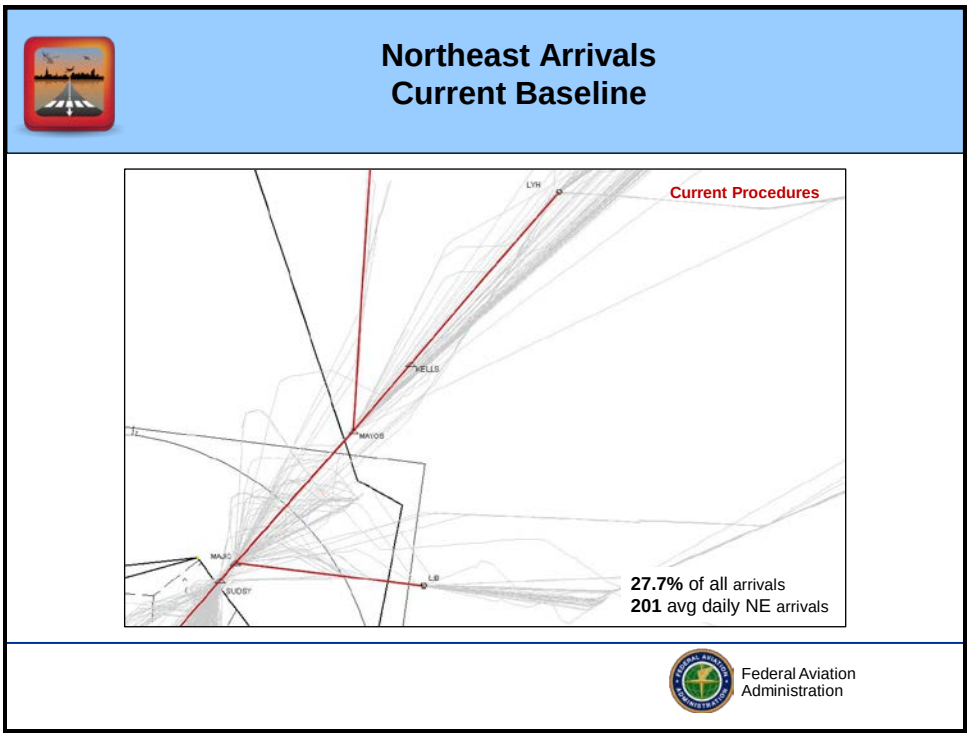


A 90th percentile day was chosen to determine the impact of raising the CLT ceiling from 14,000 feet to 16,000 feet. The overall increase to CLT daily traffic was 1.7% (31 aircraft) A maximum of four additional aircraft were observed in the TRACON during four 15-minute periods. With the ceiling of 16,000 feet the maximum number of aircraft at any given time in the TRACON was 42 aircraft, whereas with today's ceiling of 14,000 feet, the maximum was 40. ZTL47's peak number of aircraft decreased from 10 to 8. This information is displayed in the following graphic.



4.1.2.3 Arrivals from the Northeast

Below is a depiction of the current SUDSY STAR at the northeast corner post. The tracks represent a day's traffic between 0700 and 2300 local time. The transition from the north starts at Roanoke (ROA).

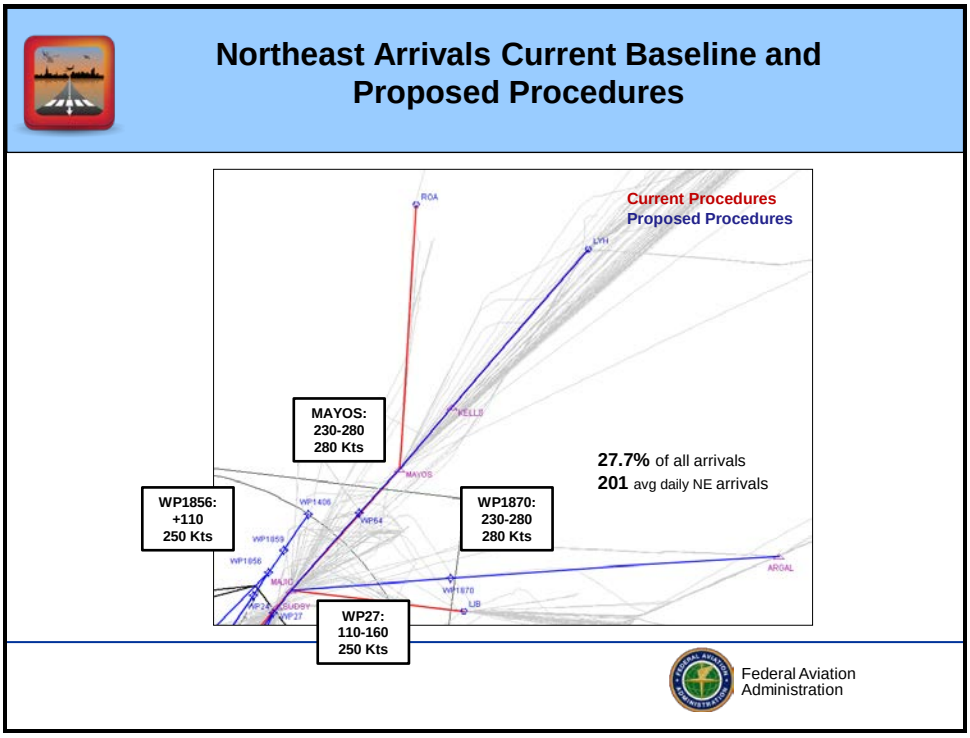


Based upon discussion with CLT, ZTL, and ZDC during the outreach meetings, there are various issues regarding current arrivals from the northeast, and also a number of considerations for the proposed design of the northeast arrivals:

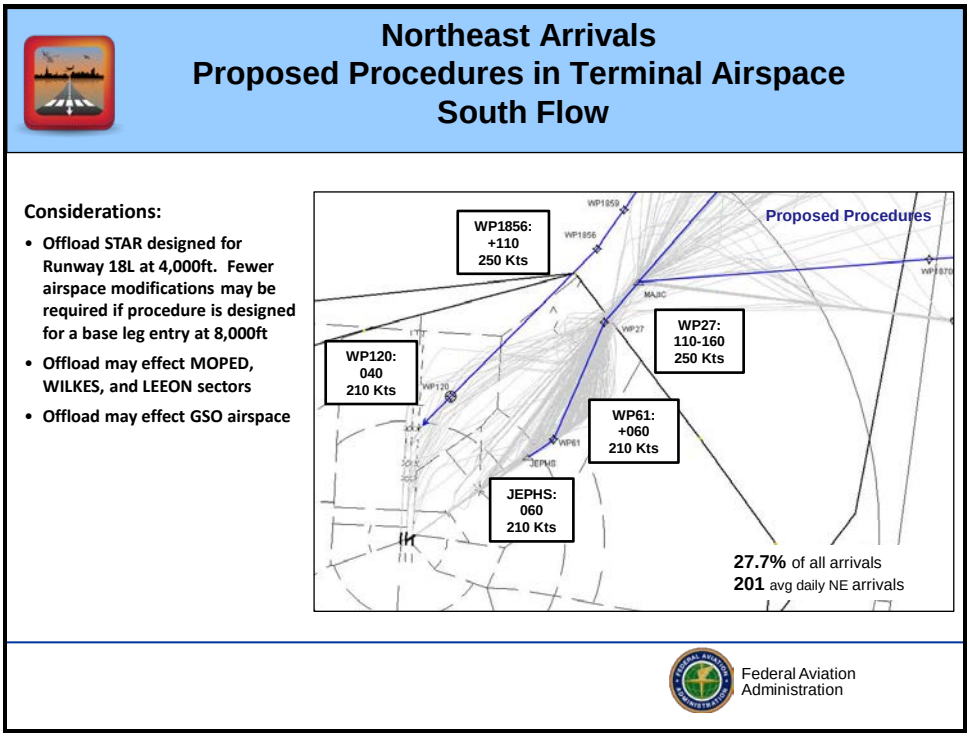
- Due to the proximity of ZDC to CLT, ZDC may be required to issue KCLT landing direction (north/south) instead of ZTL
- The new ARGAL transition replaces the old Liberty (LIB) transition and de-conflicts west bound KRDU departures
- A waypoint on the new ARGAL transition is required for KRDU departures landing KCLT
- The OPD STAR enhances the proposed OPD KELLS procedure
- The offload STAR routing will affect ZTL47 (MOPED), ZTL48 (WILKES), and ZTL29 (LEEON) sectors, as well as KGSO's surrounding airspace

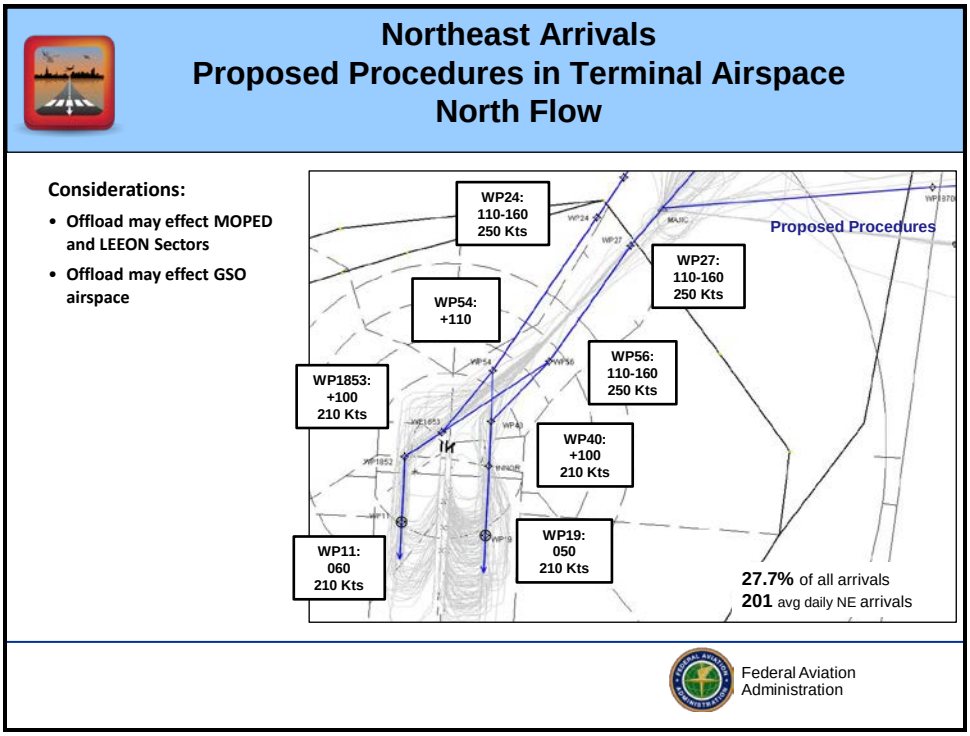
- A redesign of the airspace shelf may be required at the ZDC/ZTL boundary

Those considerations, as well as an expressed desire by ZDC to remove the ROA transition on the current SUDSY, affected the conceptual design presented in the graphic below. The following is a composite display of the current SUDSY STAR with the proposed OPD overlay and parallel ATC assigned offload STAR. The proposed Northeast RNAV OPD STAR overlays the lateral path of the conventional STAR from the Lynchburg (LYH) transition, and removes the ROA transition. KCLT arrivals are given a more direct route between ARGAL and MAJIC compared to the former LIB transition. Key waypoints with their respective proposed altitude constraints are displayed.



The following two graphics illustrate the considerations and altitude constraints for the proposed primary and offload RNAV STARs for both south and north flow operations.

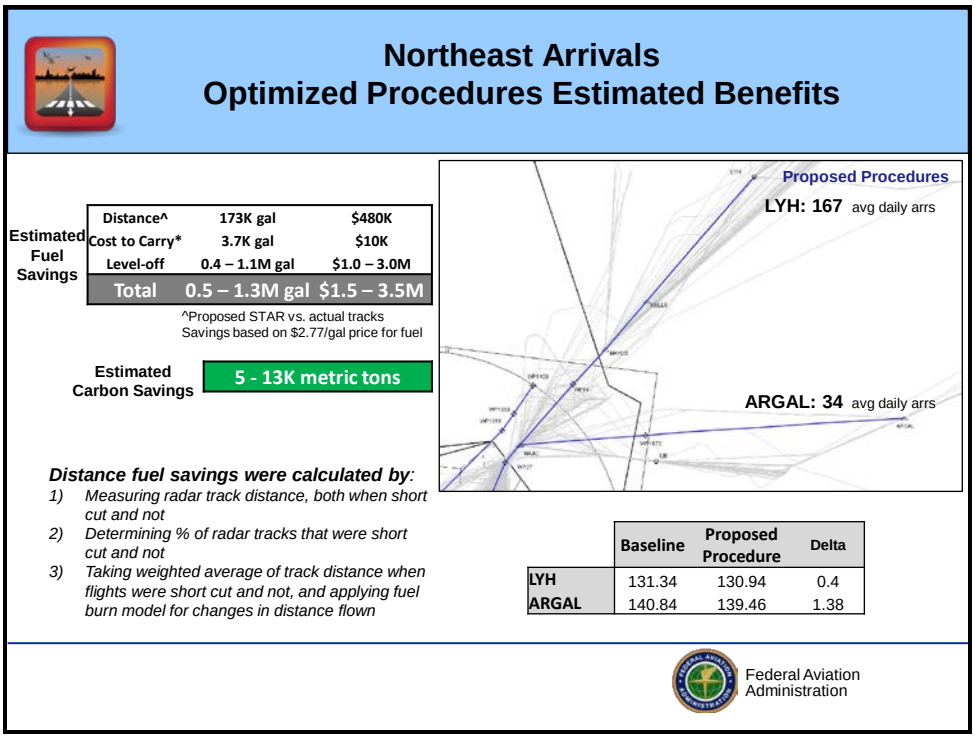




Although the proposed OPD STAR overlays the currently published STAR, the ability to move traffic to the offload STAR should create gaps in the LYH stream. This will allow traffic flying the ARGAL transition to merge into the LYH flow, reduce delay vectoring and allow traffic to utilize the OPD.

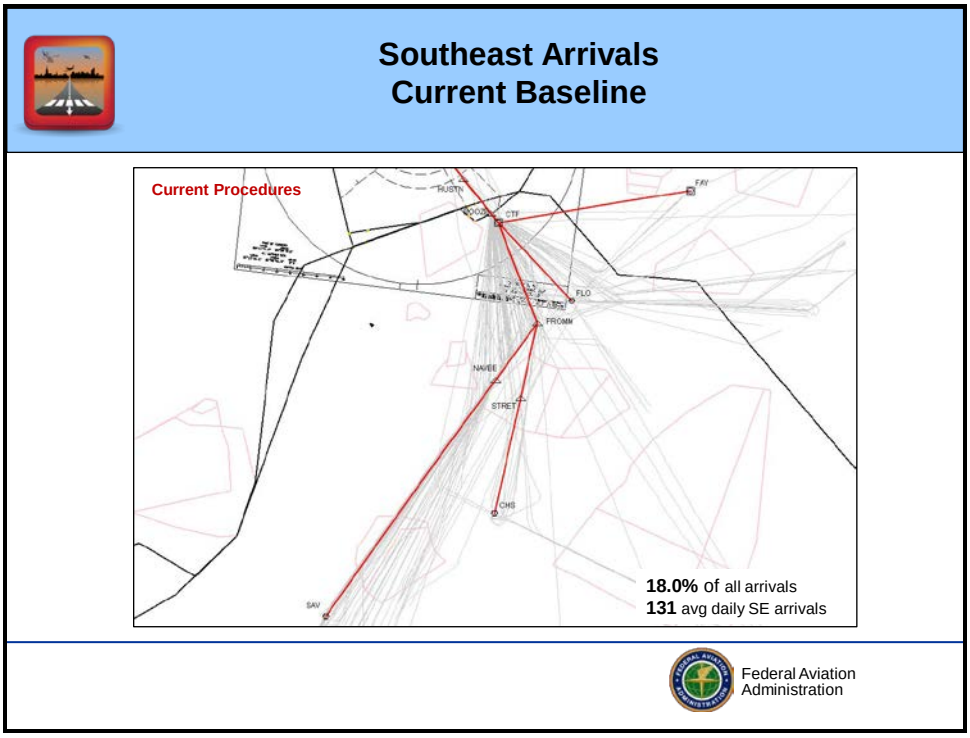
Compared to currently flown tracks, flights on the proposed OPD STAR fly a route 0.4 NM shorter from LYH and 1.38 NM shorter from ARGAL. The reduction in distance flown results in an estimated annual fuel burn savings of $480K. The annual cost-to-carry savings for this proposed design is $10K.

In addition to the savings from reduction in distance flown, the elimination of level segments on the Northeast OPD RNAV STAR is estimated to result in a savings of $1.0 – 3.0M per year. This results in a total estimated annual savings of $1.5 – 3.5M, and an estimated annual reduction in CO_2 emissions of 5 – 13K metric tons. The proposed procedure, along with a summary of how distance fuel savings were calculated, as well as the estimated fuel and carbon savings, are provided in the graphic below.



4.1.2.4 Arrivals from the Southeast

Below is a depiction of the current RNAV HUSTN STAR from the southeast corner post. The tracks represent a day's traffic between 0700 and 2300 local time.



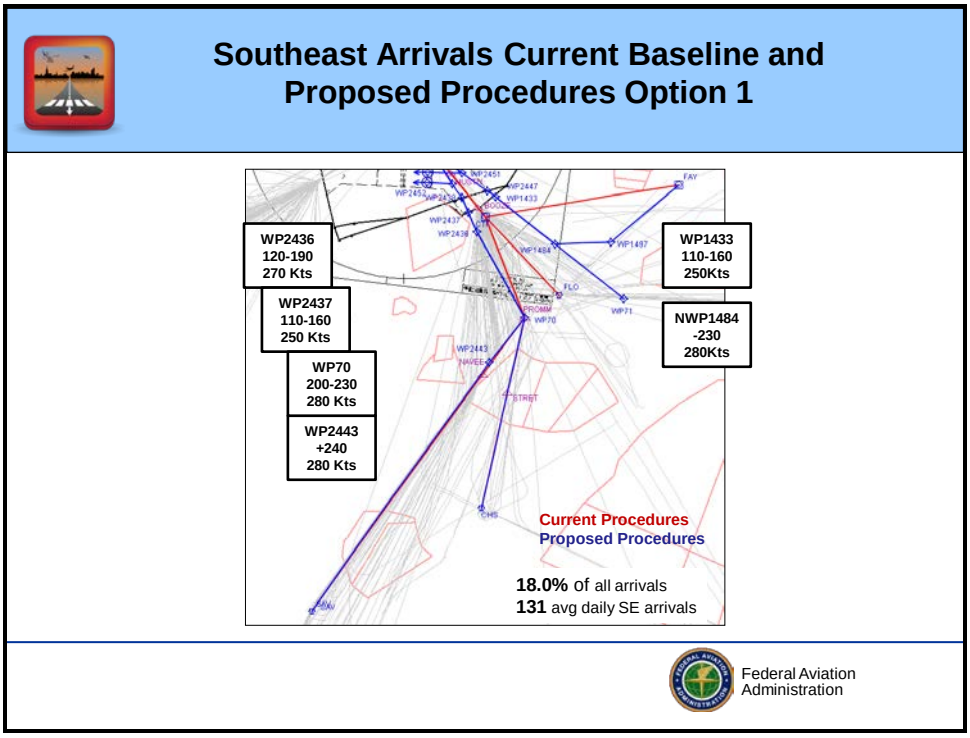
The OST proposed two designs for the Southeast RNAV STARs. Each proposal is described in detail, with considerations for the design and estimated benefits.

4.1.2.4.1 Option 1 for the Southeast Arrivals

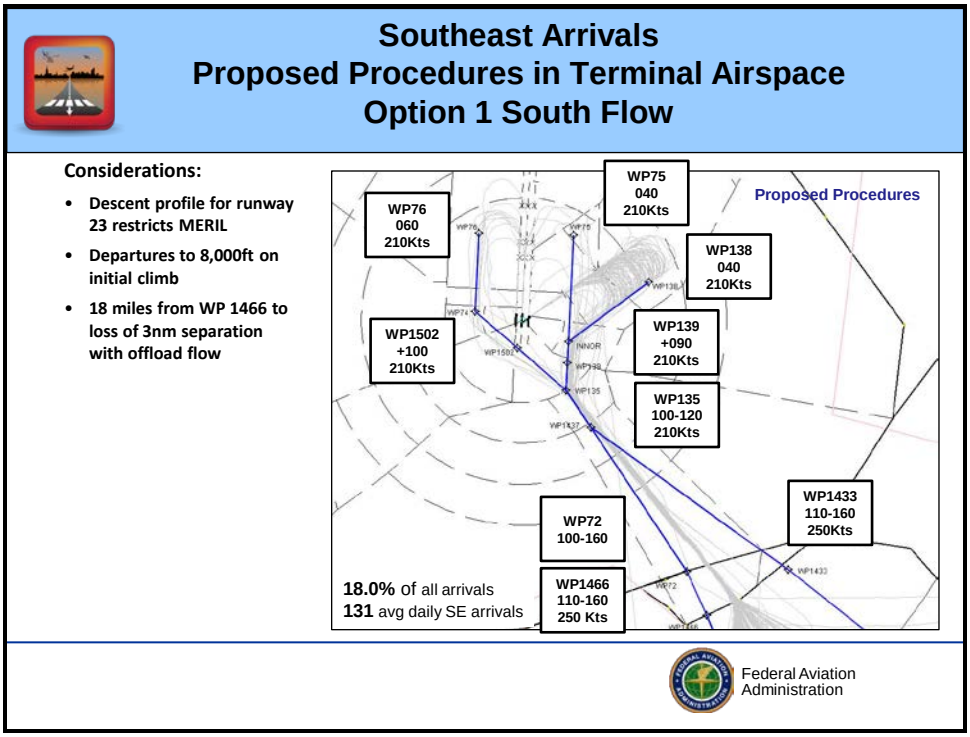
There are various issues the OST discussed regarding current arrivals from the southeast, and also a number of considerations for the proposed design of the first option for the southeast arrivals:

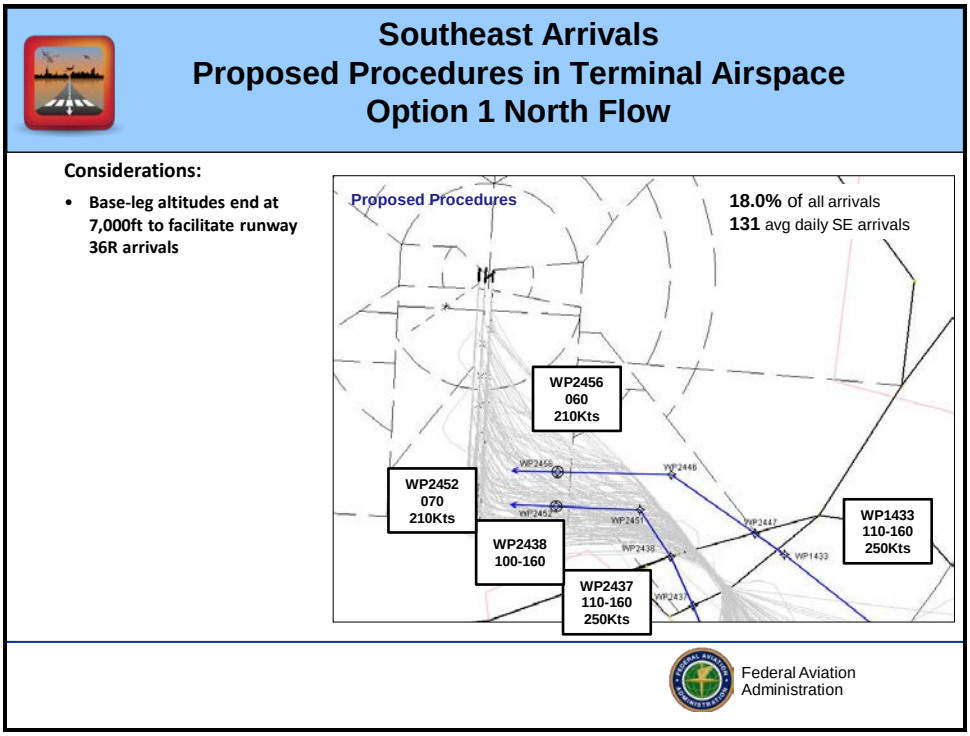
- Traffic within ZJX66 impacts the proposed transitions from Savannah (SAV) and Charleston, SC (CHS)
- Special Activity Airspace (SAA) (GAMECOCK, Aerial Refueling [AR600], and Restricted Area [R6002]) impact on transitions from SAV and CHS
- Parachute area near Laurinburg-Maxton Airport (KMEB) affects the design of the Fayetteville (FAY) transition
- Handoffs from ZDC in close proximity to CLT limits ZJX's time to sequence KCLT arrivals
- WP2443 misses GAMECOCK D Military Operations Area (MOA) but does not separate from ZJX74. Boundary changes may be required for ZJX71 and ZJX74.
- The OPD from CHS cannot be issued until WP70 when GAMECOCK D is active
- OPD arrival should avoid CHILI holding pattern for Shaw Air Force Base (AFB) High Tactical Air Navigation (HI-TACAN) approach
- KRDU arrivals over TENNI and KCAE departures
- Altitude restrictions at CLT boundary eliminates point outs from ZJX to ZTL, assuming a 16,000 feet ceiling for CLT airspace

Based upon the above considerations, the following is a composite display of the current HUSTN STAR with the proposed Option 1 OPD overlays. This proposed option for the Southeast RNAV OPD STAR overlays the lateral paths of the RNAV STAR from the SAV transition and the CHS transition. A second OPD STAR allows a more direct route between Florence (FLO) and the CLT boundary. The new FAY transition is now assignable (it should be noted that aircraft are not assigned the current FAY transition due to airspace conflictions) while reducing mileage. Key waypoints with their respective proposed altitude constraints are displayed.



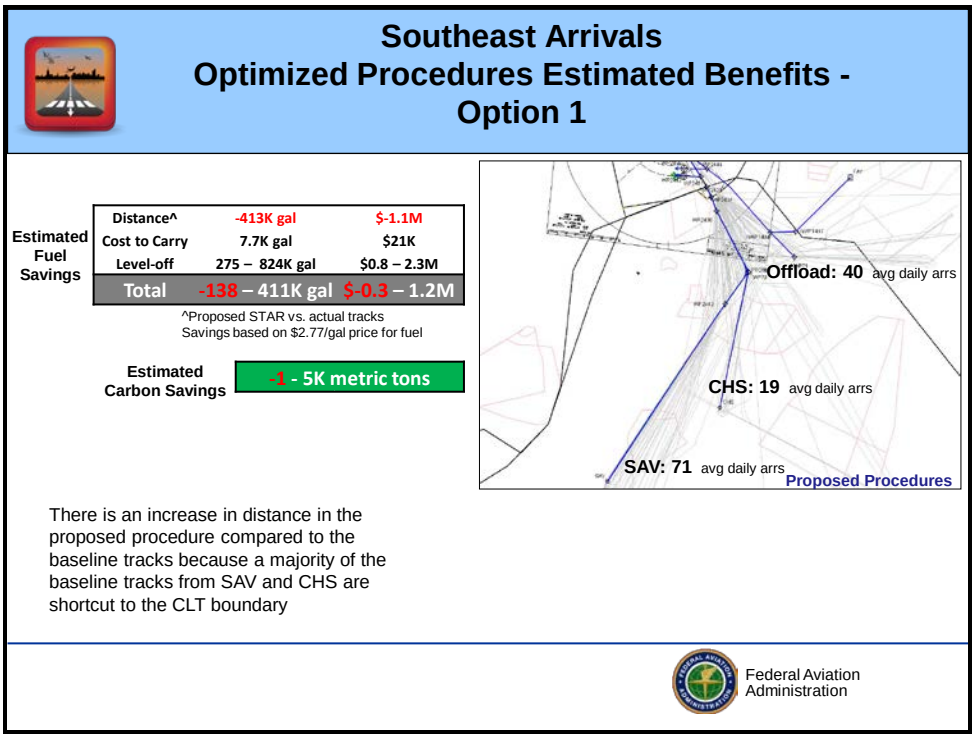
The following two graphics illustrate the considerations and altitude constraints for the proposed Option 1 primary and offload RNAV STARs for both south and north flow operations.





The proposed Option 1 OPD STAR overlays the en route transitions on the currently published STAR from SAV and CHS. While current operations allow controllers to shortcut once descended below ZJX66, aircraft descending on an OPD must follow a predictable lateral path. Criteria and ZJX concerns limited the ability to optimize the routing. Therefore, this design could not take full advantage of an OPD due to today's sectorization and traffic flows. The resulting OPD design shows a disbenefit in lateral track distance. The increase in distance from the proposed procedure to the flown tracks results in an additional estimated annual fuel burn cost of $1.1M, assuming all aircraft fly the proposed route. The annual cost-to-carry savings for this proposed design is $21K.

The elimination of level segments on the Southeast OPD RNAV STAR is estimated to result in a savings of $0.8 – 2.3M per year. However, due to the cost from additional miles flown, this results in a total estimated annual cost/savings of $-0.3 – 1.2M, and an estimated annual increase/reduction in CO_2 emissions of -1 – 5K metric tons.

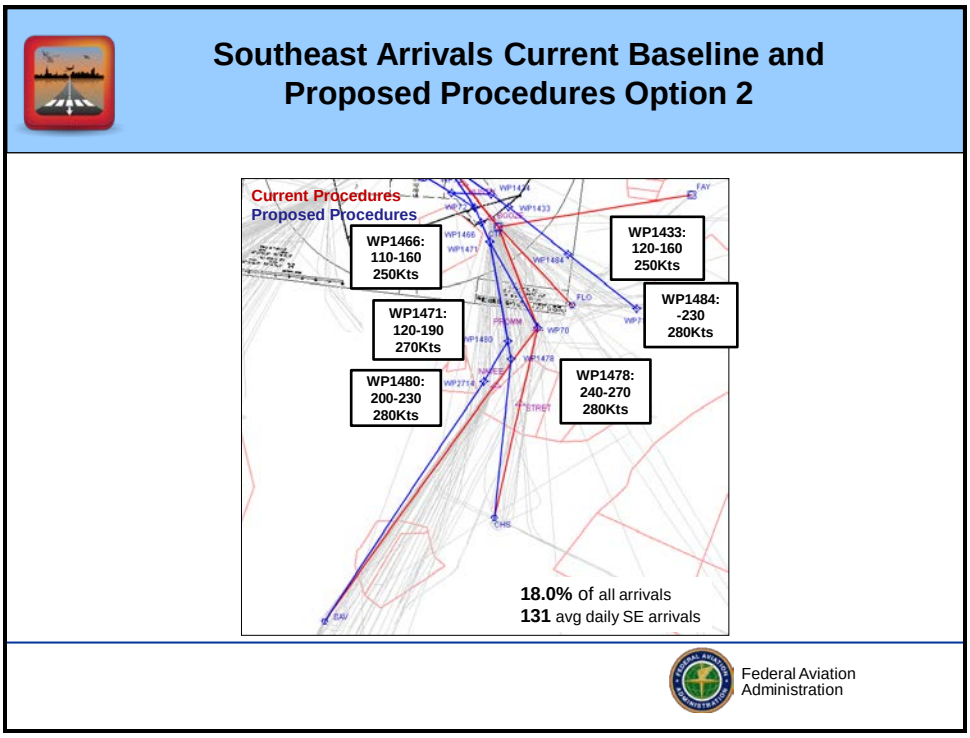


4.1.2.4.2 Option 2 for the Southeast Arrivals

There are various issues the OST discussed regarding current arrivals from the southeast, and also a number of considerations for the proposed design of the second option for the southeast arrivals:

- Facility concerns require further testing to validate operational feasibility of this option
  - Additional miles needed for blending the SAV and CHS transitions and space needed for TMA sequencing
  - Point outs required if the aircraft could not fly the OPD
- Traffic within ZJX66 impacts the proposed transitions from SAV and CHS. As a result, the proposed SAV transition remains clear of ZJX66
- Reduces flying miles compared to the proposed STAR Option 1
- OPDs can be conducted on the CHS transition when GAMECOCK SAA is active
- SAAs (GAMECOCK, AR600, and R6002) are concerns that have been mitigated with transitions from SAV and CHS
- WP71 and FAY transitions are interchangeable in design options 1 and 2
- Parachute area near KMEB affects the design of the FAY transition
- Handoffs from ZDC in close proximity to CLT limits ZJX's time to sequence KCLT arrivals
- WP2443 misses GAMECOCK D MOA but does not separate from ZJX74. Boundary changes may be required for ZJX71 and ZJX74.
- OPD arrival should avoid CHILI holding pattern for Shaw AFB HI-TACAN approach
- KRDU arrivals over TENNI and KCAE departures
- Altitude restrictions at CLT boundary eliminates point outs from ZJX to ZTL, assuming a 16,000 feet ceiling for CLT airspace

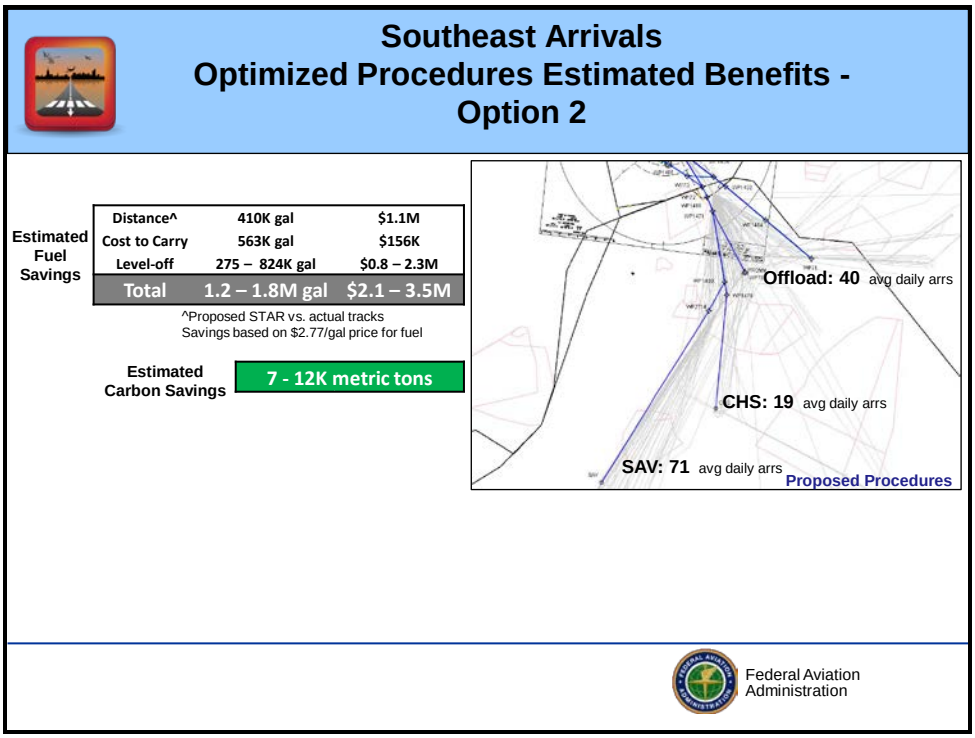
The following is a composite display of the current HUSTN STAR with the proposed Option 2 OPD overlays. The proposed Southeast RNAV OPD STAR overlays the lateral paths of the RNAV STAR from the SAV transition and the CHS transition. A second OPD STAR allows arrivals a more direct route between FLO and the CLT boundary. The new FAY transition from Option 1 is still available in Option 2 and is assignable while reducing mileage. Key waypoints with their respective proposed altitude constraints are displayed.



Within the terminal area, the designs for the proposed RNAV STARs are the same for Option 2 as they are in Option 1. As a result, those proposals are not displayed again.

The proposed Option 2 of the Southeast OPD RNAV STAR provides more direct routing to the TRACON boundary when compared with the en route transitions on the currently published STAR from SAV and CHS. The reduction in distance from the proposed procedure to the flown tracks results in an estimated annual fuel burn savings of $1.1M. The cost-to-carry savings for this proposed design is $156K.

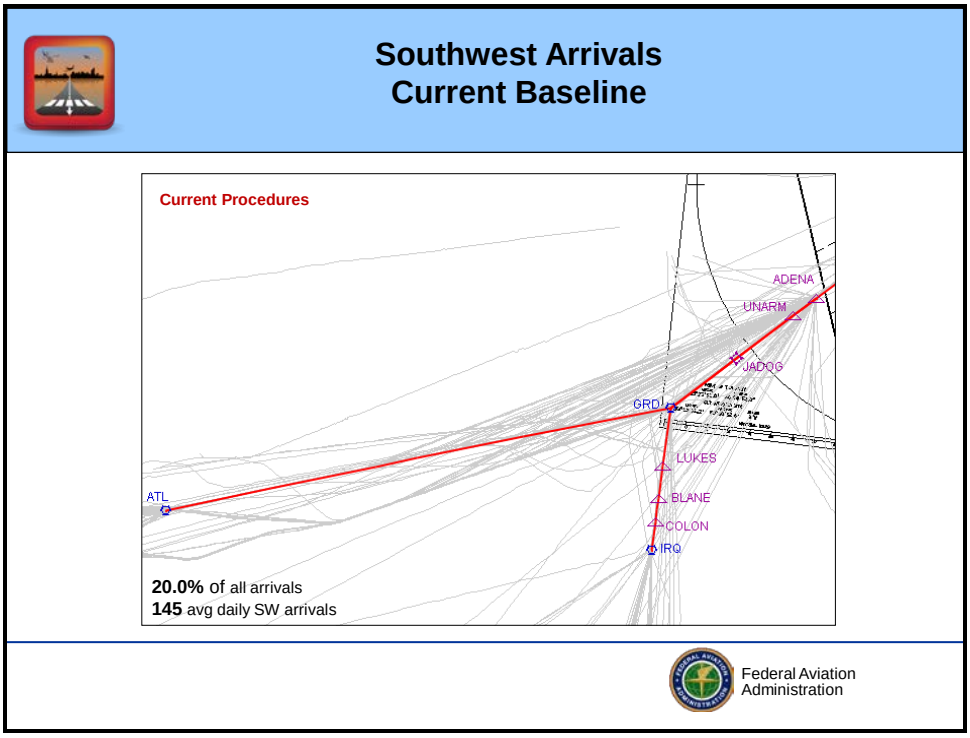
The elimination of level segments on the Southeast OPD RNAV STAR is estimated to result in a savings of $0.8 – 2.3M per year. This results in a total estimated annual savings of $2.1 – 3.5M, and an estimated annual reduction in CO_2 emissions of 7 – 12K metric tons.



Due to the benefits that can be achieved by this second option, it is the recommendation of the OST that Option 2 for the Southeast RNAV STARs be pursued by the D&I team. It is recognized that, at the time of this report, ZJX has concerns with this option. ZJX has agreed to further investigate the feasability of Option 2 through Human-in-the-Loop (HITL) simulations.

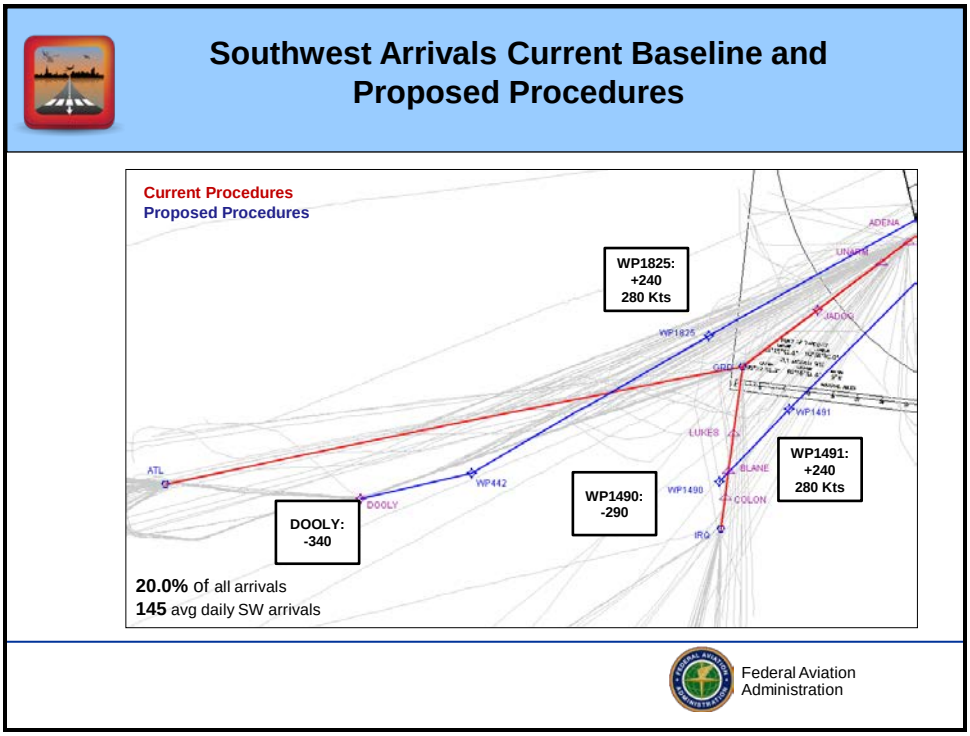
4.1.2.5 Arrivals from the Southwest

Below is a depiction of the current RNAV ADENA STAR from the southwest corner post. The tracks represent a day's traffic between 0700 and 2300 local time.



Final design will require coordination with the Atlanta OST, however, routings have been shortened to mimic current tracks and an additional parallel routing created to reduce delay vectoring.

The following is a composite display of the current ADENA STAR with the proposed OPDs. The proposed Southwest OPD STAR provides a more direct routing to the CLT boundary, while providing a possible preferential route from Hartsfield – Jackson Atlanta International Airport (KATL) to KCLT. A second OPD STAR gives KCLT arrivals a more direct route from Colliers (IRQ). Key waypoints with their respective proposed altitude constraints are displayed.

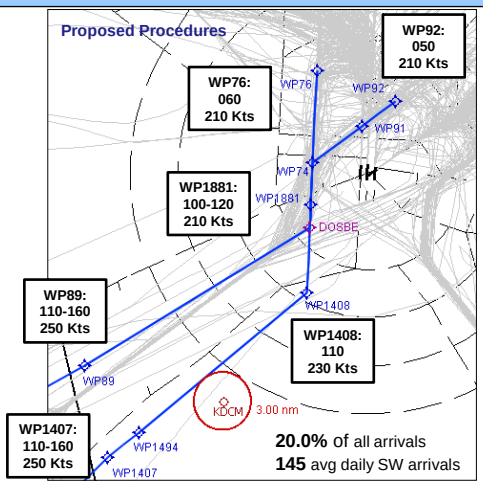


The following two graphics illustrate the considerations and altitude constraints for the proposed primary and offload RNAV STARs for both south and north flow operations.

Southwest Arrivals
Proposed Procedures in Terminal Airspace
South Flow

Considerations:

- **STARs avoid DCM airport sky diving area**
- **Proposed transition to Runway 23**

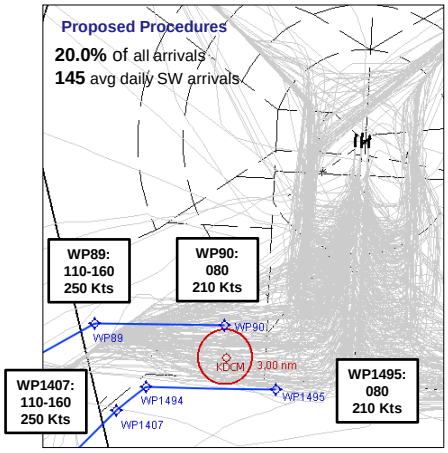


Federal Aviation Administration

Southwest Arrivals
Proposed Procedures in Terminal Airspace
North Flow

Considerations:

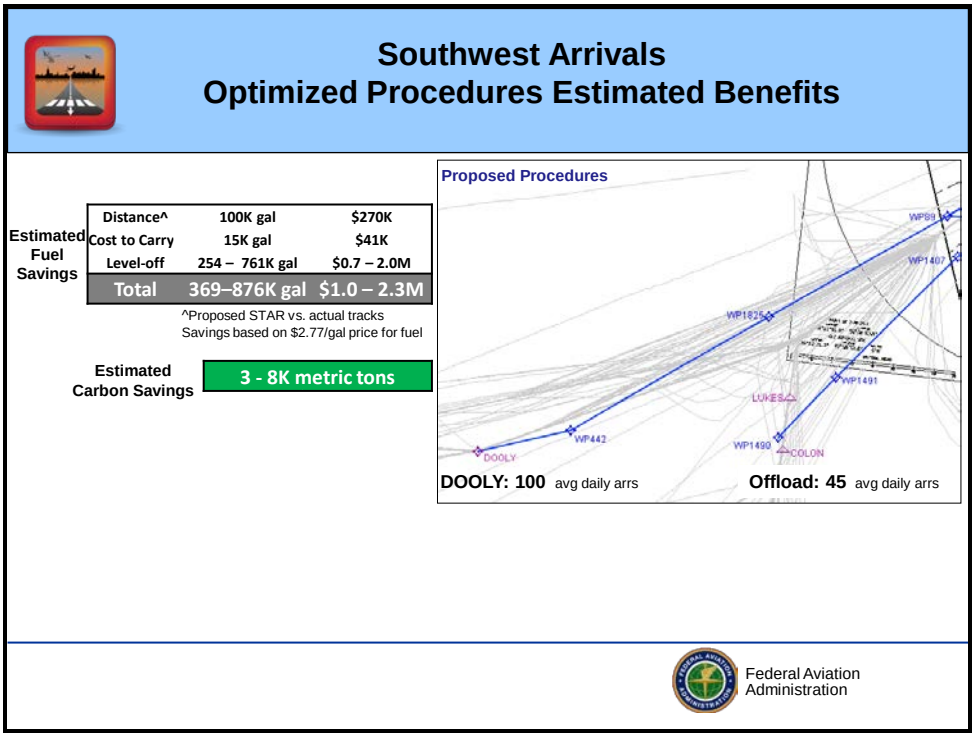
- **Base-leg altitudes end at 8,000ft to facilitate runway 36L and 36C arrivals**
- **STARs avoid DCM sky diving area**



Federal Aviation Administration

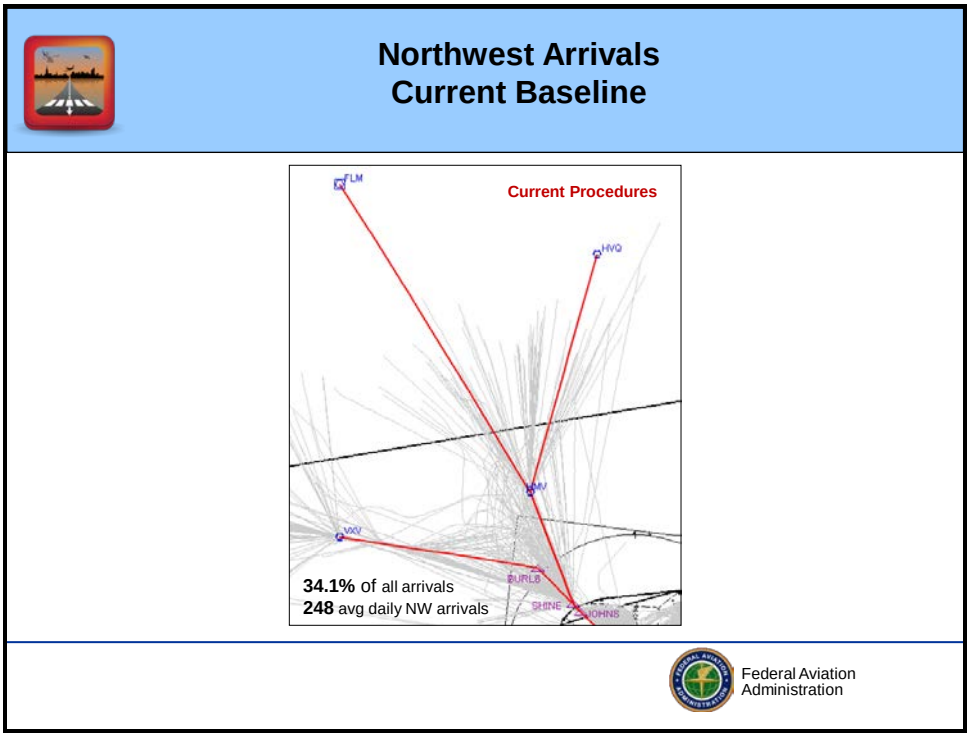
The proposed OPD STAR provides more direct routing to the CLT boundary when compared with the en route transitions on the currently published STAR from ATL and IRQ. The reduction in distance from the proposed procedure to the flown tracks results in an estimated annual fuel burn savings of $270K. The annual cost-to-carry savings for this proposed design is $41K.

The elimination of level segments on the Southwest OPD RNAV STAR is estimated to result in a savings of $0.7 – 2.0M per year. This results in a total estimated annual savings of $1.0 – 2.3M, and an estimated annual reduction in CO_2 emissions of 3 – 8K metric tons.



4.1.2.6 Arrivals from the Northwest

Below is a depiction of the current RNAV JOHNS STAR from the northwest corner post. The tracks represent a day's traffic between 0700 and 2300 local time.



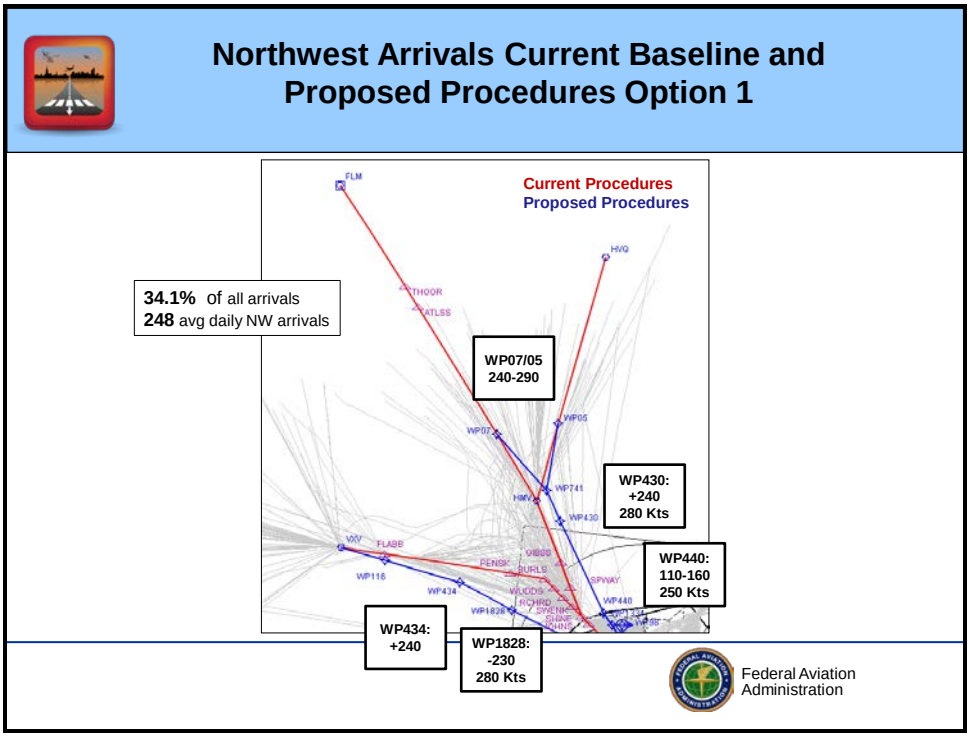
The OST has three proposed designs for the Northwest RNAV STARs. The third option (similar to today's single stream with the three transitions merging farther out in ZTL airspace) will not be included in this report due to having negative benefit. The remaining two options will be described in detail, with considerations for the design and estimated benefits.

4.1.2.6.1 Option 1 for the Northwest Arrivals

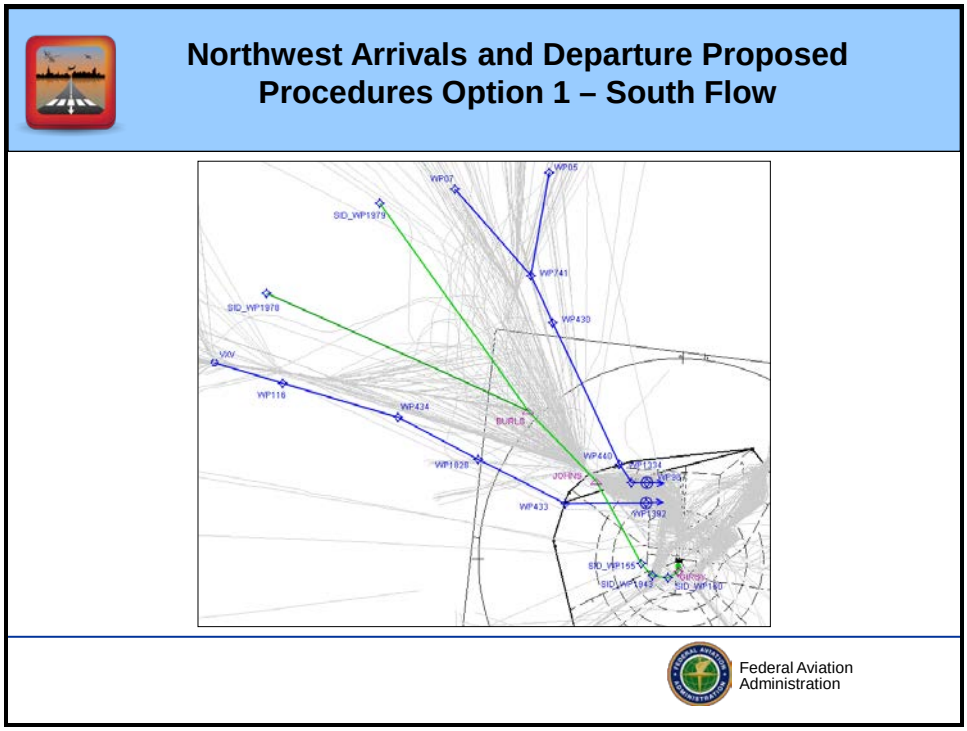
There are various issues the OST discussed regarding current arrivals from the northwest, and also a number of considerations for the proposed design of the first option for the northwest arrivals:

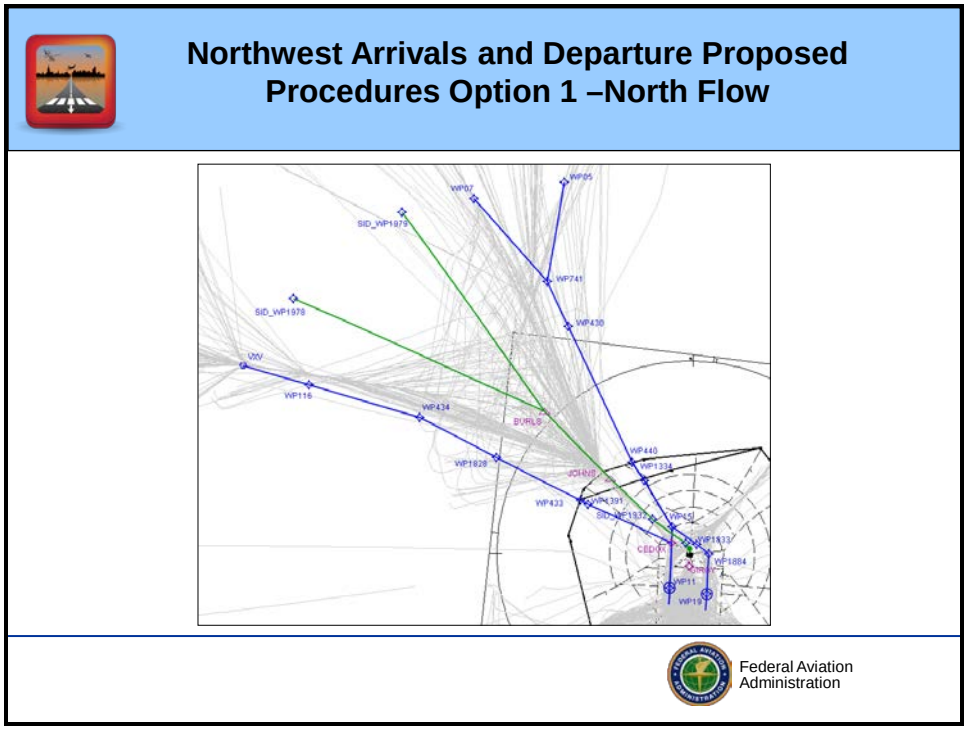
- Coordination with ZID indicated that they prefer no changes to TMA procedures for delivery of aircraft to ZTL on the northwest feed to CLT. Delivery of aircraft to the proposed ZTL boundary fixes is acceptable
- Blending of traffic with dissimilar ground speeds increases vectoring
- Proposed RNAV OPD splits the arrivals into two independent flows
- Proposed north bound SID Option 1 climbs out between the two arrival flows
- PITTY SID will need to be modified
- Sector workload will be more balanced due to splitting arrival/departure flows into two sectors
- KATL arrivals will dictate final altitude design and will require coordination with Atlanta OST

The following is a composite display of the current JOHNS STAR with the proposed Option 1 of the OPDs. The proposed Northwest OPD STARs provide more direct routings to the TRACON boundary. Key waypoints with their respective proposed altitude constraints are displayed.

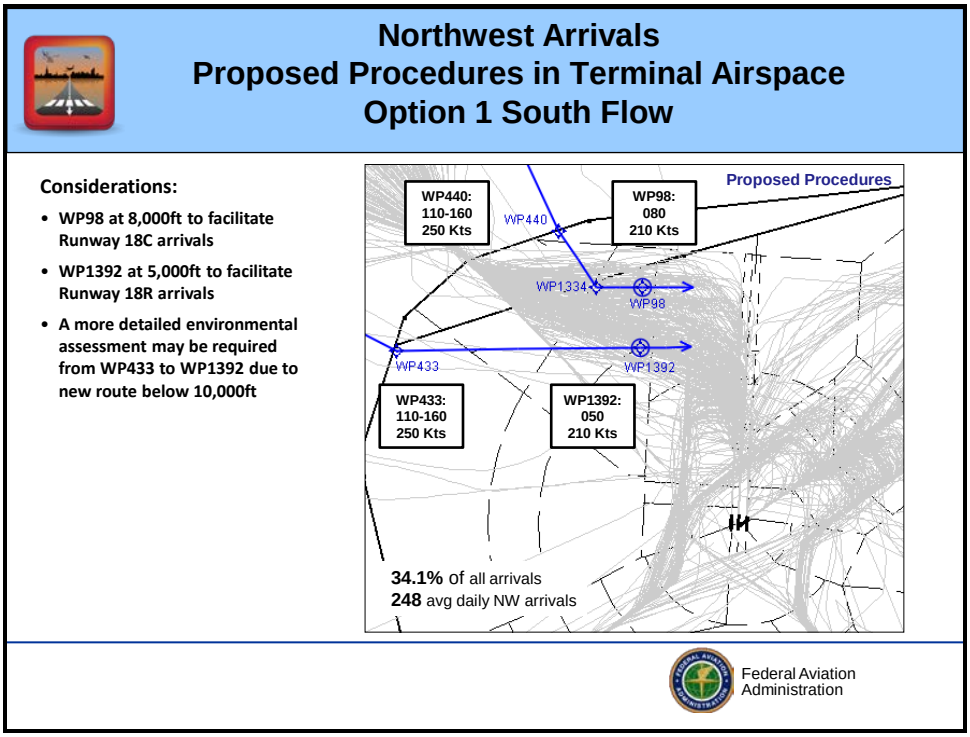


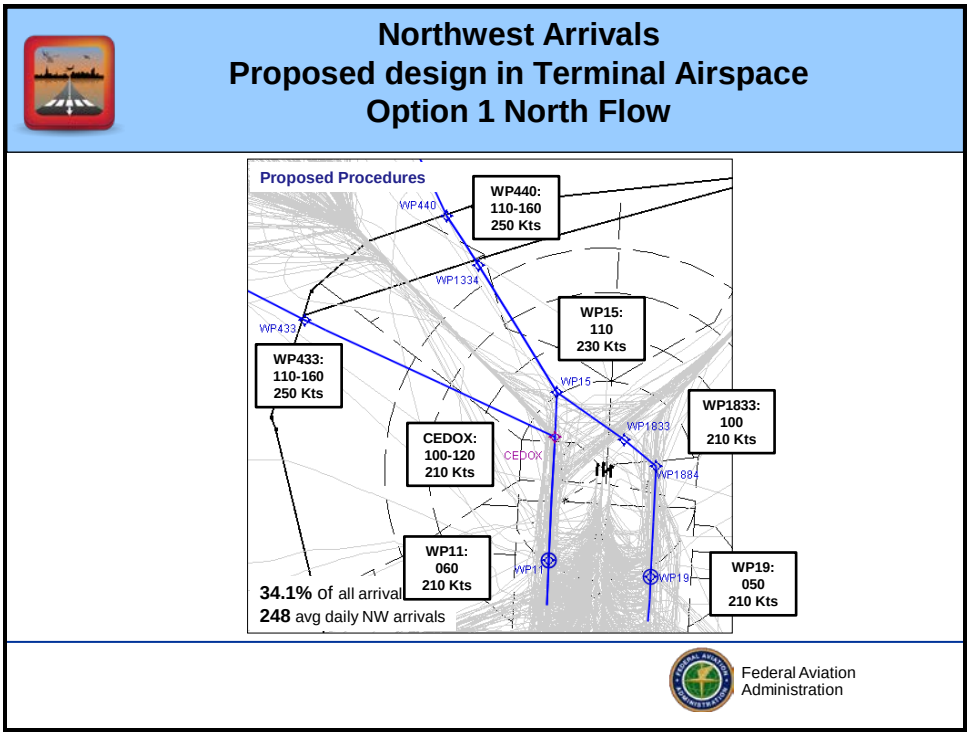
Option 1 for the northwest arrivals is designed to coincide with the first option to be proposed for the north bound RNAV SIDs, allowing for a SID between the northwest arrivals. The following two graphics depict Option 1 (blue) and the proposed Option 1 of the North RNAV SID (green).





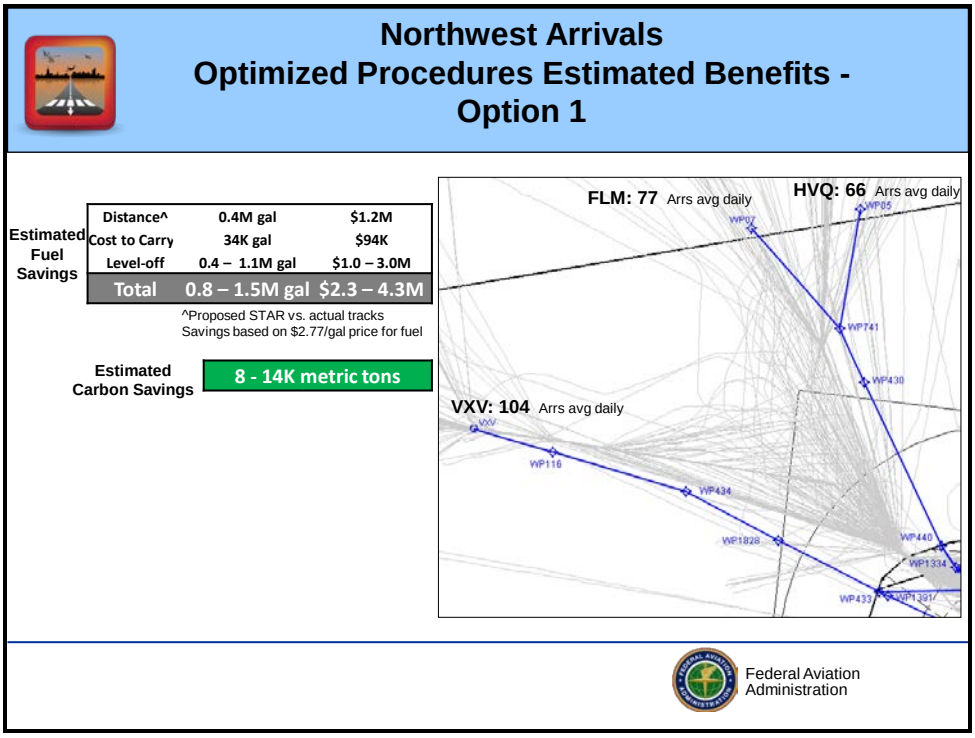
The following two graphics illustrate the considerations and altitude constraints for the proposed dual RNAV STARs for both south and north flow operations.





The proposed Option 1 of the Northwest RNAV OPD STAR**s** provide more direct routing to the CLT boundary when compared with the en route transitions on the currently published STAR from Volunteer (VXV), Charleston WV (HVQ), Holston Mountain (HMV), and Falmouth (FLM). The reduction in distance from the proposed procedure to the flown tracks results in an estimated annual fuel burn savings of $1.2M. The annual cost-to-carry savings for this proposed design is $94K.

The elimination of level segments on the Northwest RNAV OPD STAR is estimated to result in a savings of $1.0 – 3.0M per year. This results in a total estimated annual savings of $2.3 – 4.3M, and an estimated annual reduction in CO_2 emissions of 8 – 14K metric tons.

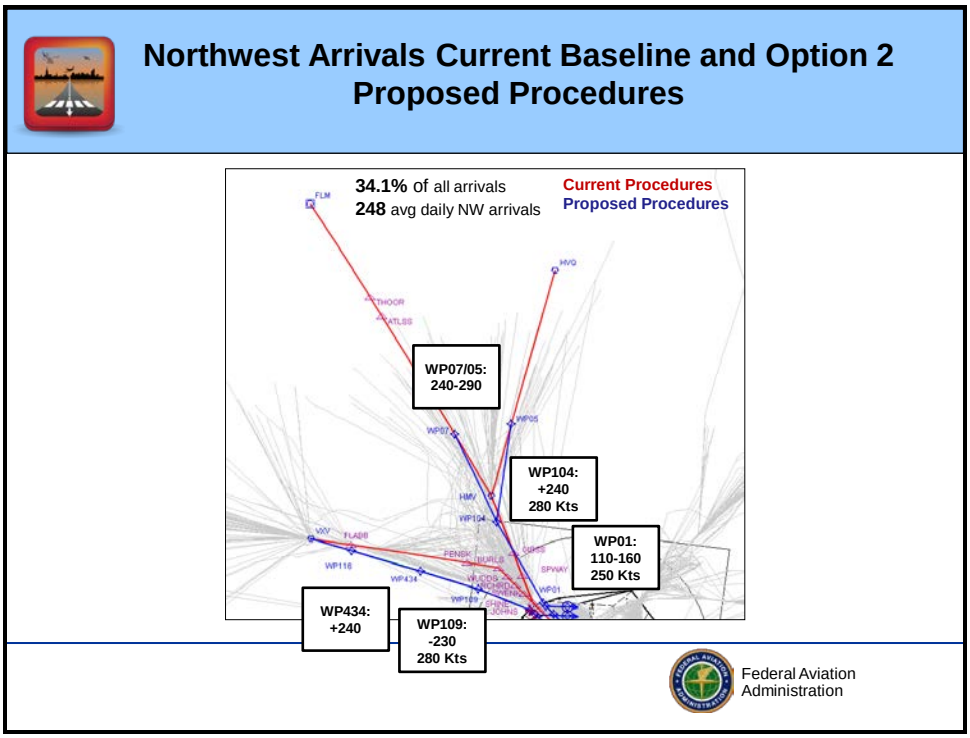


4.1.2.6.2 Option 2 for the Northwest Arrivals

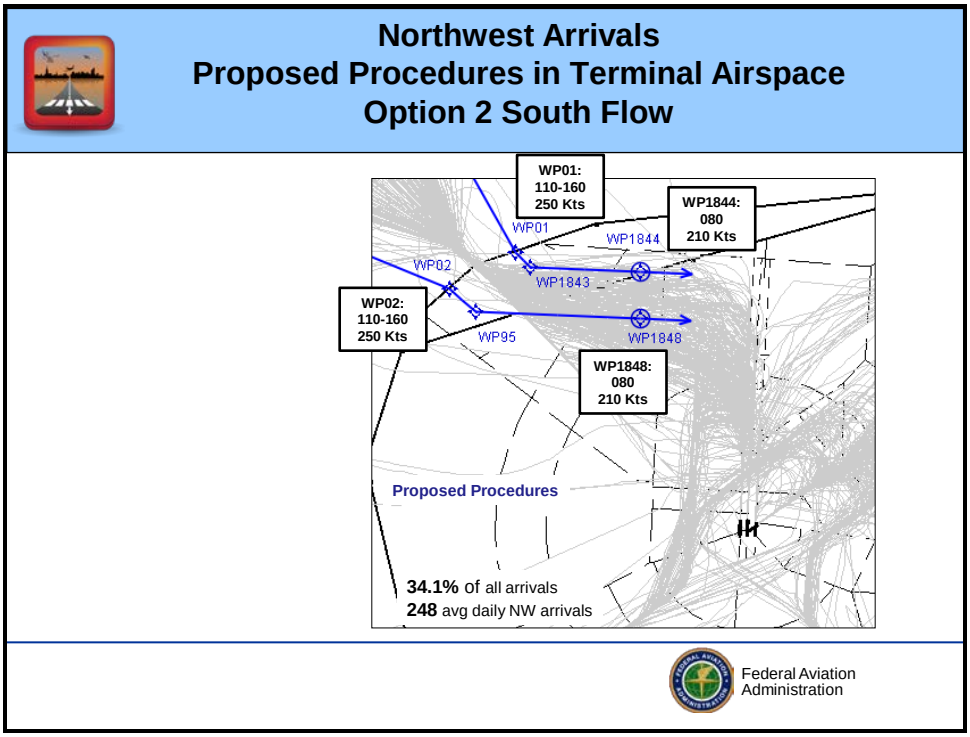
There are various issues the OST discussed regarding current arrivals from the northwest, and also a number of considerations for the proposed design of the second option for the northwest arrivals:

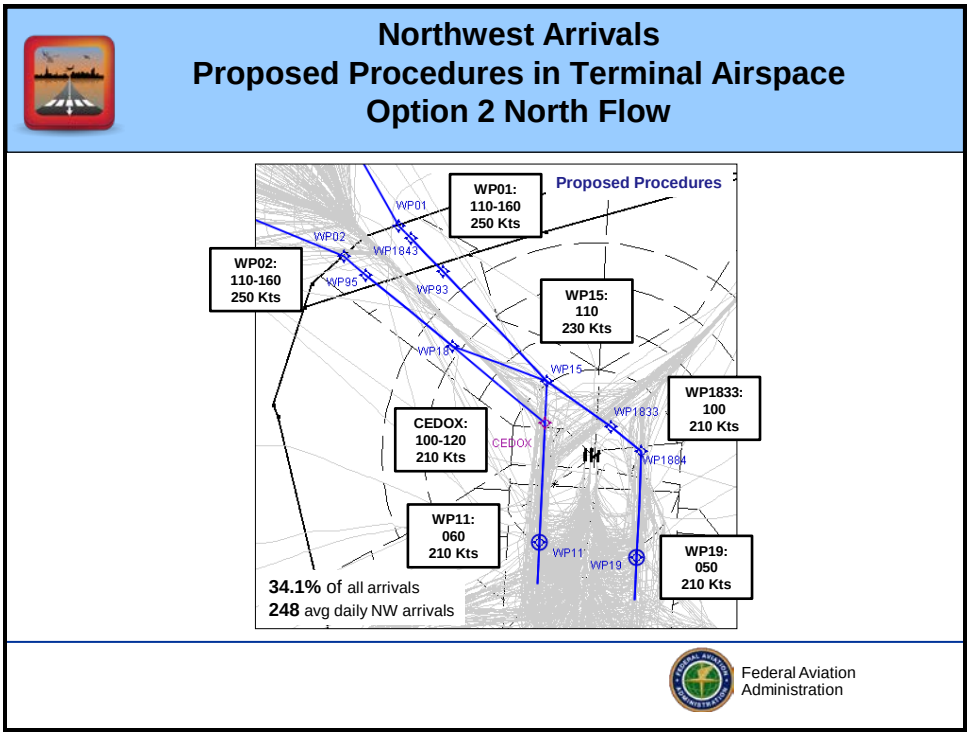
- Coordination with ZID indicated that they prefer no changes to TMA procedures for delivery of aircraft to ZTL on the northwest feed to CLT. Delivery of aircraft to the proposed ZTL boundary fixes is acceptable
- KATL arrivals will dictate final altitude design and will require coordination with Atlanta OST
- Blending of traffic with dissimilar ground speeds increases vectoring
- The proposed RNAV OPD STARs split the arrivals into two independent flows
- Sector workload will be balanced due to splitting arrival/departure flows into two sectors

The following is a composite display of the current JOHNS STAR with the proposed Option 2 OPDs. The proposed Northwest OPD STARs provide more direct routings to the CLT boundary. Key waypoints with their respective proposed altitude constraints are displayed.



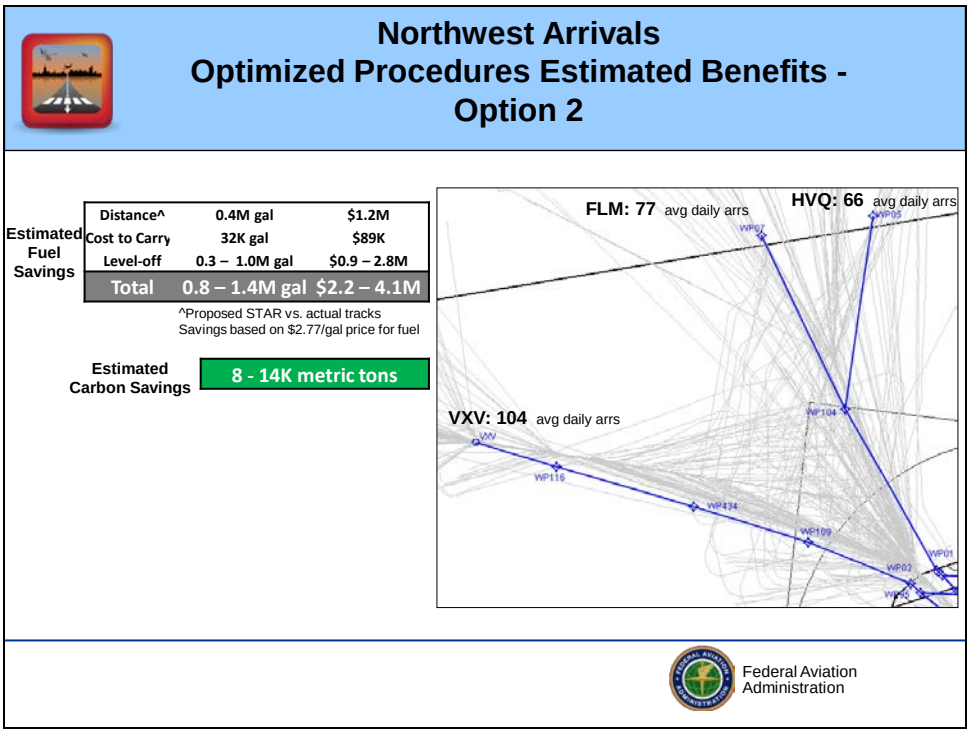
The following two graphics illustrate the considerations and altitude constraints for the proposed dual RNAV STARs for both South and North flow operations.





The proposed Option 2 of the Northwest RNAV OPD STARs provide more direct routing to the TRACON boundary when compared with the en route transitions on the currently published STAR from VXV, HVQ, HMV, and FLM. The reduction in distance from the proposed procedure to the flown tracks results in an estimated annual fuel burn savings of $1.2M. The annual cost-to-carry savings for this proposed design is $89K.

The elimination of level segments on the Northwest RNAV OPD STAR is estimated to result in a savings of $0.9 – 2.8M per year. This results in a total estimated annual savings of $2.1 – 4.0M, and an estimated annual reduction in CO_2 emissions of 8 – 14K metric tons.



While there is no difference in the benefits that can be achieved from distance savings between the two options, and very little difference in the benefits that can be achieved from reduction in level-offs, it is the recommendation of the OST that Option 1 for the Northwest dual RNAV OPD STARs be pursued by the D&I team. This recommendation is largely due to the mileage savings that can be achieved by the out-the-center RNAV SID that is associated with this option, described in a later section. It should be noted that further coordination with ZID will need to occur.

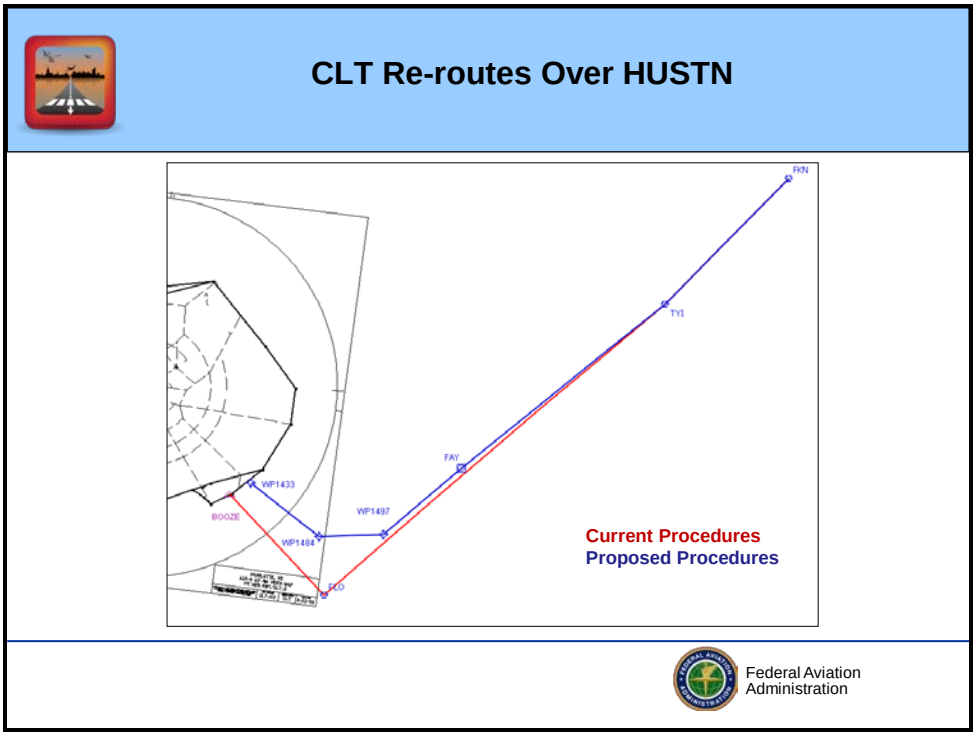
4.1.3 Identified Issue: KCLT Re-Routes over HUSTN

Industry identified an issue regarding the re-routing of aircraft from the Northeast SUDSY STAR to the Southeast HUSTN STAR prior to departing. This re-route results in additional miles flown for those KCLT arrivals affected.

This occurs for multiple reasons: due to weather affecting the northeast corner post, traffic may be re-routed to alleviate demand on the controllers and reduce the need for holding and delay vectoring in the northeast; to facilitate on-time departures at the origin airports, operators are filing the HUSTN route in order to depart on time, but are unable to re-route back over to SUDSY.

4.1.4 OST Recommendation: Implement Proposed RNAV STARs

By implementing the offload RNAV STAR recommended for the northeast arrivals, and the new FAY transition recommended for the southeast arrivals, the Charlotte OST believes that this issue can be mitigated. The offload RNAV STAR in the northeast may reduce the number of operators filing HUSTN in order to depart on time. Secondly, it should reduce the impact of weather on that corner post. The implementation of the new FAY transition for the southeast can decrease the distance flown for those aircraft that still have to be re-routed. The figure below illustrates the difference in the HUSTN re-route based upon the new FAY transition.



The Charlotte OST examined potential operational and airspace user benefits, impacts, and risks. The results of that examination are described in the tables below.

Operational/Safety	
Benefits	**Impacts/Risks**
- Proceduralized OPD on the FAY transition - Additional options due to the ATC assigned offload STAR	- Additional flying miles and fuel burn/emissions

Airspace User	
Benefits	**Impacts/Risks**
- Increased availability of the Northeast STAR - Reduced track miles Reduced fuel burn/emissions	

4.2 Departure Issues

The OST noted various improvements that could serve to increase CLT's efficiency and throughput during peak periods. Specifically, the solution proposals to increase arrival efficiency included the following:

- Optimizing departure climb profiles by mitigating/reducing periods of level-off
- Minimizing the distance flown on all current SIDs
  - Incorporate earlier route divergence
  - Increase departure throughput
- Creating additional en route transitions and new SIDs
  - MERIL departure procedure to the east
  - Departures to the south over CHOPN
  - Departure procedures to the west
  - JACAL departure procedure to the north

4.2.1 Identified Issues for SID Procedure Designs

The Charlotte OST identified multiple areas of optimization affecting the departure operations for KCLT ranging from minor level-offs experienced in both the en route and terminal airspace, less-efficient SID design, and lack of connectivity in the en route airspace structure.

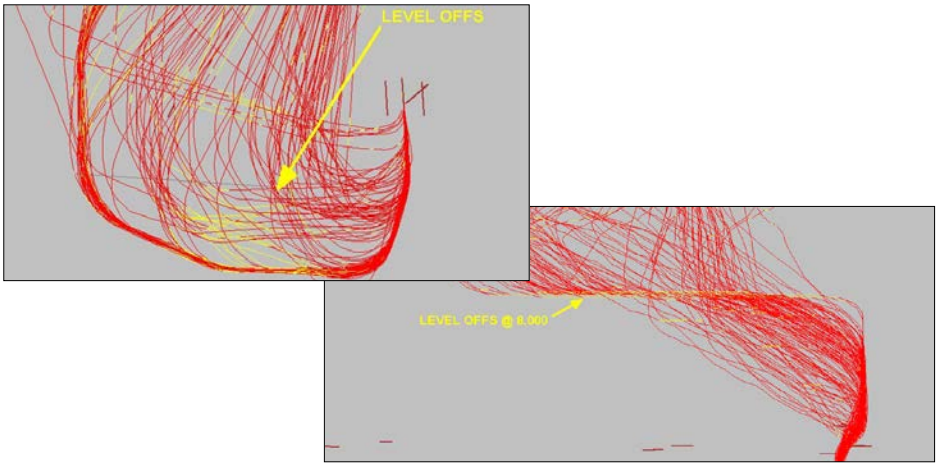
4.2.1.1 Terminal Airspace Level-Offs

KCLT departures can experience level-offs at 8,000 feet due to overhead arrival traffic at 9,000 feet.

In addition, current climb gradients result in some KCLT north departures (JACAL SID) on a south flow leveling off at 14,000 feet due to current sector boundaries in ZTL airspace. Aircraft must remain at or below 14,000 feet until within the lateral boundaries of ZTL47 (MOPED) unless coordination is achieved with ZTL30, resulting in non-optimal fuel burn. This also occurs for some south departures in a north flow. This coordination increases ATC task complexity.

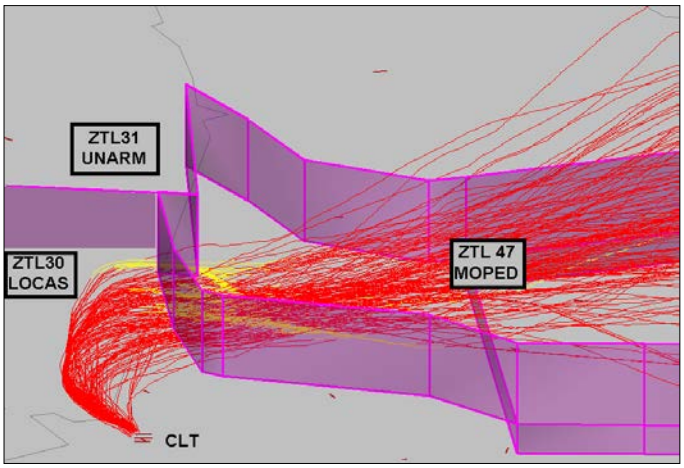
These issues are illustrated in the following two figures, respectively.

CLT Operational Issues Identified: Departure Level Offs Inside TRACON Airspace



Federal Aviation Administration

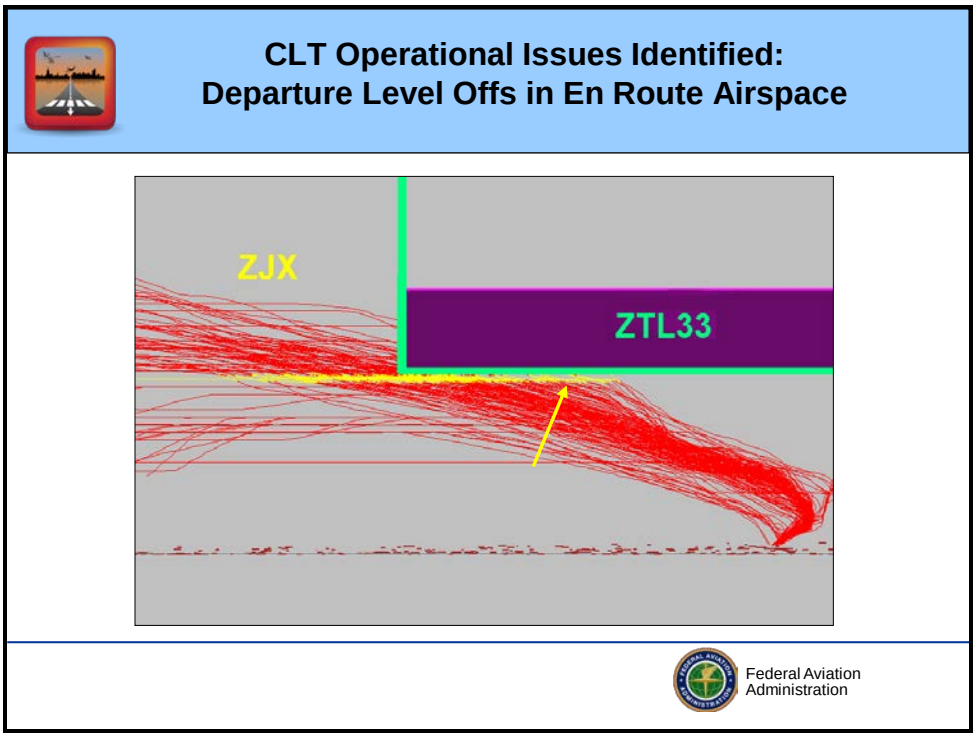
CLT Operational Issues Identified: Departure Level Offs Inside TRACON Airspace



Federal Aviation Administration

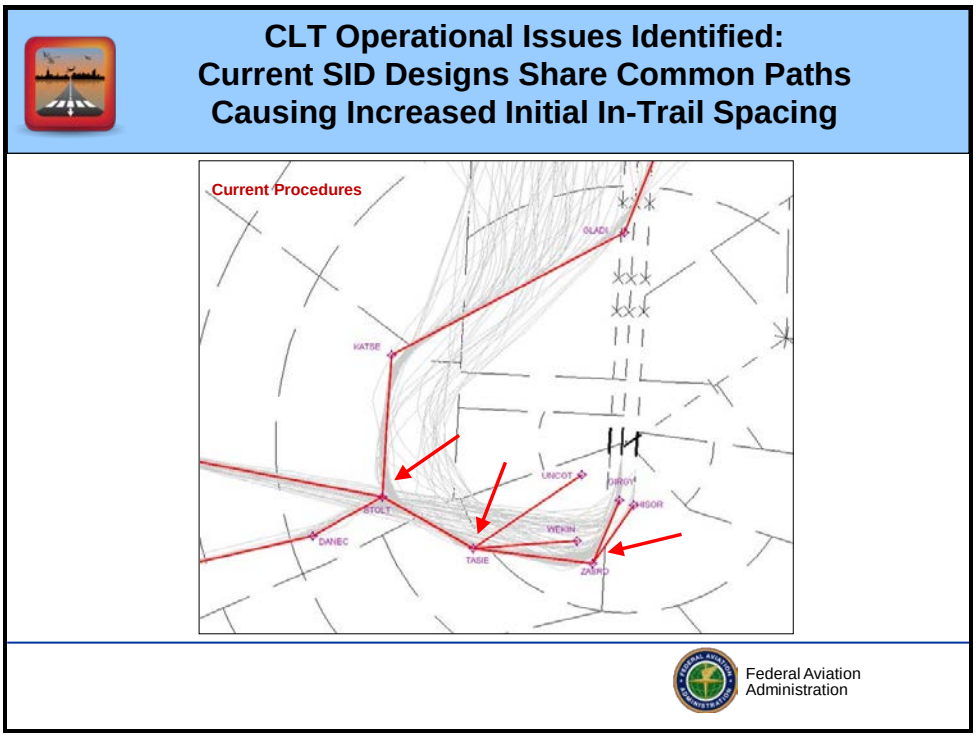
4.2.1.2 En Route Airspace Level-Offs

As depicted in yellow in the diagram below, current climb rate gradients require KCLT south departures on a north flow to level off at FL230 and FL270 due to the stratification of ZTL and ZJX sectors. Aircraft must remain at or below FL230 and/or FL270 until within the lateral boundaries of ZJX66 unless coordination is achieved with ZTL33, resulting in non-optimal fuel burn. This coordination increases ATC task complexity.



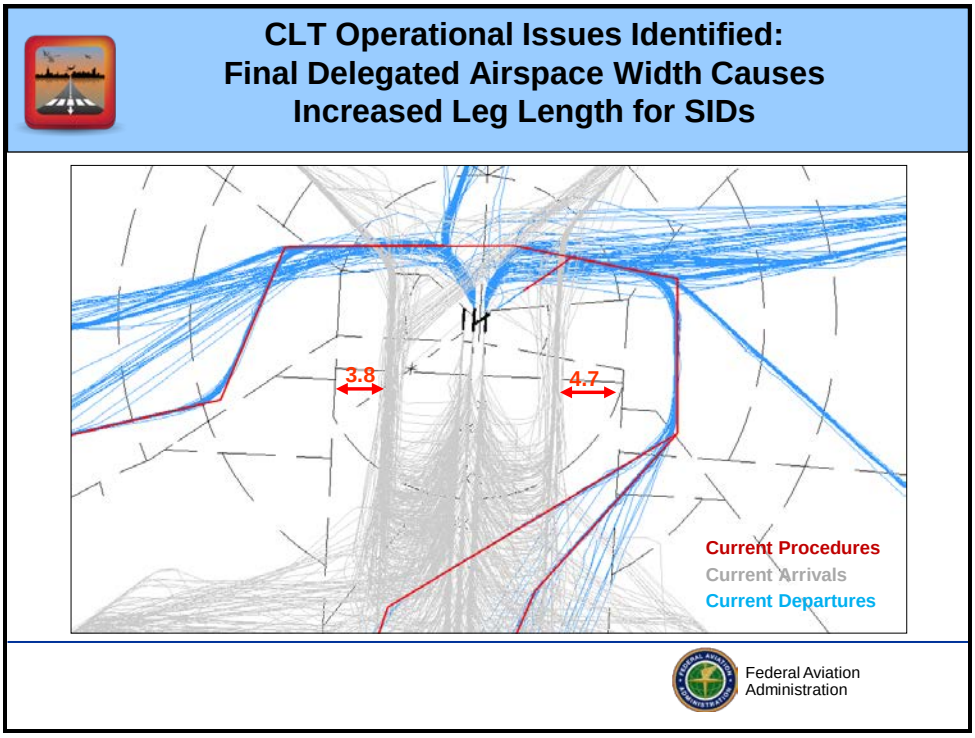
4.2.1.3 Increased Initial In-Trail Spacing Due to SID Design

Current RNAV SID routes follow a lengthy common path prior to course divergence. This results in an increase in departure in-trail spacing. Earlier divergence points to departure fixes will increase departure throughput, reduce miles flown, and lead to a more optimal fuel burn.



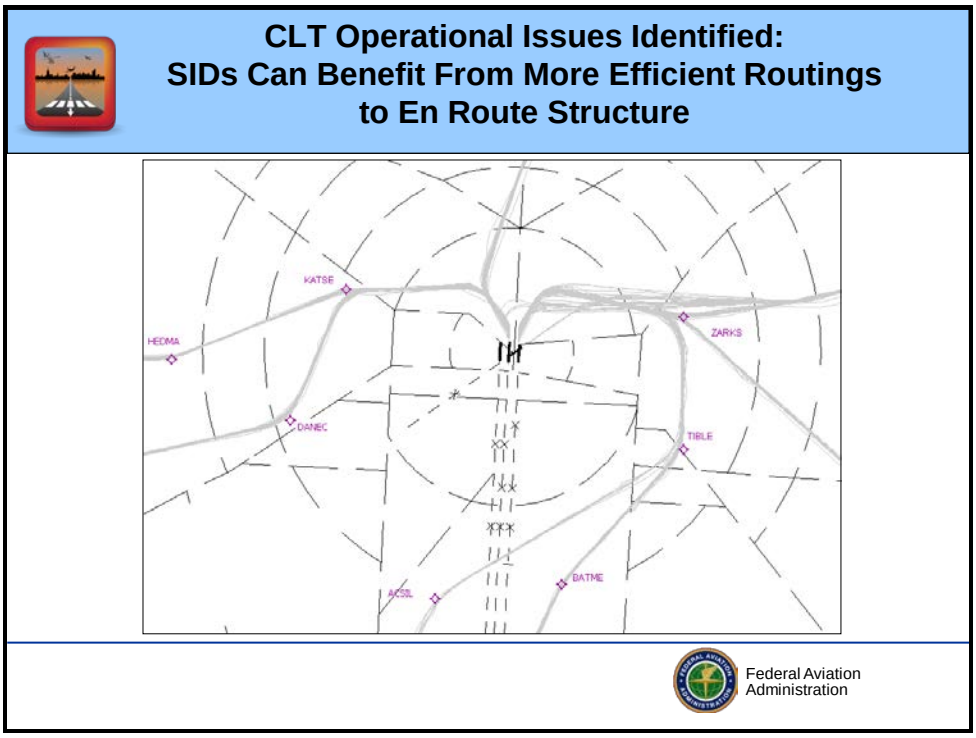
4.2.1.4 Width of Final Sector Impacts SID Leg Lengths

Observation of track data identified an opportunity to optimize final sector's airspace to more closely mimic standard final sector dimensions. The current final sector design requires increased track miles on departure procedures, as SIDs must remain laterally separated from final sector airspace.



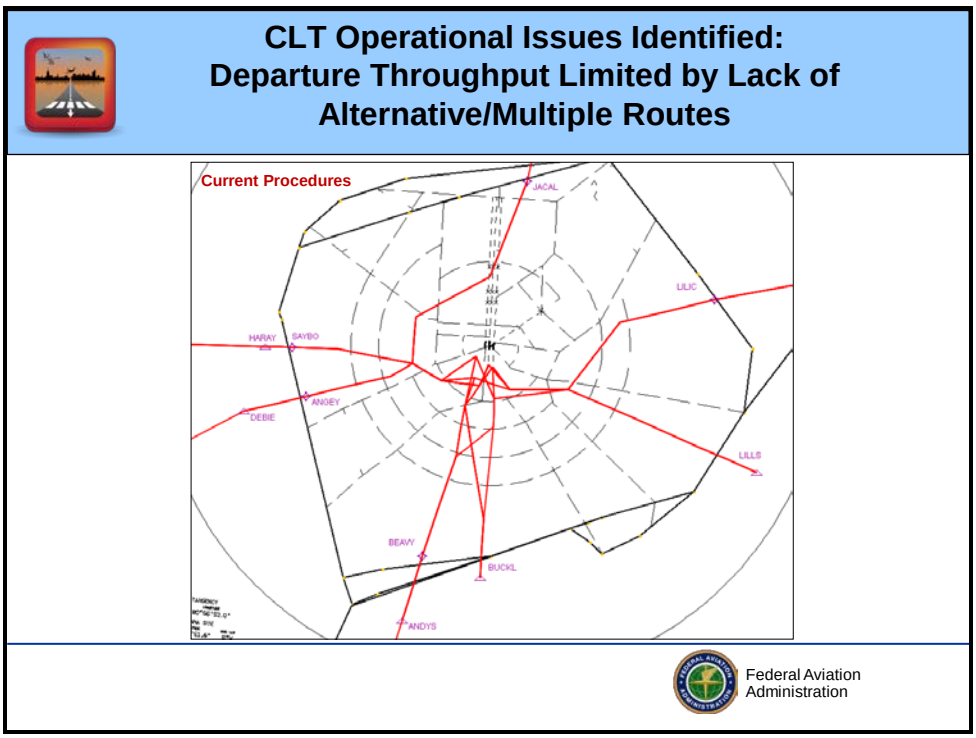
4.2.1.5 Less-Efficient Routings to En Route Structure

Some RNAV SID routes incorporate unnecessary doglegs creating excessive miles flown. Historical data indicates an opportunity to route aircraft direct to exit fixes, reducing miles flown and leading to more optimal fuel burn.



4.2.1.6 Need for Additional En Route Transitions and/or New SIDs

There is a lack of RNAV SIDS in all directions which results in reduced departure throughput, increased departure delays, and increased inter-departure times.



4.2.2 OST Recommendations: Optimize Current and Add New RNAV SIDs

The Charlotte OST recommends the optimization of the lateral paths for the current RNAV SIDs as well as the creation of additional RNAV SIDS to support KCLT departure flows. Optimizing the lateral path may also have the added benefit of reducing the occurrence of level-offs in both CLT and en route airspace.

The following tables describe the qualitative benefits, impacts, and risks of the solution concept, in regard to operational and airspace user concerns, as well as initial environmental screening issues.

Operational/Safety	
Benefits	**Impacts/Risks**
-Separated city pair flows reduce inter-departure delays -Designed with lateral spacing to accommodate future parallel routings -Eliminates high altitude crossover and provides more direct paths -Provides connectivity to en route structure -Provides published routes which mimic actual traffic flows	-Increased departure volume -Slight increase in track distance for aircraft during CLT north flow (less than 1nm) -East departures required to climb to 8,000ft due to Runway 23 arrival feed. All other departures climb to 9,000ft -Non-traditional interaction with northwest arrival routes -May require airspace modifications for second tier ARTCCs

Airspace User	
Benefits	**Impacts/Risks**
-Reduced "Out to Off" times -Reduces miles flown and may eliminate level offs between CLT, ZTL, and ZJX -City Pair routes aid in flight planning	-Possible level off for departures on the VXV/BNA route when departing north at CLT -Slight increase in track distance for aircraft during CLT north flow (less than 1nm)

Initial Environmental Screening
- Environmental Assessment required - All new routes that do no overlay current traffic are at or above 10,000ft. Routes do not appear to overlay any National Parks or Wilderness Areas.

The expected benefits associated from distance savings associated with the proposed procedures are described below, with more detail regarding the proposed optimizations described in upcoming sections of the document. The following graphic describes the total estimated annual benefit to be achieved from implementing the OST recommendations for all the RNAV SIDs.

Estimated Annual Fuel Savings from Distance^

North	599K gal	$1.7M
East	183K gal	$0.5M
South	186K gal	$0.5M
West	133K gal	$0.4M
Cost to Carry	132K gal	$0.4M
Total	**1.2M gal**	**$3.4M**

^Proposed SID vs. actual tracks

Estimated Carbon Savings **11K metric tons**

Savings reflect North option 1

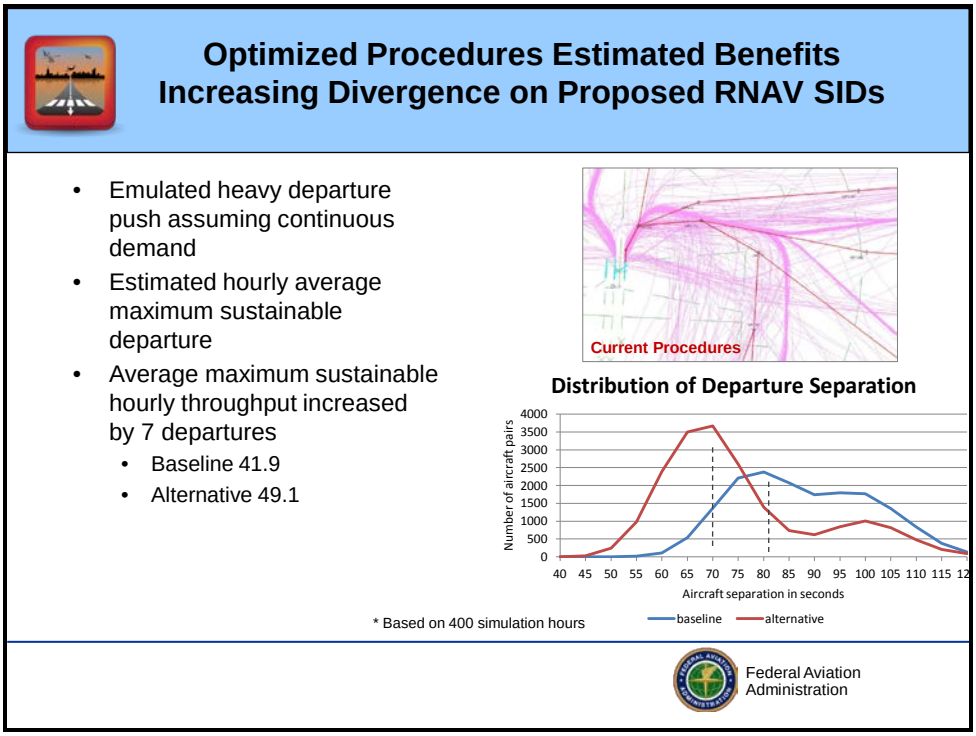
4.2.2.1 General Considerations for the Conceptual RNAV SIDs

The following issues were general considerations employed by the Charlotte OST while designing the conceptual RNAV SIDs for each departure direction:

- CLT airspace vertical limits expanded to include up to 16,000 feet
- Requires CLT and en route airspace changes
- Environmental Assessment will be required. Consideration must be given to flight tracks over National Parks and Wilderness Areas where a quiet setting is a generally recognized purpose and attribute
- Non-RNAV SIDs remain and may have to be redesigned by the D&I team
- Optimized STAR designs allow proposed SIDs an initial climb up to 9,000 feet, except for east (MERIL) departures on a south flow which permit an initial climb to 8,000 feet
- Routes diverge sooner, allowing reduced initial departure spacing and addressing airport concerns
- Optimizes PBN departure procedures to all fixes
- Reduces miles flown
- Direct/short cut ATC vector routings continue to be available when traffic and workload permit
- Facilitates interaction with current and future Q-Routes
- Pilot/controller training

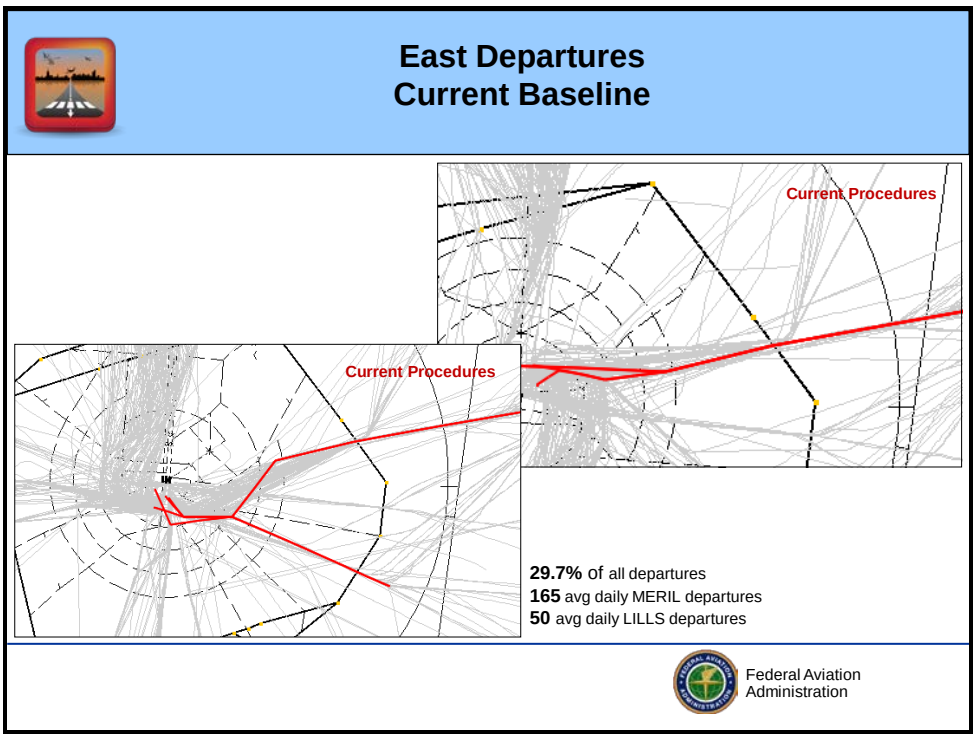
4.2.2.2 Impact of Increased Divergence

One of the main focuses for Charlotte OST in optimizing the KCLT departure procedures was to increase the number of divergence points and shifting them closer to the runway to allow for more efficient routing, decreased distance flown, and increased throughput. The NAT modeled the effects of this change, examining aircraft separation to determine average maximum sustainable departure throughput per hour. Based upon this simulation, it was found that during periods of high demand and assuming proper queuing of aircraft on the runways, an additional 7 aircraft could depart per hour.



4.2.2.3 Departures to the East

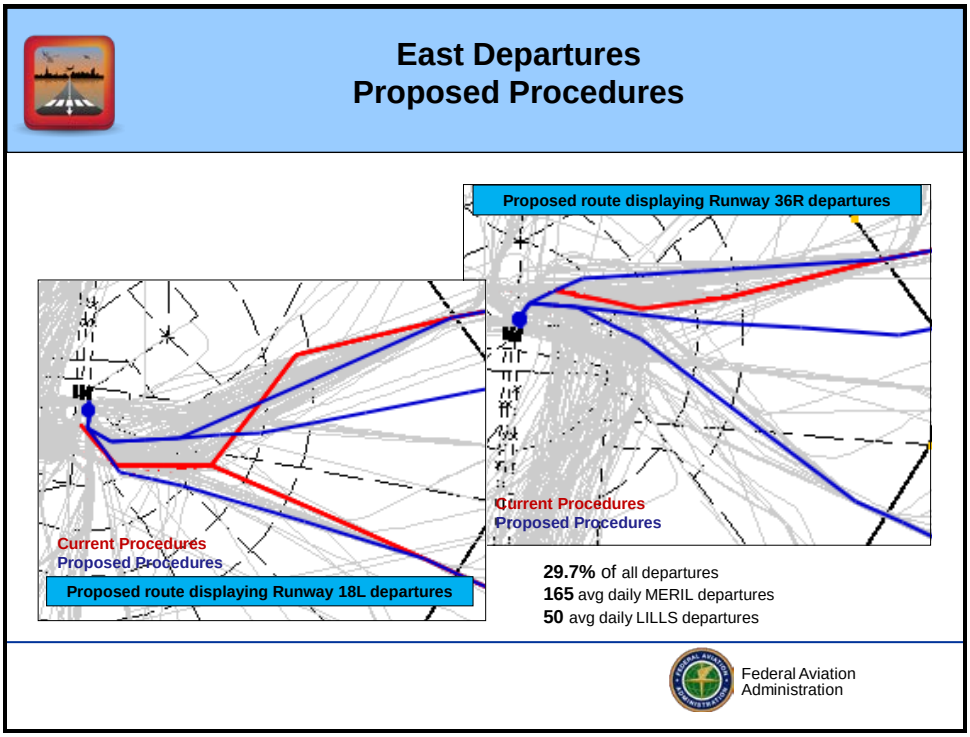
Below is a depiction of the current RNAV MERIL SID (east departure). North and south operations are depicted. The tracks represent a day's traffic between 0700 and 2300 local time.



The following issues were considered by the Charlotte OST while designing the conceptual RNAV SIDs for the east departure direction:

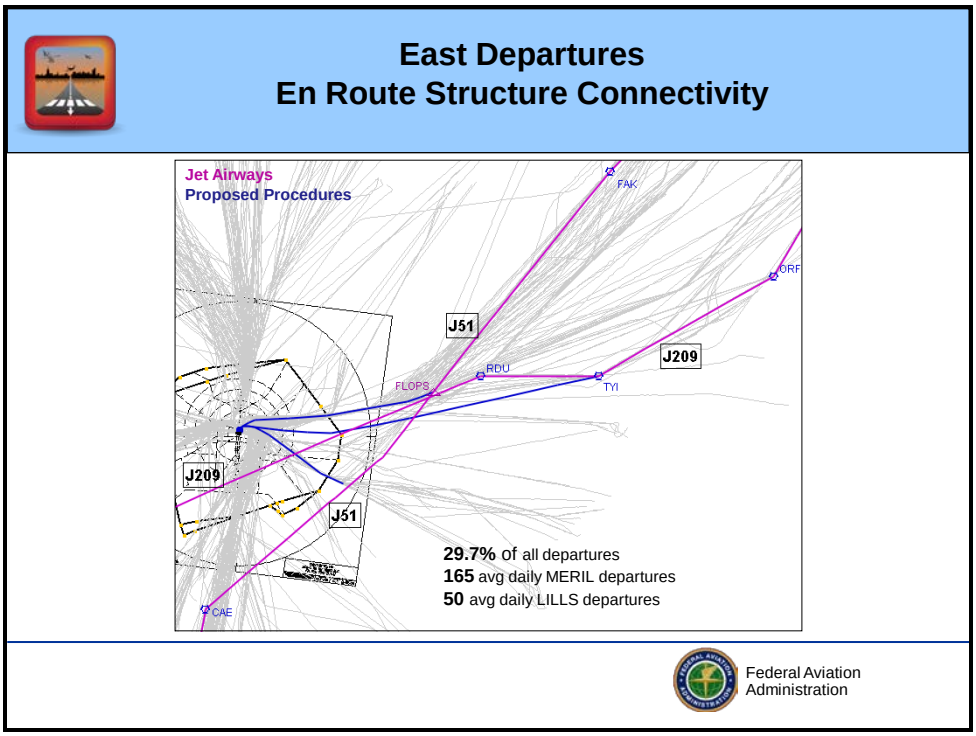
- Saturated en route sectors and overhead flows on jet routes J209 and J51 cause Miles-in-Trail (MIT) spacing on the current MERIL SID
- Current MERIL SID handles 29.7% of all KCLT daily departures and serves DC and NY metropolitan areas
- RDU departure routes conflict with the MERIL routing
- The east departure routes share common paths for approximately 15 miles prior to course divergence at TIBLE
- Continuity with DC OAPM Project should be considered

Below are the proposed east departures in blue, shown with the current procedures in red. North and south operations are also depicted. This procedure incorporates course divergence as close to the airport as possible.

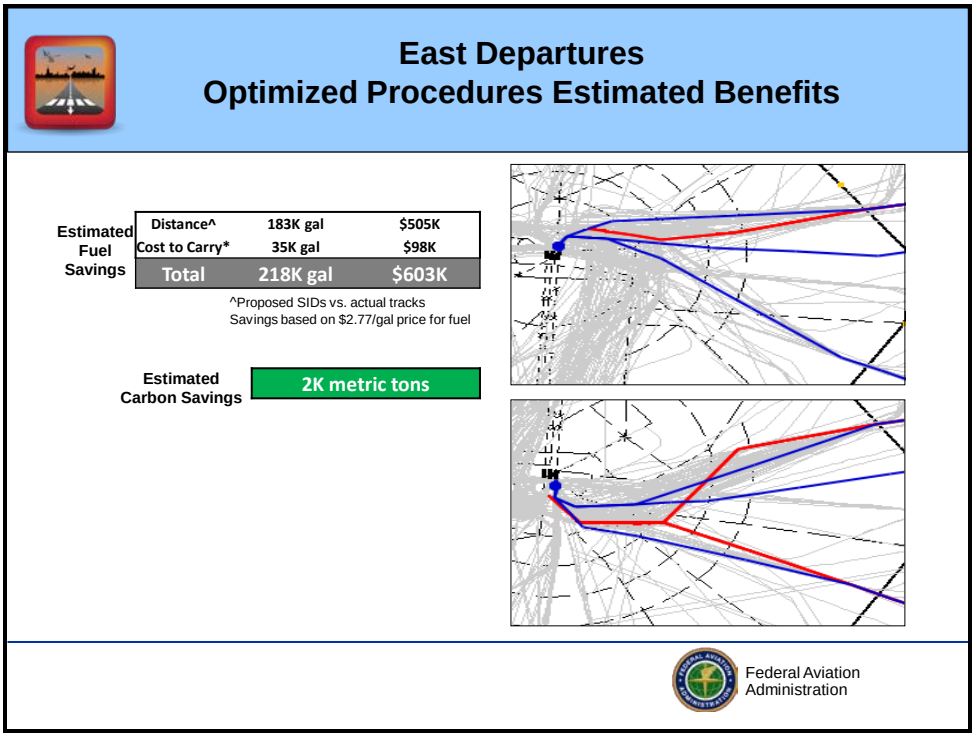


The following issues were considered by the Charlotte OST while considering en route connectivity for the optimized and new east departure procedures:

- Both departure procedures (modified MERIL and the new departure procedure) provide initial en route connectivity with transitions joining existing east coast routes
- Using two separate departure routes will de-couple major metropolitan destinations
- Routing is designed with lateral spacing between en route transitions



Most notably, the proposed RNAV SIDs more-closely overlay the currently flown tracks, proceduralizing some of the shortcut benefits gained by today's operations. This will allow for increased divergence between the modified MERIL and the new RNAV SID. The reduction in distance flown results in an estimated annual fuel burn savings of $505K. The annual cost-to-carry savings for this proposed design is $98K.



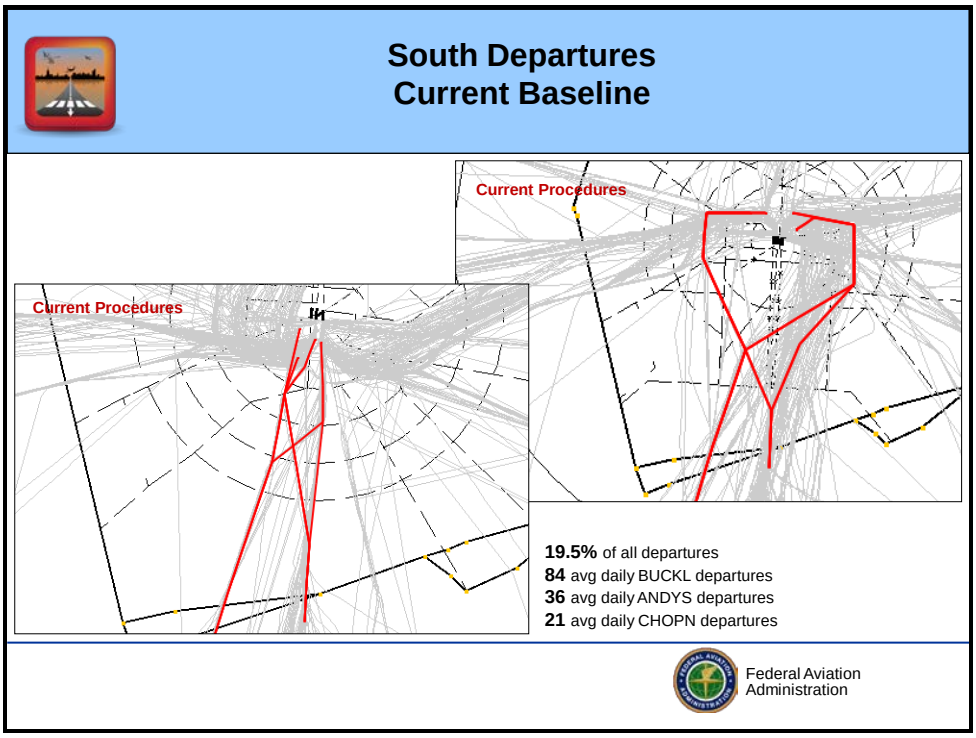
The tables below describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users. The industry interpretation of “Out to Off” refers to the amount of time between push back from the gate and departure.

Operational/Safety	
Benefits	**Impacts/Risks**
- Separated city pair flows reduce inter-departure delays - Specific routes connect to J209 and J51	- Increased departure volume - Slight increase in track distance for aircraft during CLT north flow (less than 1nm) - Departures required to climb to 8,000ft due to lower Runway 23 overhead arrival feed. All other departures climb to 9,000ft

Airspace User	
Benefits	**Impacts/Risks**
- Reduced “Out to Off” times	

4.2.2.4 Departures to the South

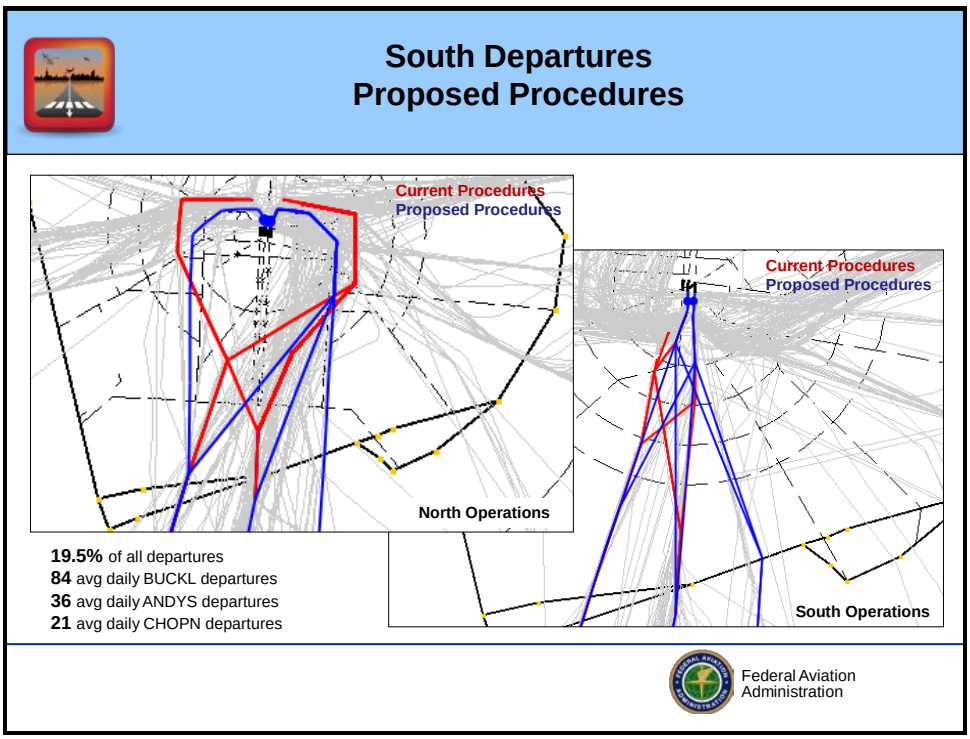
Below is a depiction of the current BUCKL and ANDYS SIDs (south departures). North and south operations are depicted. The tracks represent a day's traffic between 0700 and 2300 local time.



The following issues were considered by the Charlotte OST while designing the conceptual RNAV SIDs for the south departure direction:

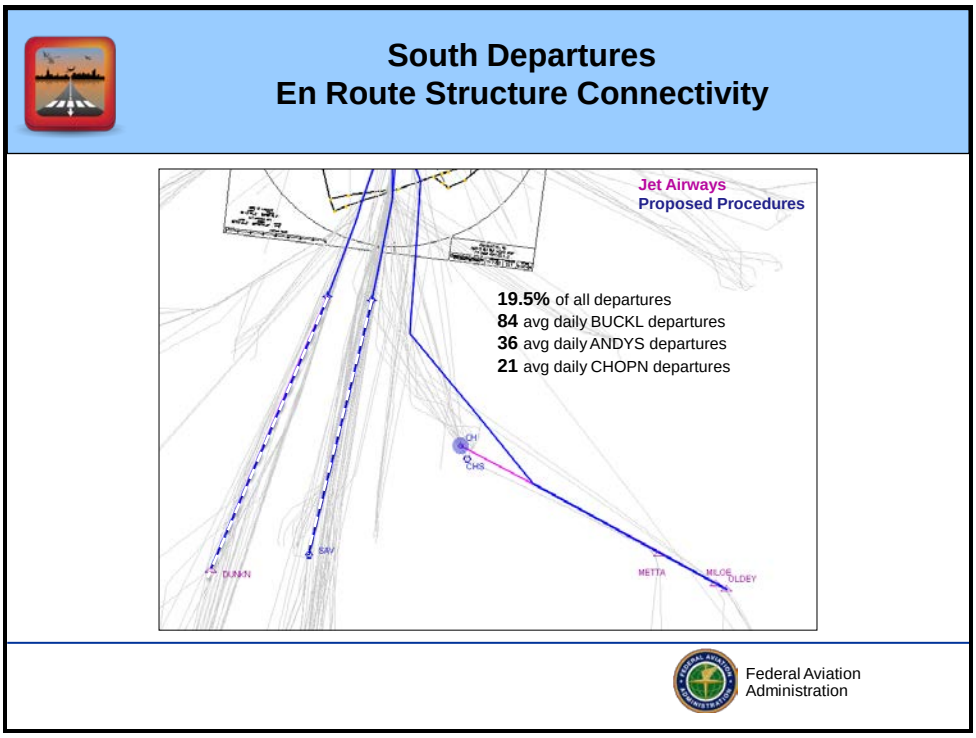
- Current ANDYS/BUCKL SIDs handle 19.5% of all KCLT daily departures
- The south departure routes share common paths for approximately 27 miles when departing north, which decreases throughput due to increased off-the-runway separation

Below are the proposed south departures in blue, shown with the current procedures in red. North and south operations are also depicted. This procedure incorporates course divergence as close to the airport as possible.

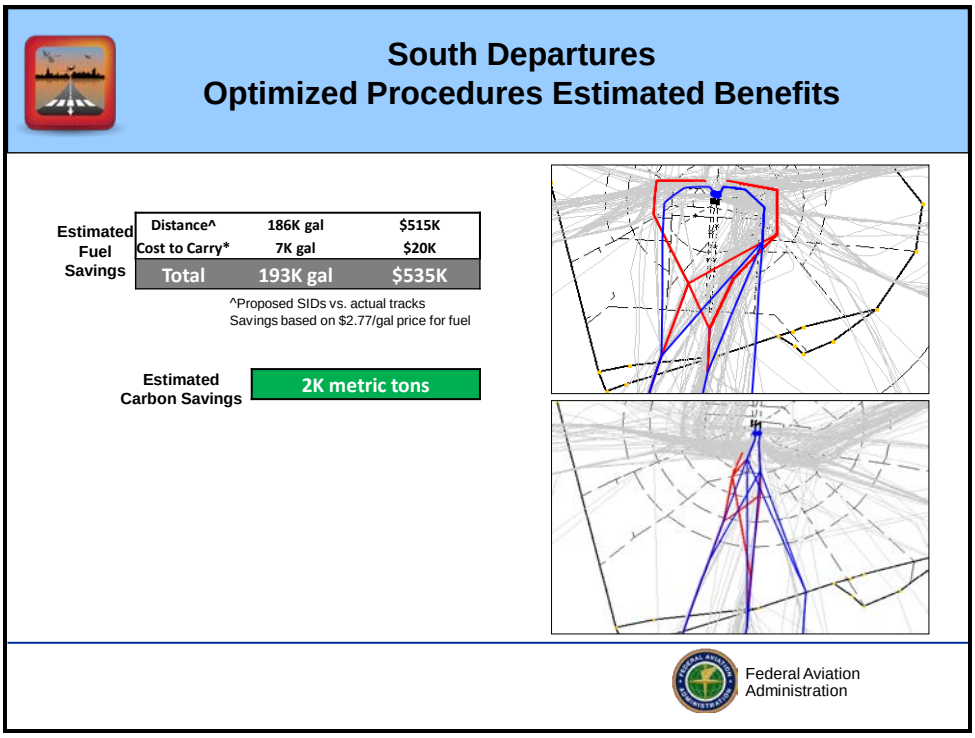


The following issues were considered by the Charlotte OST while considering en route connectivity for the optimized and new south departure procedures:

- ANDYS and BUCKL departures preserve connectivity with Atlantic Route 4 (AR4), J51, J53, J55, J75, J81, and J103
- Design en route transitions with adequate lateral spacing
- An additional turbojet departure route over CHOPN increases throughput for AR4 traffic and KCHS arrivals



The proposed RNAV SIDs closely overlay the currently flown tracks, proceduralizing some of the shortcut benefits gained by today's operations. This will allow for earlier divergence on the ANDYS and the BUCKL procedures. In addition, adding a new SID over CHOPN will allow for an additional dedicated turbojet route. The reduction in distance flown results in an estimated annual fuel burn savings of $515K. The annual cost-to-carry savings for this proposed design is $20K.



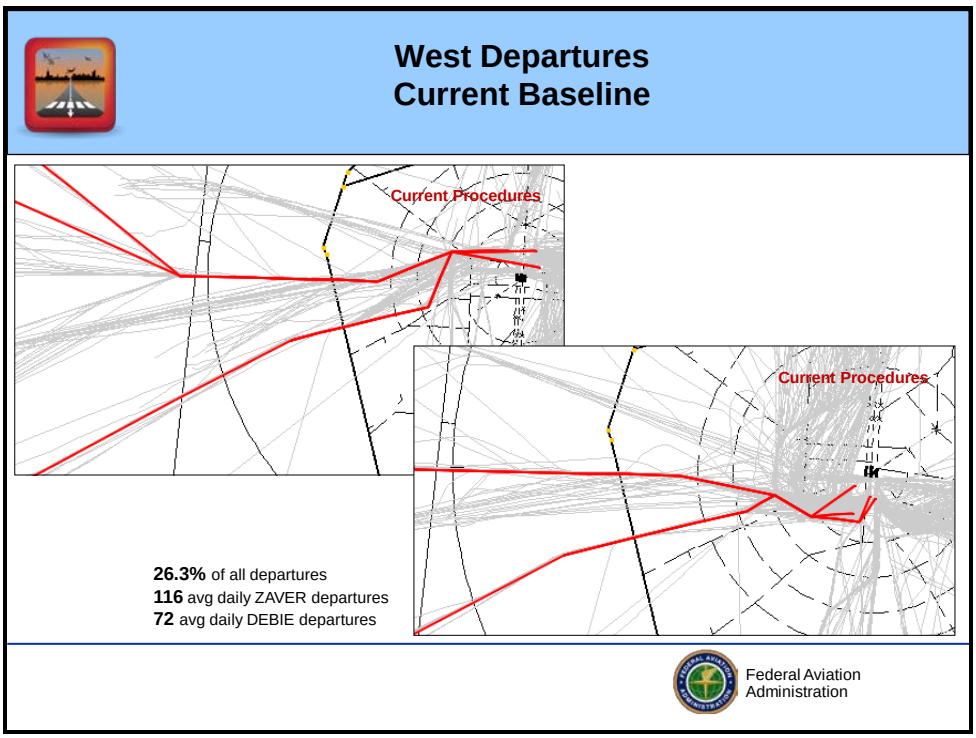
The tables below describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users.

Operational/Safety	
Benefits	**Impacts/Risks**
- CHOPN provides an additional, dedicated turbojet route to AR4. Can also be used for CLT-CHS flights - Designed with lateral spacing to accommodate future parallel routings - May eliminate coordination between ZTL and ZJX	- Increases departure volume

Airspace User	
Benefits	**Impacts/Risks**
- Reduces miles flown and may eliminate level offs between CLT, ZTL, and ZJX	

4.2.2.5 Departures to the West

Below is a depiction of the current ZAVER and DEBIE SIDs (west departures). North and south operations are depicted. The tracks represent a day's traffic between 0700 and 2300 local time.

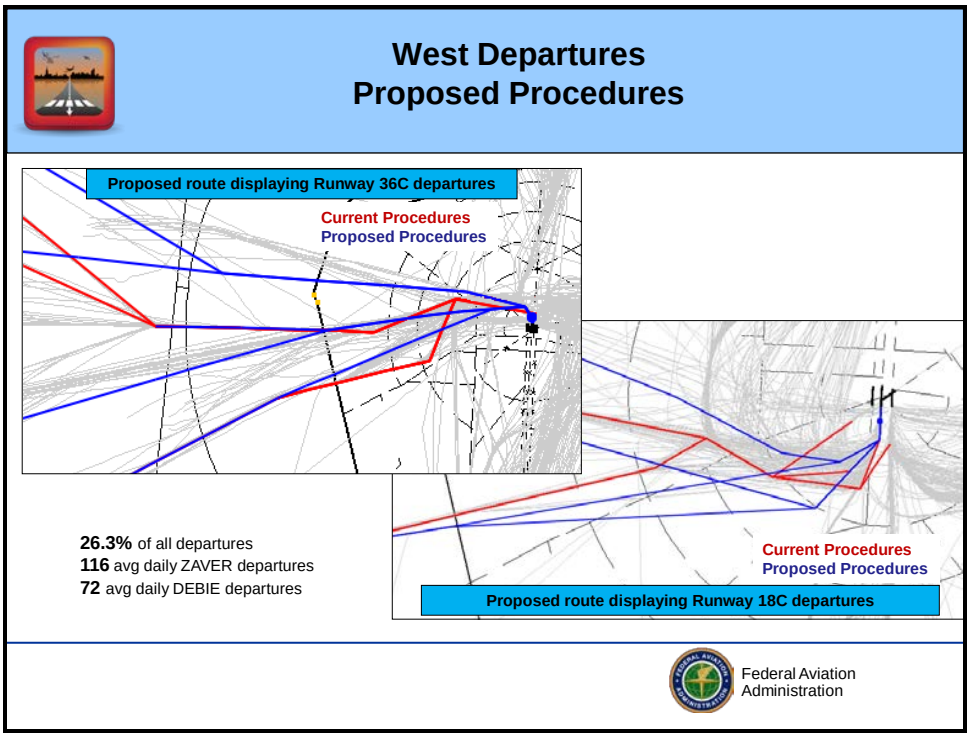


The following issues were considered by the Charlotte OST while designing the conceptual RNAV SIDs for the east departure direction:

- Current ZAVER/DEBIE/PITTY SIDs handle 26.3% of all KCLT daily departures
- The west departure routes share common paths for approximately 16 or 19 miles, dependent on departure runway
- The PITTY fix is used for propeller-driven aircraft only

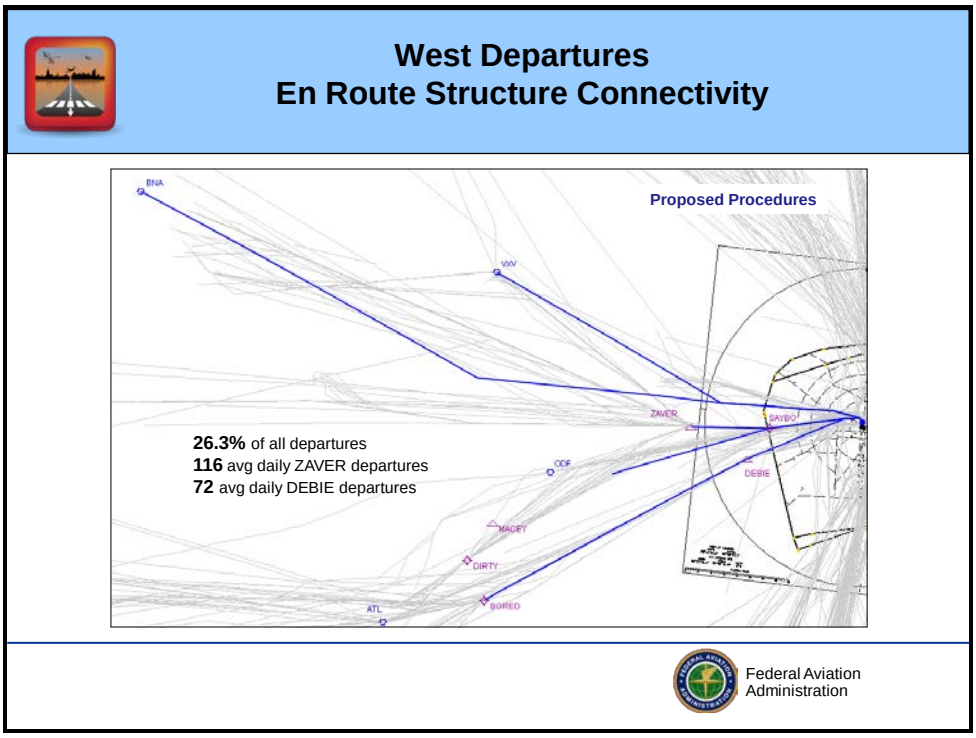
Below are the proposed west departures (blue), shown with the current procedures (red). North and south operations are also depicted. This procedure incorporates course divergence as close to the airport as possible.

Any redesign of SIDs over PITTY should complement the proposed Option 1 of the northwest arrivals illustrated earlier.

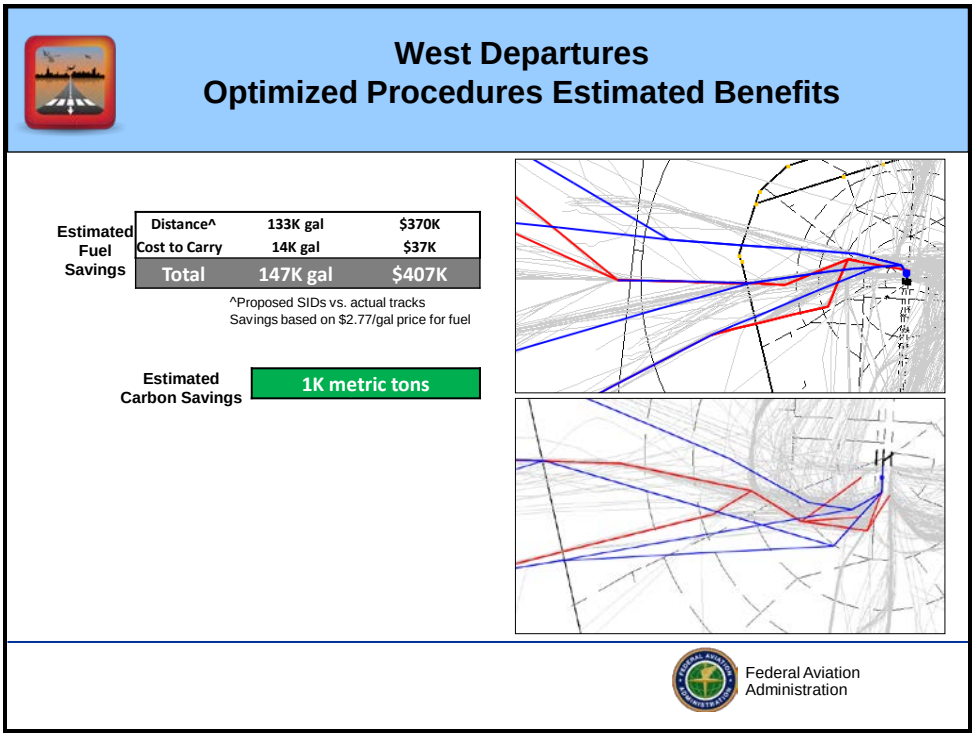


The following issues were considered by the Charlotte OST while considering en route connectivity for the optimized and new west departure procedures:

- Transitions to VXV and Nashville (BNA) are designed to complement Option 1 of the Northwest STAR
- KCLT departures to Asheville (KAVL) can utilize the VXV transition
- The initial design of a KCLT/KATL city-pair air route is proposed. Atlanta OST will finalize connectivity



The proposed RNAV SIDs overlay the currently flown tracks, proceduralizing some of the shortcut benefits gained by today's operations. This will allow for earlier divergence for traffic between the ZAVER, DEBIE, and the new proposed departure procedure. This reduction in distance flown results in an estimated annual fuel burn savings of $370K. The annual cost-to-carry savings for this proposed design is $37K.



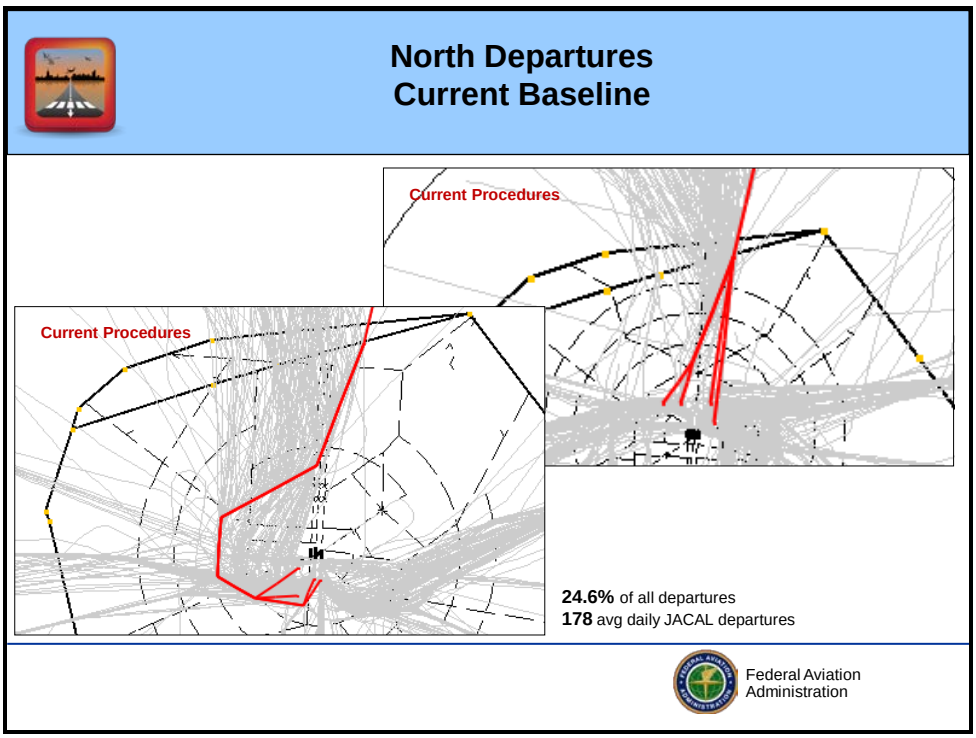
The following tables describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users.

Operational/Safety	
Benefits	**Impacts/Risks**
- CLT-ATL City Pair route reduces miles flown and mimics current traffic flows - VXV and BNA routes eliminate high altitude crossover near HMV and provide a more direct path	- Increase in traffic volume - Shift in traffic patterns

Airspace User	
Benefits	**Impacts/Risks**
- City Pair routes aid in flight planning - VXV and BNA provide a more direct path	

4.2.2.6 Departures to the North

Below is a depiction of the current JACAL SID (north departures). North and south operations are depicted. The tracks represent a day's traffic between 0700 and 2300 local time.



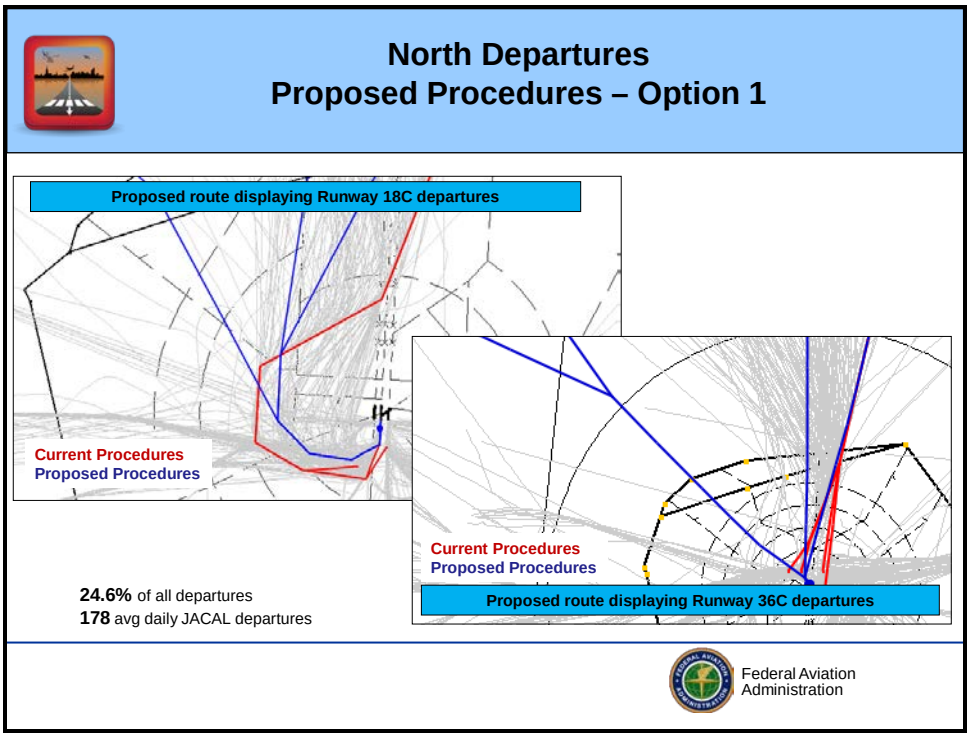
The following issues were considered by the Charlotte OST while designing the conceptual RNAV SIDs for the north departure direction:

- Current JACAL SID handles 24.6% of all KCLT daily departures
- Single northbound route limits throughput and creates inefficiencies
- Existing track data indicates a lack of structured routes. On an average day, only 23% of departures fly to JACAL termination point at NALEY

The OST has two proposed designs for the north SIDs. These options will be described in detail, with considerations for the design and estimated benefits.

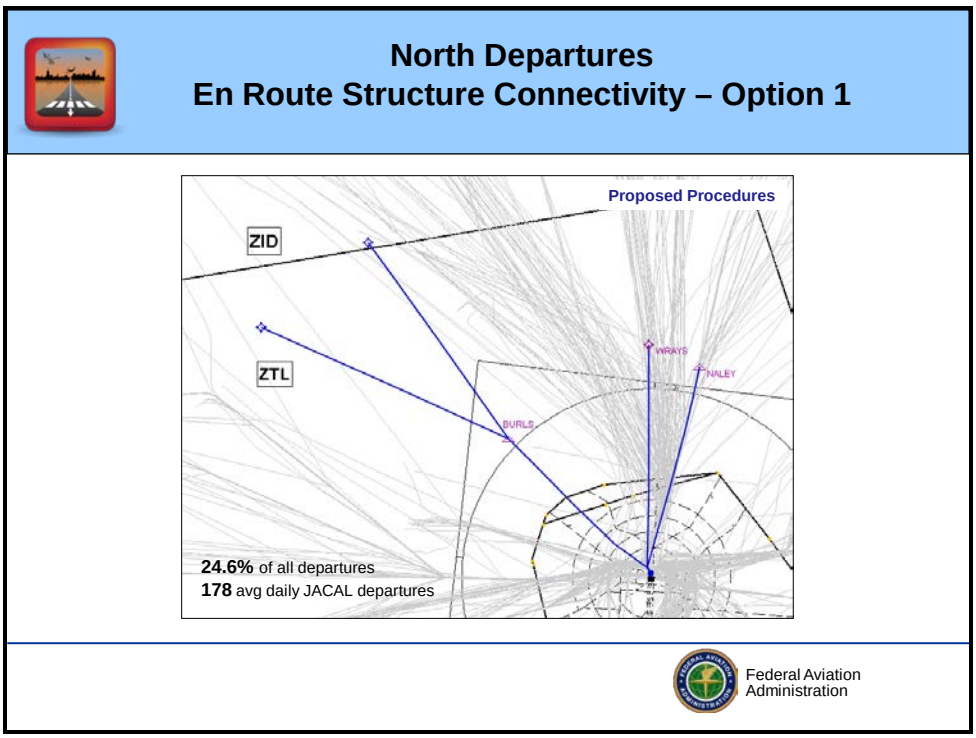
4.2.2.6.1 Option 1 for the North Departures

Below are the proposed Option 1 north departures (blue), shown together with the current procedure (red). North and south operations are also depicted. This procedure incorporates course divergence as close to the airport as possible. The northwest out-the-center departure, associated with the recommended Option 1 for the northwest arrivals, will require coordination between ZID, the Atlanta OST, and Charlotte D&I.

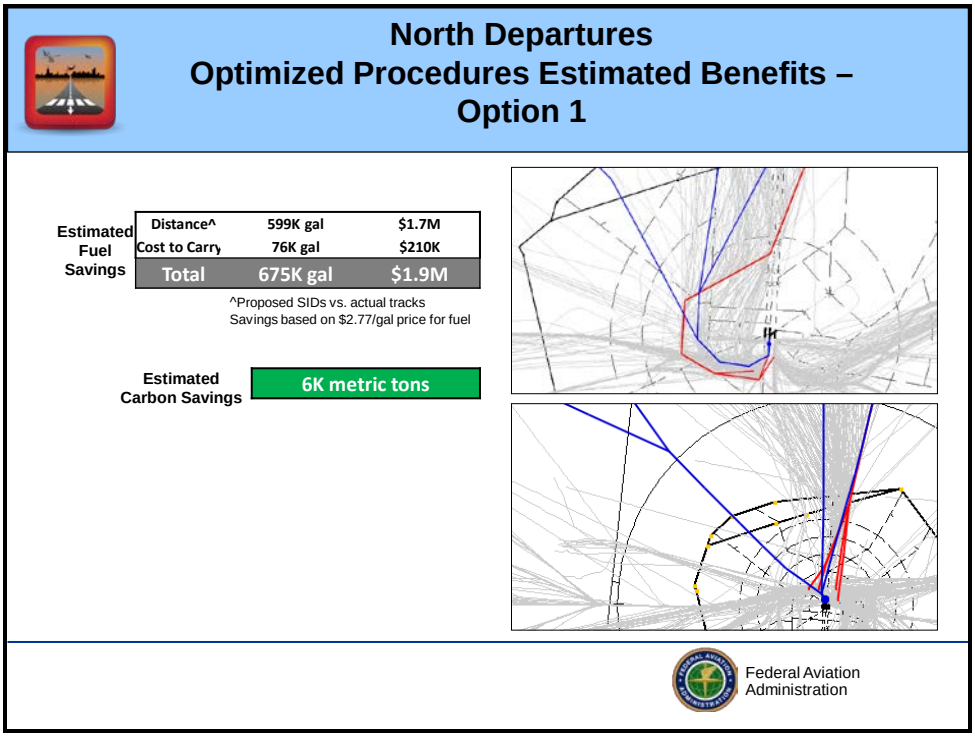


The following issues were considered by the Charlotte OST while considering en route connectivity for Option 1 of the optimized and new north departure procedures:

- ZID will need to address connectivity for the northwest route connecting to BURLS
- Routes work in concert with Option 1 for the northwest STAR
- The two north routes connecting to WRAYS and NALEY follow existing flight tracks



The proposed RNAV SIDs overlay the currently flown tracks, proceduralizing some of the shortcut benefits gained by today's operations. This allows for increased divergence for traffic between the optimized JACAL and the new proposed departure procedures. The reduction in distance flown results in an estimated annual fuel burn savings of $1.7M. The annual cost-to-carry savings for this proposed design is $210K.



The tables below describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users.

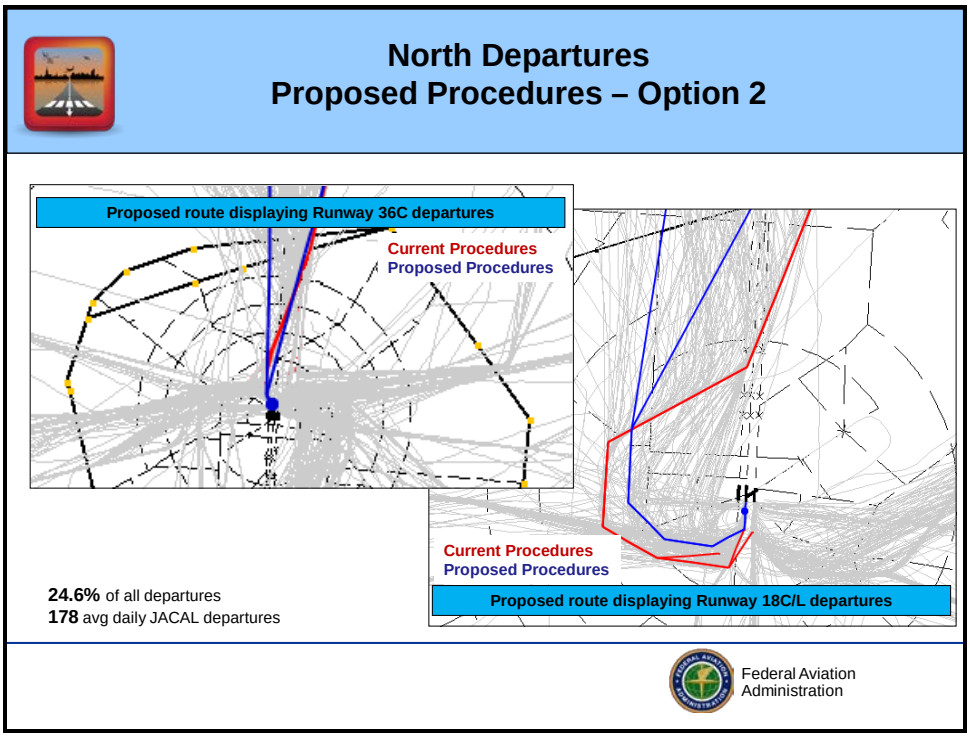
Operational/Safety	
Benefits	**Impacts/Risks**
- Provides connectivity to en route structure - Provides published routes which mimic actual traffic flows - Eliminates cross-out near HMV - Supports northwest STAR Option #1	- Possible increase in traffic volume - VXV/BNA departure route splits dual arrival routes - Non-traditional interaction with northwest arrival routes - May require airspace modifications for second tier ARTCCs

Airspace User	
Benefits	**Impacts/Risks**
- Predictable published routes aids in flight planning - Promotes consistent City Pair flight planning	- Possible level off for departures on the VXV/BNA route when departing north at CLT

Due to the additional savings in fuel burn associated with reduced flight distance, it is the recommendation of the OST that Option 1 for the north departures be pursued by the D&I team. The savings from this option are achieved when implemented together with Northwest STAR Option 1. The OST understands that this option would require increased coordination with other facilities, and incorporates a unique cornerpost design.

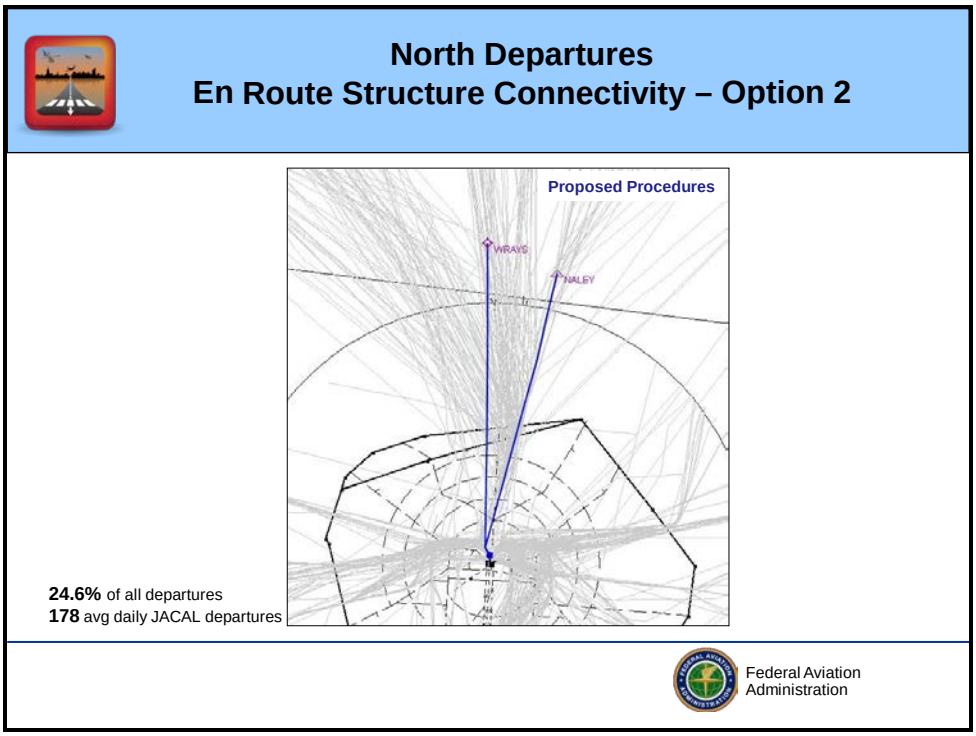
4.2.2.6.2 Option 2 for the North Departures

Below are the proposed Option 2 north departures (blue), shown together with the current procedure (red). North and south operations are also depicted. This procedure incorporates course divergence as close to the airport as possible.

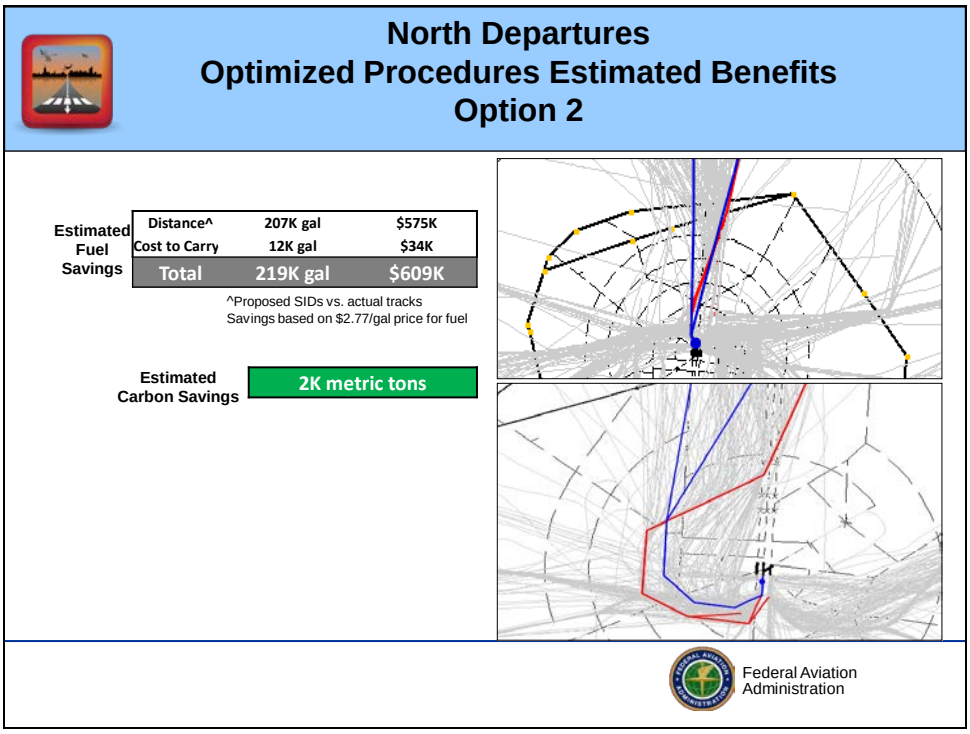


The following issues were considered by the Charlotte OST while considering en route connectivity for Option 2 of the optimized and new north departure procedures:

- Routes work in concert with Option 2 for the northwest STARs
- The two north routes connecting to WRAYS and NALEY follow existing flight tracks



The proposed RNAV SIDs overlay the currently flown tracks, proceduralizing some of the shortcut benefits gained by today's operations. This allows for increased divergence for traffic between the optimized JACAL and the new proposed departure procedures. The reduction in distance flown results in an estimated annual fuel burn savings of $575K. The annual cost-to-carry savings for this proposed design is $34K.



The tables below describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users.

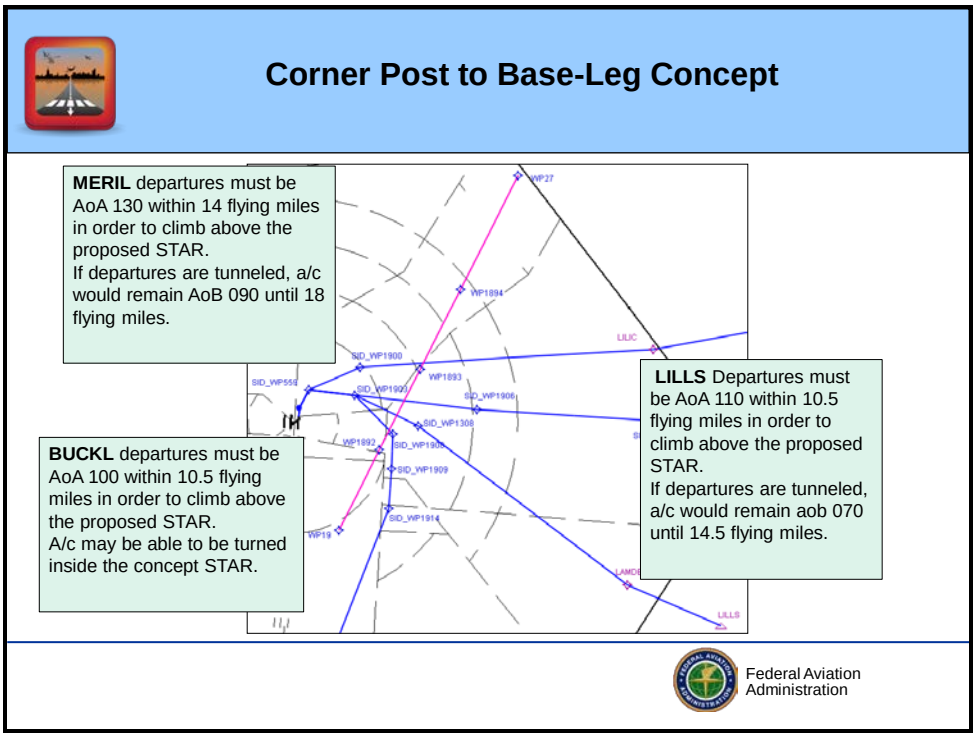
Operational/Safety	
Benefits	**Impacts/Risks**
- Provides connectivity to en route structure - Provides published routes which mimic actual traffic flows - Supports northwest STAR Option #2	- Possible increase in traffic volume - May require airspace modifications for second tier ARTCCs

Airspace User	
Benefits	**Impacts/Risks**
- Predictable published routes aids in flight planning - Promotes consistent City Pair flight planning	

4.2.3 Alternate KCLT Arrival and Departure Leg Concepts

The OST examined two different non-traditional concepts for arrival and departure routes within the terminal area. These concepts are planned to allow for either a reduction in miles flown in the approach environment, or unrestricted climbs on the departures. No benefits were estimated for applying either of these concepts. The OST is presenting these concepts to address Industry comments and to present additional procedure design options to the D&I team.

One of the concepts examined was the Corner Post to Base-Leg Arrival. This reduces miles flown in the approach environment by routing aircraft via an OPD directly from the arrival fix to a base-leg pivot point in final sector airspace in lieu of a traditional base-leg. While this concept shortens mileage from an arrival perspective, it appears it would require excessive level segments for departures. The graphic below denotes the potential leveling impacts this concept would have on the proposed east and south departures.

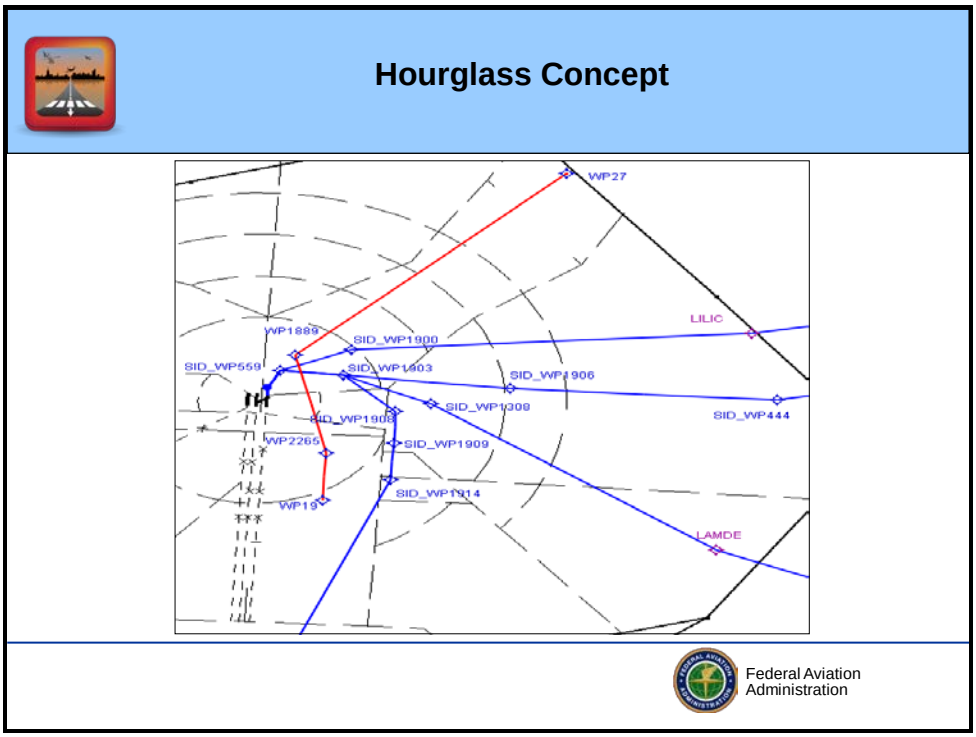


The following tables describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users.

Operational/Safety	
Benefits	**Impacts/Risks**
- Enhances procedural separation between arrival and departure routes	- Reduces flexibility to flow aircraft from one side of the airport to the other side - Reduces opportunities to shorten final length - Environmental concerns due to altered aircraft paths

Airspace User	
Benefits	**Impacts/Risks**
- "Downwind" departure paths may be shortened - Modified departure profiles and (lengthened) SIDs may permit continuous climb and descent profiles	- Additional flying miles inside CLT airspace - Departure level offs

The second concept examined by the OST is referred to as the Hourglass approach. This concept routes aircraft in the approach environment to a point inside of the traditional downwind leg, allowing for unrestricted climbs on departures. The graphic below depicts a potential “hourglass” arrival from the northeast.



The following tables describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users. This concept can result in additional miles flown.

Operational/Safety	
Benefits	**Impacts/Risks**
- Deconflicts arrival and departure traffic	-Dual STARs merge sooner in CLT airspace than proposed designs - Reduced flexibility for controller shortcuts in CLT airspace

Airspace User	
Benefits	**Impacts/Risks**
-Eliminates level offs for departures	- Additional flying miles inside CLT for all RNAV arrivals

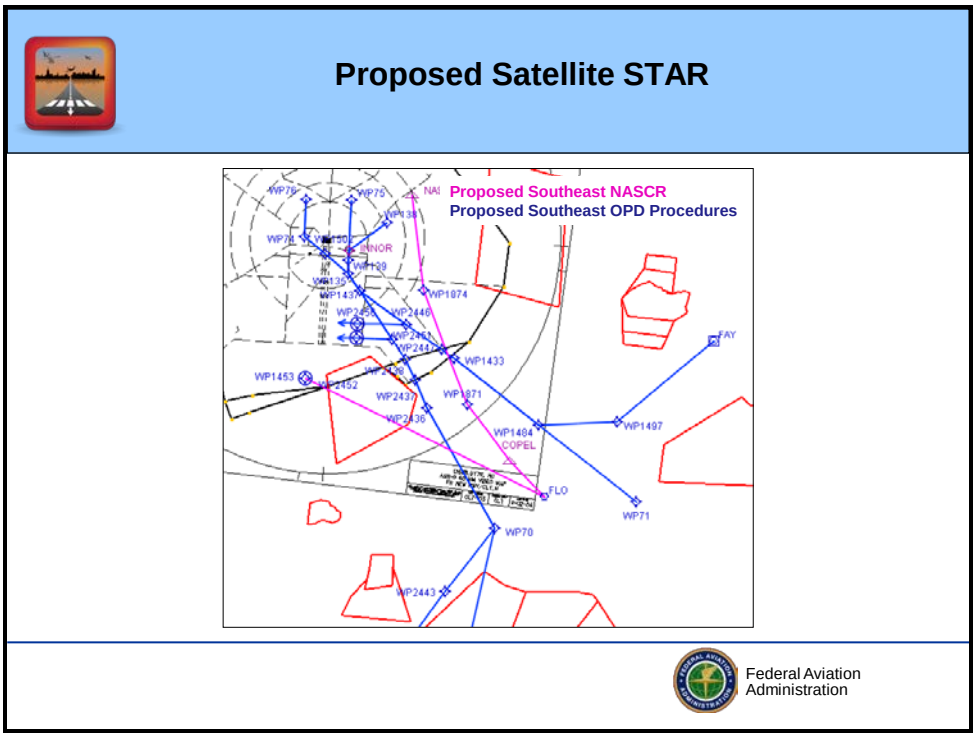
4.2.4 Charlotte Satellite Airport Arrivals

Both KCLT arrival and selected satellite airport arrival traffic are currently sequenced together on the HUSTN/Chesterfield (CTF) STARs creating additional ATC task complexity and possible delays to both satellite and KCLT arrivals. In addition, southern arrivals into Hickory (KHKY) and Statesville (KSVH) fly head-on with southbound KCLT departures, increasing aircraft level-offs, vectors, and ATC task complexity.

To address these issues, the OST recommends that the southern transition on the existing NASCR STAR be replaced with a proposed new STAR from the southeast that will serve Charlotte satellite airports, as well as KHKY and KSVH.

The graphic below shows the proposed satellite STAR, and Option 1 of the Southeast STARs.

- The satellite STAR remains laterally separated from the Southeast CLT STARs as long as feasible to provide distinct descent corridors
- CLT delivery altitudes will be determined by D&I teams



The tables below describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users. No benefits were assessed on this proposal.

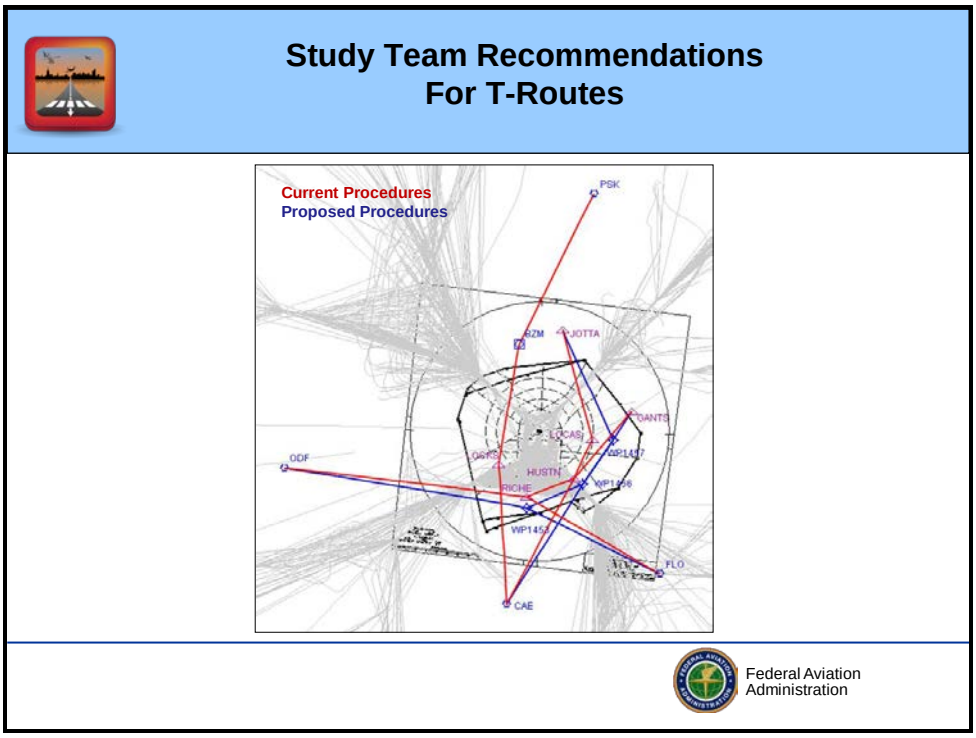
Operational/Safety	
Benefits	**Impacts/Risks**
- Segregates flows for different airports - Deconflicts with CLT departures	- Multiple arrivals flows may increase ATC task complexity - Western transition overflies SAA - Possible multiple facility involvement

Airspace User	
Benefits	**Impacts/Risks**
-Segregates flows for different airports -Defines procedures for satellite airports	- Possible increase in track miles

4.2.5 T-Routes

Another aspect of Charlotte Metroplex operations examined by the OST was the use, design, and efficiency of T-Routes traversing CLT. It was noted to the OST by Industry that current T-Routes are not assigned, most likely due to their close proximity to congested CLT arrival/departure traffic. Additionally, the high MEA on T-200 through CLT airspace limits its practicality.

To address these concerns, the OST proposed slight modifications that will relocate the current T-Routes clear of CLT congested traffic areas to improve their accessibility. Additionally, a lower MEA on T-200 will create more usable altitudes through CLT airspace. The graphic below illustrates the current T-Routes (red) along with the proposed changes (blue).



The OST also proposes that an east-west T-Route be built north of KCLT to help alleviate the impact of satellite and adjacent airport operations. Further discussion between CLT and ZTL is needed before such a route can be pursued.

The tables below describe the qualitative benefits, impacts, and risks of the solution concept, both operationally and for airspace users.

Operational/Safety	
Benefits	**Impacts/Risks**
- Availability of predictable routes through CLT airspace	

Airspace User	
Benefits	**Impacts/Risks**
- Availability of predictable routes through CLT airspace - Decreased track miles on the new south route (T-200)	- Additional track miles on the new east route (T-201/T-202)

4.2.6 Charlotte Adjacent Airport Operations

The OST examined four adjacent airports for potential interactions with CLT operations, and proposed conceptual PBN procedures to de-conflict operations.

The following tables describe the qualitative benefits, impacts, and risks of the solution concept, in regard to operational and airspace user concerns. No initial environmental screening suggestions are listed.

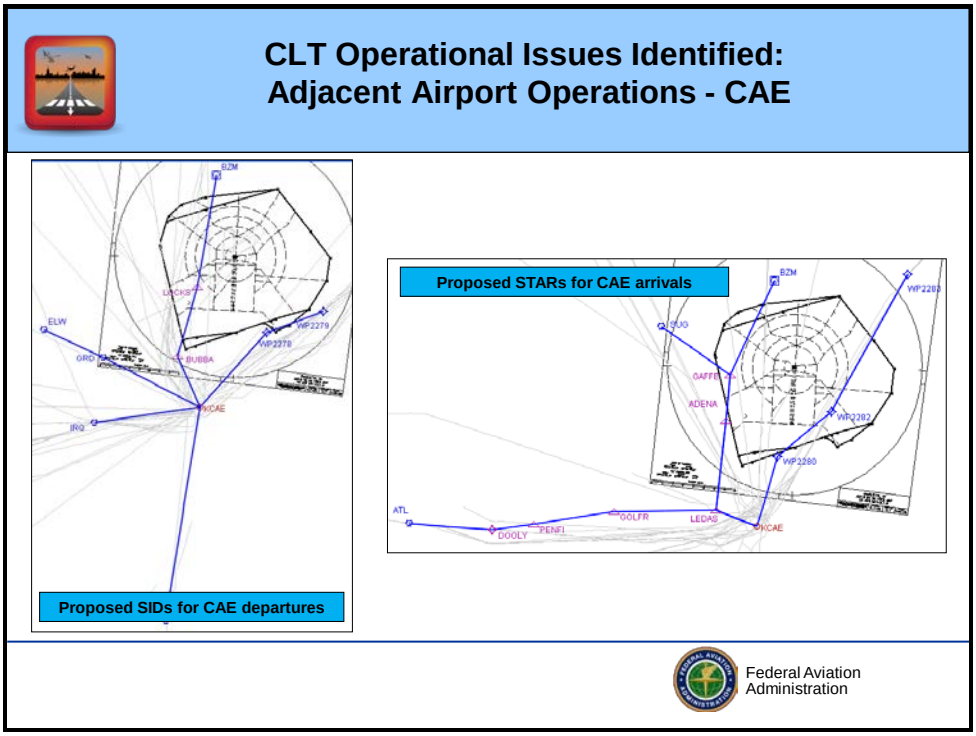
Operational/Safety	
Benefits	**Impacts/Risks**
- Increases use of OPD procedures into CLT - Deconflicts adjacent airport and CLT operations	

Airspace User	
Benefits	**Impacts/Risks**
- Increases use of OPD procedures into CLT - Possible PBN procedures for adjacent airports - Predictable published routes which aid in flight planning	- May increase track mileage - May increase fuel burn/ carbon emissions

4.2.6.1 KCAE Arrivals and Departures

KCAE northwest arrivals interact with KCLT southwest arrivals. KCAE northbound and eastbound departures interact with KCLT southwest and southeast arrivals, and with KCLT south departures.

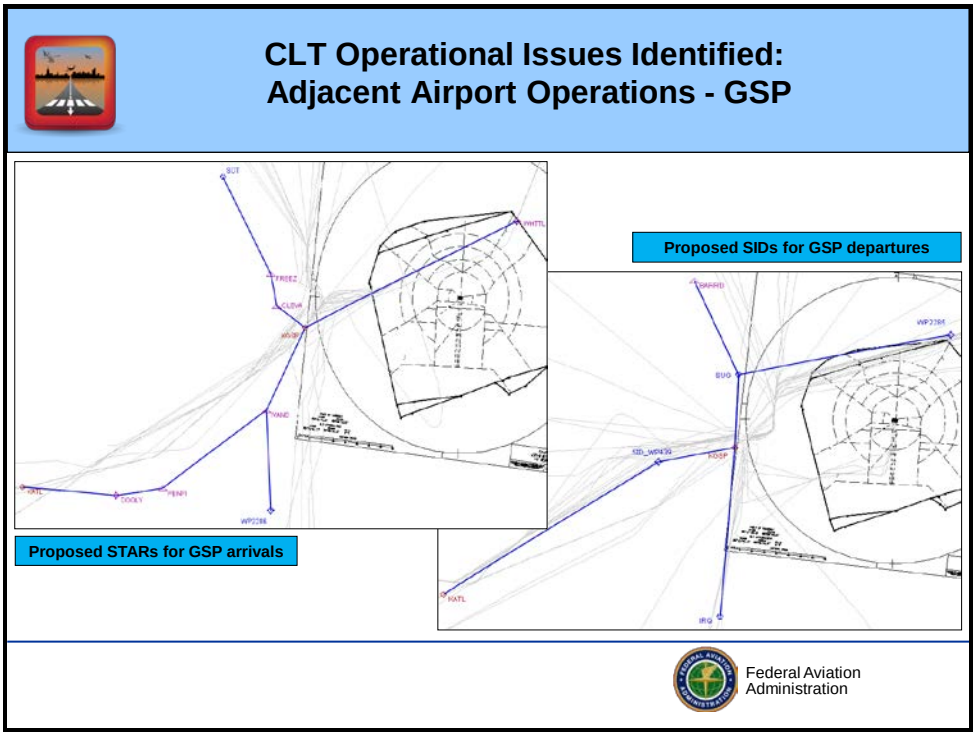
The figure below displays the proposed KCAE SID and STAR designs. These routes were designed in conjunction with ZTL, ZJX, and CLT to determine placement and to improve interaction with current en route flows and proposed KCLT and satellite operations. The proposed design lays the groundwork for PBN procedures, including vertical navigation, for future KCAE operations.



4.2.6.2 KGSP Arrivals and Departures

KGSP southwest arrivals interact with KCLT southwest arrivals. KGSP northeast arrivals interact with KCLT departures and KCLT northwest arrivals. KGSP northbound departures interact with KCLT northwest arrivals. KGSP northwest arrivals interact with KCLT northwest arrivals.

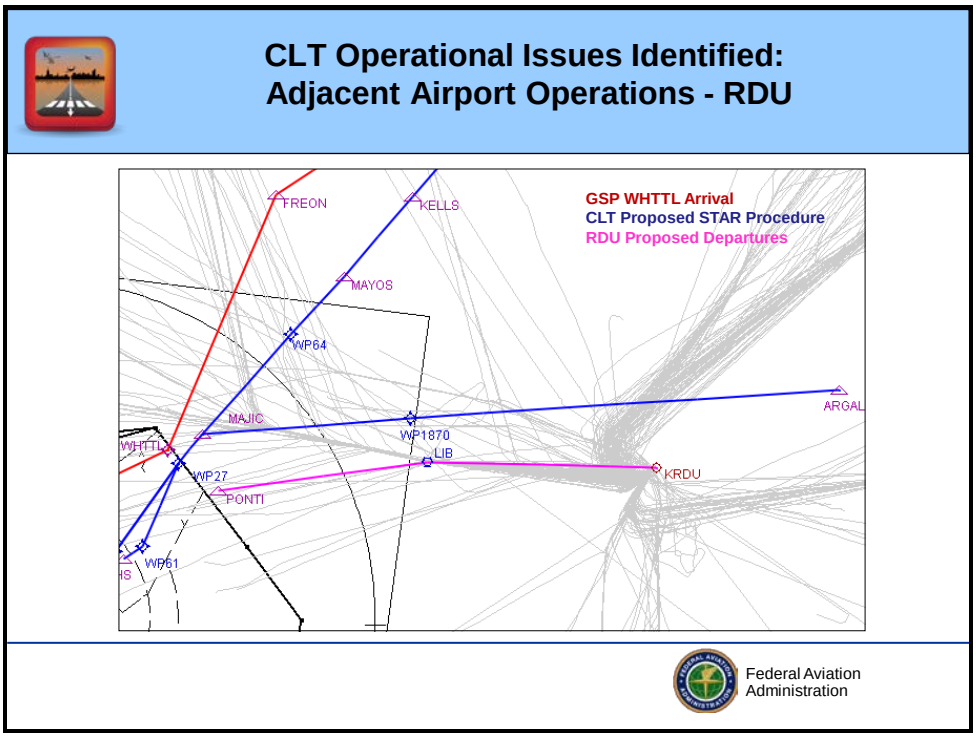
The figure below displays the proposed KGSP SID and STAR designs. Routes were designed in conjunction with ZTL and CLT to determine placement and to improve interaction with current en route flows and proposed KCLT and satellite operations. The proposed design lays the groundwork for PBN procedures, including vertical navigation, for future KGSP operations.



4.2.6.3 KRDU Departures

KRDU westbound departures interact with KCLT northeast arrivals and KGSP arrivals.

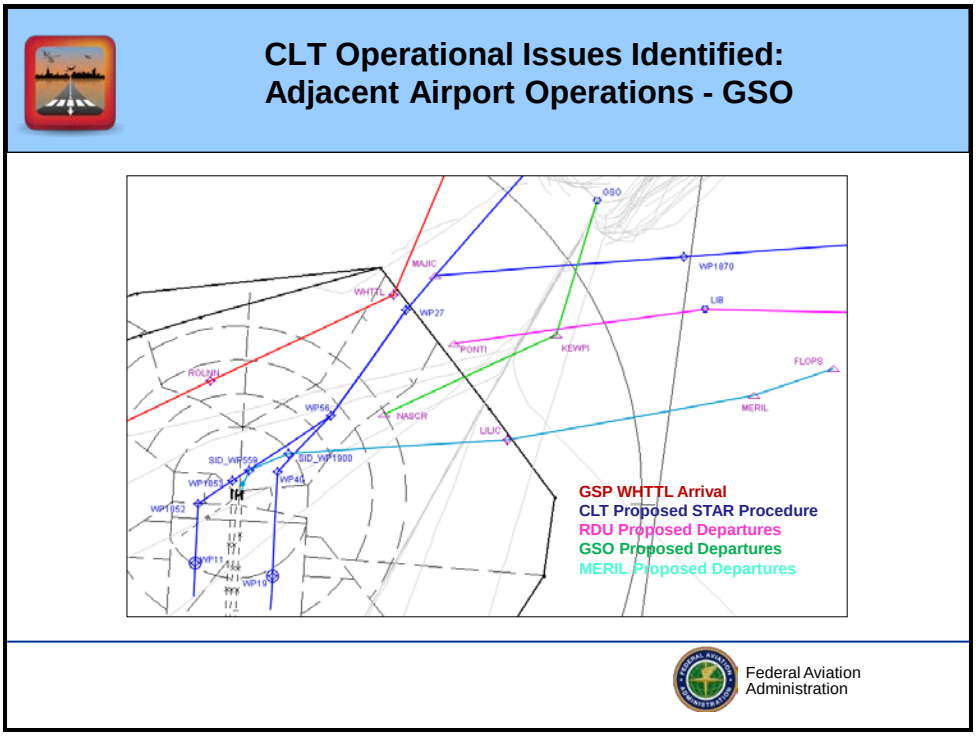
The graphic below displays the proposed KRDU SID design. KRDU west arrivals/departures are the primary traffic that interacts with CLT operations. Routes to the west were designed to facilitate unrestricted climbs and accommodate the OPD on the proposed ARGAL transition into KCLT. The D&I team will integrate remaining routes in and out of KRDU's surround airspace, as well as lay the groundwork for PBN procedures, including vertical navigation, for future KRDU operations.



4.2.6.4 KGSO Departures

KGSO southbound and eastbound departures interact with KCLT northeast arrivals.

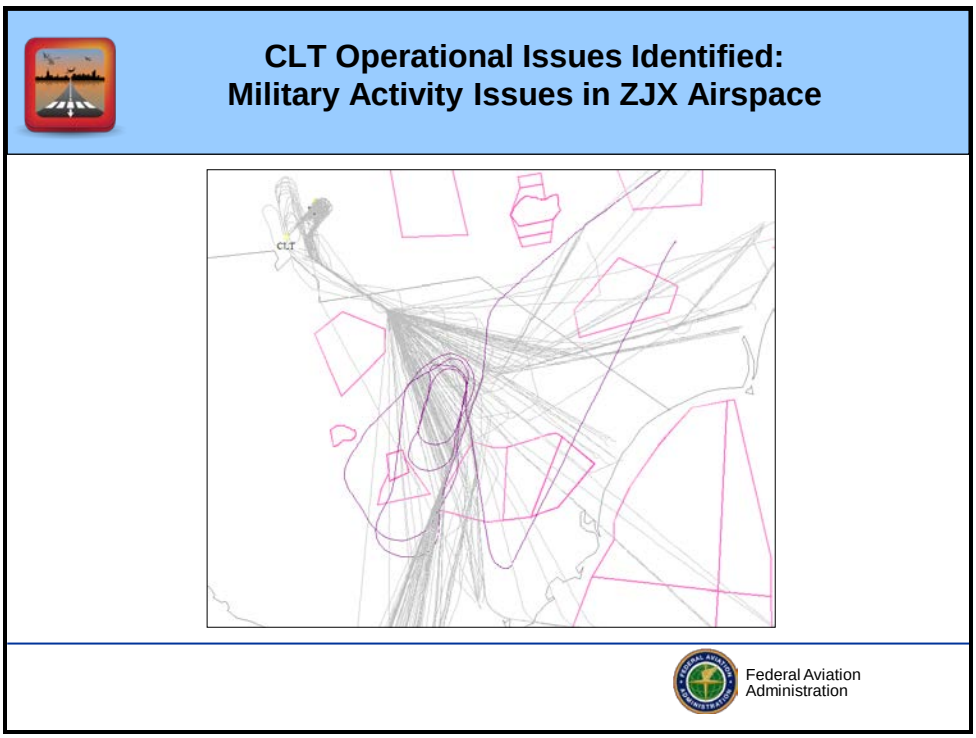
The graphic below displays the proposed KGSO SID design. KGSO southern departures are the primary traffic that interacts with CLT operations. Additional considerations were GSP WHTTL arrivals, KRDU proposed departures, and the proposed MERIL departure. The proposed KGSO route was designed to facilitate unrestricted climbs and accommodate the OPD on the proposed ARGAL transition into KCLT. The D&I team will integrate remaining routes in and out of KGSO's surround airspace, and lay the groundwork for PBN procedures, including vertical navigation.



Concerns were raised that FedEx may increase operations out of KGSO, but after further research and discussions with industry, it was determined that no near-term plans exist to expand FedEx operations. However, if operations are increased, additional design work may be required.

4.2.7 Military Activity Issues in ZJX Airspace

The AR600 refueling track impacts CLT arrivals descending on the HUSTN/CTF STARs. When active, arrivals must descend prior to NAVEE to fly below the refueling aircraft, or arrivals must be vectored around this area. The graphic below depicts the refueling traffic (purple) and KCLT arrival traffic (gray).



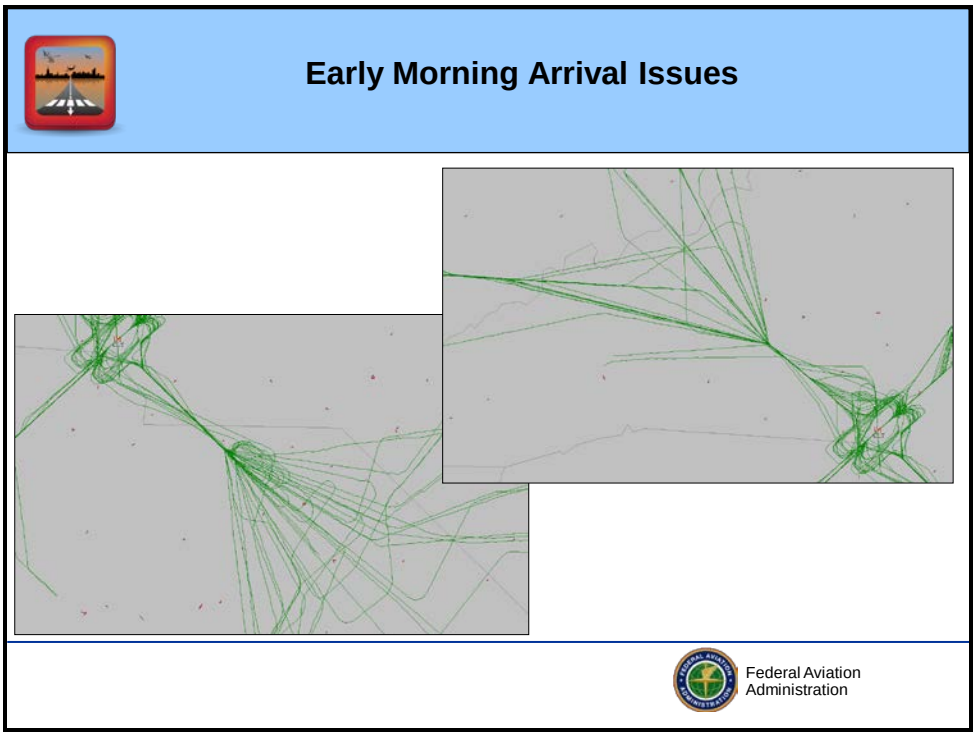
The Department of Defense (DoD) has been made aware of this concern and its impact on CLT arrivals. It is expected that the DoD will be actively involved during the D&I phase to ensure a mutually beneficial working solution. The group should consider the following:

- The design of KCLT Southeast OPD south of PROMM
- A real time usage of AR600 to accommodate high traffic volume periods into CLT
- Military aircraft are not Reduced Vertical Separation Minima (RVSM) equipped (exclusionary aircraft)
- ZJX66 boundary
- A minimal lateral move of AR600
- Military scheduling of area
- Additional SAAs

4.2.8 Early Morning Arrival Issues

Demand can exceed KCLT capacity while single runway noise abatement procedures are in effect between 0600 and 0700. This leads to holding/vectoring, altitude/speed restrictions, and MIT requirements, resulting in increased flight crew and ATC task complexity.

The OST recommends that implementing TMA earlier to mitigate the use of expanded MIT and holding between 0600 and 0700 could help improve this issue. In addition, KCLT staff has already started the process to re-evaluate early morning noise abatement procedures (Part 150 modification). The OST recommends that this be continued and expedited where possible.



5 Issues Not Analyzed by Charlotte OAPM Study Team

The following issues were identified by the facilities, but were not addressed by the Charlotte OST. These issues were outside of the OAPM process, and should be handled by the facilities through existing processes (TMIs, LOAs, etc.):

- Severe Weather Avoidance Plan (SWAP) routes do not exist for offloading arrival traffic from the CLT southeast corner post to the CLT southwest corner post. Lack of playbook routes increase ATC task complexity during convective weather activity.
- CLT arrival traffic being vectored by ZJX near the CLT airspace boundary must proceed to BOOZE before entering CLT airspace. ZJX would prefer to clear aircraft direct to a fix inside CLT's airspace.
- KCLT departure procedures are posted as "do not exceed 280kts" causing variations in departure speeds as aircraft enter the en route environment.

The following issue was not analyzed by the Charlotte OST, but will be forwarded to the D&I Team for future consideration:

- Ultra-high sector over ZDC36 (RDU) and ZDC38 (TYI) in ZDC to alleviate congestion issues due to overhead traffic. When these sectors become saturated, restrictions or ground stops are placed on KCLT departures.

6 Summary

The focus of the Charlotte OST was to address identified issues through the application of PBN procedures and airspace changes that enable predictable, repeatable flight paths, reduce ATC task complexity, and maximize efficiency. The two phases of this approach consisted of:

- Collaboratively identifying and characterizing existing issues and then
- Proposing conceptual designs and airspace changes that will address the issue and optimize the operation

The expected benefits for the proposed solutions were derived primarily from the differences in fuel burn between the current operation and the conceptual changes. In all cases, the OST also identified considerations and risks associated with each proposed change.

The proposed changes are estimated to result in annual fuel savings between $10.2 million and $17.0 million due to:

- Use of OPDs
- Reduced track distances
- Reduced fuel loading requirements (cost-to-carry) of about 2.5 million nautical miles and 3.7 million to 6.2 million gallons of fuel annually

Additional benefits include

- Reduced ATC task complexity and pilot/controller communications due to reduced radar vectoring
- Foundation for NextGen capabilities (e.g., use of Relative Position Indicator; Required Time of Arrival)
- Repeatable, predictable flight paths
- Increased throughput due to increased divergence on the departure procedures