MP 03W0000131

MITRE PRODUCT

# Summary of Re-engineering of HCI of Mature CRCT Functionality for Technology Transfer

**August 2003**

Dr. Anthony J. Masalonis
Steven L. Estes
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**Center for Advanced Aviation System Development**
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**Sponsor:** Federal Aviation Administration
**Dept. No.:** F045
**Contract No.:** DTFA01-01-C-00001
**Project No.:** 020333084A



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# Executive Summary

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) developed traffic flow management (TFM) concepts and functions, known as Collaborative Routing Coordination Tools (CRCT). CAASD conducted operational evaluations of the Free Flight Phase 2 (FFP2) baseline CRCT functions using current Federal Aviation Administration (FAA) Traffic Management Coordinators (TMCs) and Traffic Management Specialists (TMSs). Based on results from these evaluations and other considerations, the FAA deemed certain baseline functions operationally mature,[1] such as the CRCT Flow Constrained Area (FCA) and Reroute Modeling functionality. The FAA requested that CAASD facilitate an iterative technology transfer of those functions to the TFM-I development contractor, the John A. Volpe National Transportation Systems Center (VNTSC), for incorporation into the existing Enhanced Traffic Management System (ETMS).

In FY02, the final operational evaluation of the FFP2 baseline CRCT functions, conducted by CAASD, led to the conclusion that there was an operational and Human Factors need for integration of the FCA and Reroute Modeling capabilities, and the existing ETMS Create Reroute functionality.

In FY03, as part of the CRCT technology transfer process, CAASD was tasked by the FAA to work with the William J. Hughes Technical Center (WJHTC) and the John A. Volpe National Transportation Systems Center (VNTSC) on re-engineering the human-computer interface (HCI) of the CRCT functions. CAASD was asked to participate in this activity to ensure that results and lessons learned from CAASD-facilitated evaluations of CRCT functions were considered during the re-engineering.

CAASD made several contributions to this HCI re-engineering effort. First, CAASD presented the FY02 evaluation results, and mock-ups of potential integrated interfaces, to AUA-700 and the TFM User Team, resulting in a validation of the operational need for a simplified and integrated FCA/Reroute capability.

Also early in FY03, in order to corroborate the operational evaluation findings, CAASD conducted cognitive modeling analysis, using the Natural Language Goals, Operators, Methods, and Selection rules technique (NGOMSL). This analysis demonstrated a physical and mental workload benefit of integrating the FCA and Reroute Modeling functionality. This finding was incorporated into the briefings used in subsequent re-engineering meetings.

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[1] In addition to operational maturity, the FAA considered technical, procedural, and developmental maturity of the functions prior to deployment.

Over the course of FY03, CAASD briefed various FAA and airline stakeholders and Collaborative Decision Making Working Groups on the evaluation and modeling results. A proposed integrated solution was also presented using user interface mock-ups. Design meetings were held between WJHTC, VNTSC, and CAASD. CAASD's evaluation and analysis results and mock-ups served as one source of input to the re-engineering of the user interface for the FCA and Create Reroute functions. This document contains interfaces proposed by WJHTC, VNTSC, and CAASD, and describes the FCA and Rerouting functionality, resulting from the collaborative re-engineering effort, that is planned for implementation in upcoming ETMS releases.

The ETMS designs developed in FY03 represent incremental steps toward the goal of further integrating FCA, Create Reroute, and Reroute Modeling. Based on stakeholder feedback, the collaborative re-engineering effort has resulted in an improved user interface for the newly-deployed CRCT-based technology. The approach taken in FY03–ongoing communication among all stakeholders and provision of mockups, operational evaluation results, and modeling results—should be continued for future joint WJHTC/VNTSC/CAASD activities, as the remainder of the FFP2 CRCT technology is transferred to ETMS.

# Acknowledgments

The authors would like to thank Joan Arnold, Ellen Friedman, and Cheryl Mayson-Shaffer for preparing this document for publication.

Dr. Keith Campbell, Shane Miller, Paul Ostwald, and Tim Stewart, all of CAASD, contributed significantly to the development of the mockups used in CAASD's coordination with FAA, VNTSC, and airspace user stakeholders. Mark Huberdeau of CAASD was instrumental in the ongoing coordination between CAASD and the FCA-Reroute working group.

Maggie Gomes, Rafe Katkin, and Deborah Kirkman, all of CAASD, provided very useful comments on the document.

FAA personnel who have participated in the highly productive meetings and discussions described herein include Bart Brickman (Northrop-Grumman), Mike Murphy, Chuck Vomacka, Lorraine Vomacka, and Dr. Tanya Yuditsky, as well as all FAA and airspace user representatives in the FCA-Reroute and RAT working groups. Key members of the re-engineering team on the VNTSC side have included Mike Golibersuch, Ken Howard, and Rick Oiesen.

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**Section 1**

# Background

## 1.1 History

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) developed a set of traffic flow management (TFM) concepts and functions to assist traffic managers with identifying aircraft affected by congestion and determining the impact of proposed rerouting initiatives. The set of functions is known collectively as Collaborative Routing Coordination Tools (CRCT). Based on the anticipated benefits of CRCT, RTCA recommended operational implementation of the functions as part of Free Flight Phase 2 (FFP2)[1]. In response, the Federal Aviation Administration (FAA) developed a plan to assess the maturity of CRCT functions and implement them in the Enhanced Traffic Management System (ETMS) as appropriate.

CAASD conducted operational evaluations of the FFP2 baseline CRCT functions in order to assess their operational maturity, using current Federal Aviation Administration (FAA) Traffic Management Coordinators (TMCs) and Traffic Management Specialists (TMSs). The FFP2 baseline CRCT functions include FCA, Reroute Modeling, Time-In-Sector Display, and Future Traffic Display. They are described in detail in Reference 2.

Based partly on the results and recommendations of CAASD's evaluations, the FAA deemed the FFP2 baseline CRCT functions operationally mature, including the CRCT Flow Constrained Area (FCA) and Reroute Modeling functionality[3]. Conclusions regarding operational maturity of Reroute Modeling were based primarily on the study described in Reference 4. These and other evaluations were conducted at Kansas City Air Route Traffic Control Center (ARTCC) (ZKC), Indianapolis ARTCC (ZID), and/or the David J. Hurley Air Traffic Control System Command Center (ATCSCC). In addition to operational maturity, the FAA considered technical, procedural, and developmental maturity of the functions prior to deployment.

Subsequently, the FAA requested that CAASD participate in an iterative technology transfer of the mature CRCT functions to the TFM-I development contractor, the John A. Volpe National Transportation Systems Center (VNTSC), for incorporation into ETMS. This technology transfer activity was intended to be ongoing, as the CRCT functions were iteratively deployed on ETMS.

In 2001, the initial FCA functionality was deployed in ETMS. Due in part to the FY01 FFP2 CRCT evaluation results[4], the Reroute Modeling functionality was not immediately deployed in ETMS. The FY01 evaluation conclusions indicated that although the Reroute Modeling functionality was operationally suitable, it required additional Human Factors refinement. Operational feedback indicated that Reroute Modeling, as prototyped on the

CRCT Concept Demonstration and Evaluation Platform (CDEP), was cumbersome, requiring multiple steps to define and modify a reroute. The task requires the use of several windows, resulting in much interaction with the interface. Furthermore, it requires the user to remember information such as which reroute strategy is associated with each FCA, and which strategies are currently active, resulting in a high working memory load on the user. To streamline the functions, CAASD recommended integrating the FCA and Reroute Modeling functionality[4].

In FY02, CAASD designed and conducted an operational evaluation[5] addressing the integration of FCA and Reroute Modeling. This was the final operational evaluation of the FFP2 baseline CRCT functions. The evaluation, conducted using TMCs from ZKC and ZID, utilized a combination of hands-on interaction with the CRCT CDEP (some of the concepts illustrated with CDEP are seen in Appendix A), and operational storyboards consisting of series of "mockups," i.e., static illustrations of the concepts using notional user interfaces. Operationally realistic scenarios were used in both the CDEP and mockup portions. Structured interviews followed the scenarios. A key finding was that integrating FCAs and Reroute Sets into a single object was rated at or near the "very helpful" level by all participating TMCs. The TMCs stated that the integration of FCA and Reroute Modeling functionality with the existing Rerouting function in ETMS would simplify the management of multiple reroute strategies. CAASD's preliminary conclusion was that a need existed for near-term functional and display integration of these capabilities, in order to increase their operational utility and the likelihood they would be used.

As part of the iterative technology transfer activity, the FAA requested that in FY03, CAASD work with WJHTC and VNTSC on the re-engineering of the user interface for the operationally mature CRCT functions. CAASD's contributions to the re-engineering process stemmed from CAASD's role in CRCT concept development, facilitation of the CRCT operational evaluations, and general operational and Human Factors knowledge.

## 1.2 FCA Rerouting Integration

Due in part to CAASD's evaluation conclusion, validated by the FAA, regarding a near-term need for integrating the FCA, Reroute Modeling, and Create Reroute functions, the re-engineering activity in FY03 focused on this integration. Figure 1-1 illustrates the basics of the integrated FCA/Reroute definition window used in the mockup portion of the FY02 evaluation. Another proposed window, the Flight List (illustrated in Appendix B), also supports the integration concept, and has been analyzed and discussed as part of the activities detailed in Section 2. Although the Flight List was not a primary focus of the FY03 re-engineering activity, it is an important part of the integration concept and should be further considered in the future.

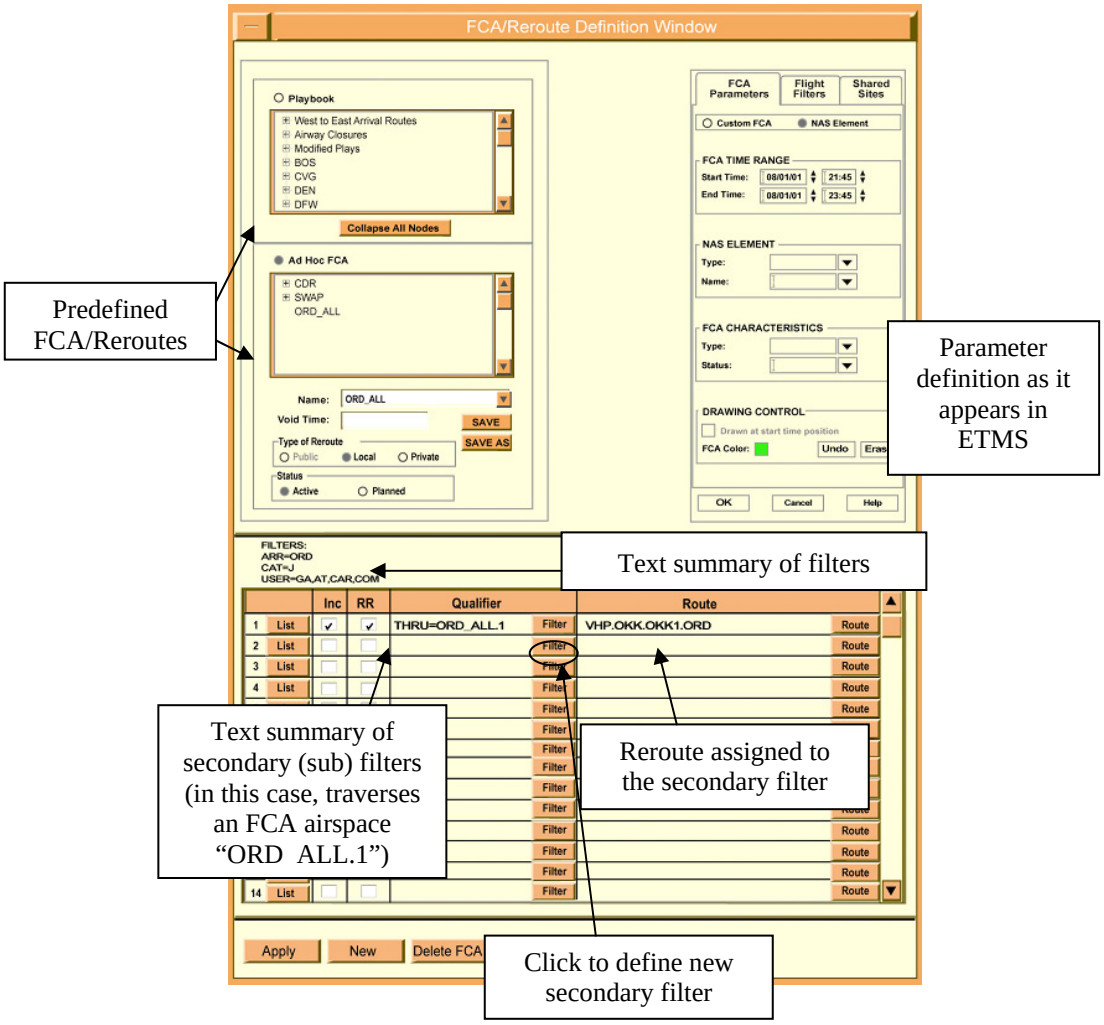


**Figure 1-1. Integrated FCA/Reroute Definition Window from FY02 Evaluation**

The integrated definition window, as designed for the FY02 evaluation, added functionality to the existing ETMS Create Reroute window. In the integrated definition concept, the filters that define which flights are to be rerouted, and the reroute proposed or assigned to those flights, are all specified and viewed in a single window. The concept also contains provisions for rerouting some, but not all, of the flights in an FCA, or for simply listing the flights in various subfilters without rerouting them. The integrated definition window as it appears above served as one starting point for the FY03 re-engineering activities.

## 1.3 Purpose and Scope

As mentioned above, CAASD was tasked by the FAA to work with WJHTC and VNTSC on re-engineering the HCI of operationally mature FFP2 baseline CRCT functions. The purpose of this document is to summarize CAASD's FY03 contributions toward this re-engineering effort. The document describes the re-engineering activities conducted for FFP2 CRCT functions implemented or designed in FY03, as well as capabilities to be designed and deployed in the near future, and a suggested approach for continued re-engineering activity as these capabilities are designed and deployed.

In this document, the term "reroute" is used to refer to two different types of functionalities. The first, Reroute Modeling, refers to the ability to display the impact of a proposed reroute strategy on specific airspaces and individual flights, before deciding to implement it. The second reroute functionality, Create Reroute, refers to the capability currently available on ETMS which allows the user to preview the text of a reroute strategy and display the routes geographically before deciding to implement it. Create Reroute now includes Reroute Advisory Tool (RAT) technology, developed by a joint FAA-airspace user-university team, with CAASD's assistance[6]. RAT functions include listing the flights expected to reroute as part of the reroute strategy, and the automatic creation of a consistently formatted advisory, disseminated to the affected FAA facilities and airspace users. In this document, the term "Reroute Modeling" or "Create Reroute" will be used as appropriate. Any reference to "Rerouting" encompasses both types of reroute functionality.

**Section 2**

# CAASD Contributions to Re-engineering of HCI

During FY03, CAASD made several contributions toward the re-engineering of the user interface for operationally mature FFP2 CRCT functions. First, CAASD validated the benefits of an integrated FCA/Reroute user interface, by meeting with appropriate FAA stakeholders and by conducting cognitive modeling analysis to corroborate the benefits of integrating the functions. These activities are described in Section 2.1. Based on the operational evaluation and cognitive modeling results, CAASD provided formal and informal input on user interface issues during design meetings with WJHTC and VNTSC, as well as during meetings of FAA and airline stakeholders, e.g., Collaborative Decision Making (CDM) Working Groups (WGs). These meetings are described in Sections 2.2 and 2.3. As VNTSC released draft requirements for CRCT-related functions, CAASD commented on these, as discussed in Section 2.4. Section 2.5 discusses the impacts of the collaborative re-engineering effort on the user interface design for the ETMS implementation of the CRCT functions. In addition to these impacts, steps have been taken in FY03 toward the design of enhanced FCA and Reroute Modeling functions planned for ETMS implementation in the near future, and these activities and functions are covered in Section 2.6.

## 2.1 Validation of FCA/Reroute Integration Benefits

The FY02 FFP2 CRCT evaluation findings regarding the need for an integrated FCA/Reroute user interface were validated via meetings with FAA stakeholders, and analytical modeling. Results of the evaluation, including TMC feedback and the integrated mockups used in the evaluation, such as the one shown in Figure 1-1, were briefed to AUA-700 in October 2002 and the TFM User Team (TUT) in November 2002. These meetings resulted in a validation of the aforementioned preliminary conclusions: that is, the TMC feedback reflected an important near-term need to integrate the FCA and Rerouting functions. This was documented as a recommendation in Reference 5, which was published following the October and November meetings.

At the time of the FY02 FFP2 CRCT evaluation, the proposed integrated interfaces existed only as static mock-ups, rather than an interactive demonstration platform such as CDEP. It was therefore important to corroborate the operational feedback by determining the extent to which the proposed interfaces would result in improved user interface interaction. During October through December 2002, cognitive modeling analysis was conducted for this purpose.

Cognitive models describe and predict human interactions with an interface during a specified task. For this analysis, a form of GOMS (Goals, Operators, Methods, and Selection

rules) known as Natural Language GOMS (NGOMSL) was selected[7]. NGOMSL models predict parameters such as the amount of time the user will spend physically interacting with an interface, and the mental workload imposed by the interface[8].

NGOMSL models require a detailed task description. For this analysis, the models were based on a rerouting task similar to those demonstrated in the FY02 FFP2 CRCT evaluation. The task was to create an FCA to identify a set of traffic, place an arrival filter on the traffic within the FCA, filter the traffic further using the crossing filter functionality, and then place a reroute on the resulting flights. The user subsequently decides to evaluate additional reroutes, requiring further filtering to capture the appropriate flights. The values for the amount of time each subtask takes, such as clicking a button or typing text, are taken from previous Human Factors research[9].

Two sets of interfaces were compared: "CRCT" (i.e., the existing CRCT CDEP functions with FCA and Reroute Modeling as separate functions) and "Integrated Planning Set," where the functions are integrated as shown in Figure 1-1 (integrated definition window) and Appendix B (integrated list window).

Using the existing CRCT CDEP, this entire task would take 118 seconds to complete for a typical user. Using the integrated definition window, the task would take 106 seconds to complete, an 11 percent reduction in interface interaction.

Further analysis showed that part of the difference is due to the time spent interacting with the interface to recover information lost from memory regarding which FCA goes with which reroute set.

In addition to investigating task execution times, mental workload was analyzed in terms of Working Memory (WM) Usage. The unit of WM for this type of analysis is the *chunk*, a string of related information that the mind can treat as a unit. Classic cognitive science work[10] indicates that a user can simultaneously process between five and nine chunks. However, in a dynamic and time-sensitive environment such as TFM, five concurrent chunks is considered a limit.

Working Memory results showed the average usage across the task was 2.6 WM chunks using the Integrated Interface and 2.8 WM chunks with the CRCT interface. The Integrated Interface never exceeds four WM chunks during the modeled task, but the CRCT interface reaches five chunks twice, and remains there as long as 5 seconds, due to the need to manage both the Reroute Set and the FCA Set mentally. In addition, the model shows that working memory failure does not become an issue using the Integrated Interface; however, using the CRCT interface results in working memory failure, due to forgetting the Reroute Set name. This necessitates additional interaction with the interface to reacquire the information. The profile of the number of WM chunks used by each interface over time is seen in Figure 2-1.

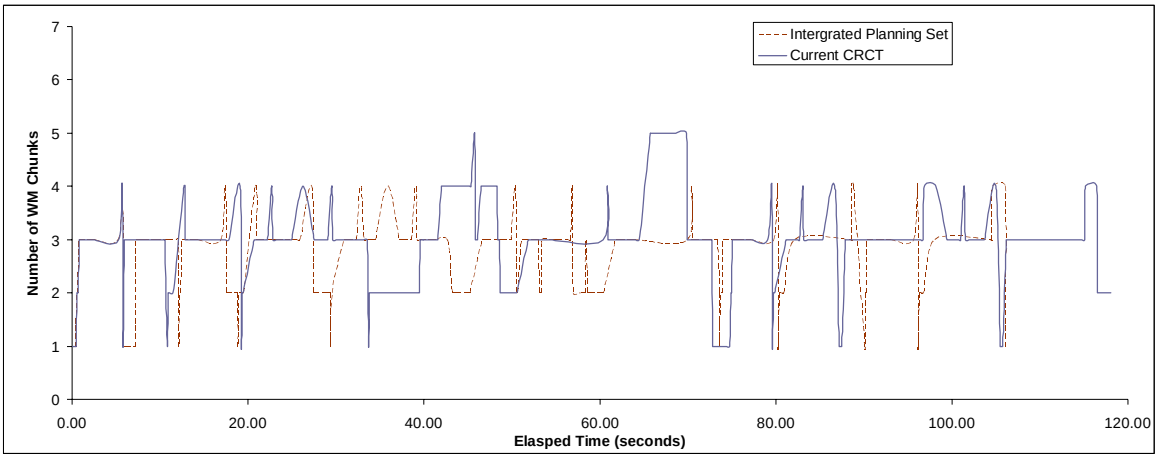


**Figure 2-1. Working Memory Usage During Rerouting Task**

In general, the NGOMSL analysis corroborates the operational evaluation findings that integrating the FCA and Reroute Modeling functions represents an improvement. The unanimous TMC support for the integration, coupled with the quantitative mental workload and time savings, result in a stronger conclusion that the integration was operationally necessary. A sample of the detailed analysis can be found in Appendix C, and a full description of the analysis is in Reference 8.

## 2.2 Design Meetings with VNTSC and WJHTC

The operational evaluation mockups, scenarios and results, and the NGOMSL analysis results, were briefed to ACB-220 (NAS Human Factors) in December 2002 at WJHTC. ACB-220 was tasked to make recommendations to VNTSC regarding the user interface for the FCA filtering functions for ETMS 7.7, and CAASD briefed ACB-220 in order to provide operational and Human Factors input to assist with their user interface recommendations. Discussion and brainstorming occurred regarding options for implementing the user interface for the FCA filtering functions as well as, in the future, integrating them with Rerouting functions.

The evaluation mockups, scenarios and results were provided to VNTSC in December 2003, and telcons and e-mails with software development personnel followed. User interface, operational, and implementation issues were discussed.

Based on comments from ACB-220 and VNTSC, a slightly modified version of the mockups was presented to ATT-230 later in December. Additional brainstorming took place, and ATT-230 provided feedback. The mockups and scenarios were accordingly modified further, for use in future design meetings and briefings, including the January 2003 FCA WG meeting described in Section 2.3.

Further interaction with VNTSC regarding the iterative development of CRCT functionality in ETMS was accomplished at the ETMS Technical Interchange Meeting (TIM) and Design Review in February 2003. CAASD personnel participated in this review, adding comments from the FY02 FFP2 CRCT evaluation and based on operational and Human Factors principles.

## 2.3 Participation in CDM Working Groups

High-level summaries of the operational evaluation results and the cognitive modeling results, along with numerous mockups, were combined into a briefing used in some of the re-engineering discussions that took place over the course of FY03. Many of the discussions took place during the regular meetings of two CDM WGs. These groups provide their input to the prioritization of ETMS enhancements. The WGs CAASD worked with on re-engineering activities were the RAT WG, and the FCA/Flow Evaluation Area (FEA)-Reroute (or simply FCA) WG. In the course of these meetings, CAASD provided input to design issues based on knowledge of the FFP2 CRCT evaluation results, TFM operations, and Human Factors. In addition, by participation in these groups, CAASD remained aware of the developments in the operational concept for procedural usage of the CRCT capabilities, especially the FCA, which is now deployed on ETMS. This enabled CAASD to create more operationally current proposals and mockups to support the re-engineering activity.

In January 2003, CAASD formally briefed the FCA WG on the FY02 FFP2 CRCT evaluation results and presented scenarios illustrating the use of potential integrated interfaces. The briefing reflected the updated operational concepts arising from FCA WG discussions. Following further revisions that reflected the evolving operational concepts discussed in FCA WG meetings, the briefing was posted to the CDM web site in April 2003, at the request of the WG. Here it could serve as a guideline for the WG's consideration of automation needs for an integrated FCA-Rerouting capability. The integration topic resurfaced in the June 2003 FCA WG meeting, and a link to the briefing was resent to the group to generate further discussion. Figures 2-2 and 2-3 show excerpts from the briefing.

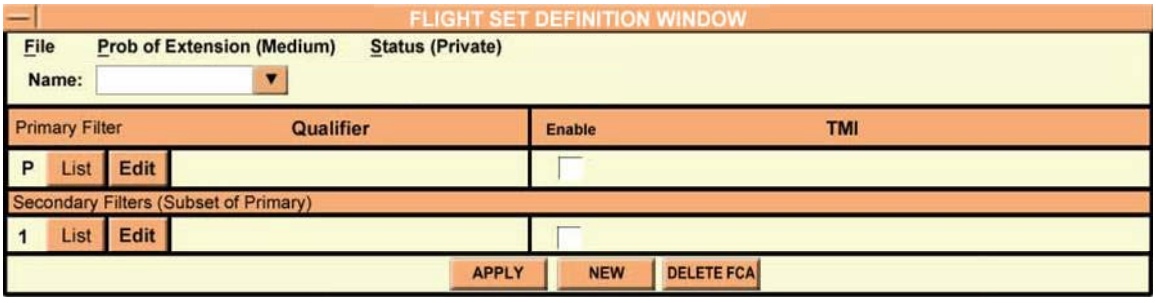


**Figure 2-2. Integrated Definition Window from Revised Mockup**

The menus in this mockup were designed to correspond with options that already existed in the ETMS Create Reroute interface. Based on operational feedback received during FY02 FFP2 CRCT evaluations, and on existing VNTSC mockups, the Primary and Secondary Filter interfaces were revised from the definition capability shown in Figure 1-1, and are now more functionally similar to the VNTSC proposal (shown later in Figure 2-4). Figure 2-3 shows the window populated with user entries.

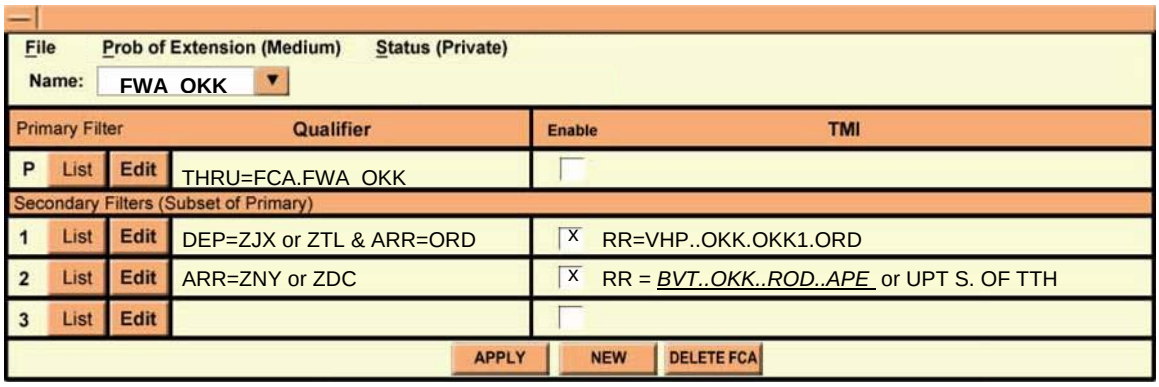


**Figure 2-3. Integrated Definition Window from Revised Mockup—Populated**

In this illustration, the primary filter is all flights expected to pass through FCA.FWA_OKK, which is a user-defined geographical airspace, during a time that has been specified as part of the FCA definition. All of these flights will be in the Flight Set. As specified in secondary filter 1, a specific reroute has been defined in the Traffic Management Initiative (TMI) column, for flights departing from Jacksonville Center (ZJX) and Atlanta Center (ZTL), and arriving at O'Hare Airport (ORD). In secondary filter 2, multiple options for NAS users—a crucial element of the operational concept for FCA functionality usage—are available for flights arriving at New York Center (ZNY) or Washington Center (ZDC). This is indicated by the "or" separating the "BVT..OKK..ROD..APE" text from "UPT S. OF TTH." The "BVT…" option is underlined to indicate that it is the default route—another important element of the FCA operational concept, referring to the route that the FAA will assign the airspace user if they do not proactively file a flight plan that avoids the FCA airspace. In the second option, the user may file a user preferred trajectory (UPT), meaning that any route avoiding the FCA is acceptable, as long as the route passes south of the TTH fix. The dropdown menu seen later in the first grid of Figure 2-5 illustrates one means that WJHTC has proposed, based on operational input, to specify "UPT" as an option for avoiding the FCA.

## 2.4 Requirements Reviews

CAASD has further contributed to the re-engineering of the CRCT functionality HCI by providing comments on VNTSC's drafts of CRCT-related ETMS requirements. Many of the software requirements for FCAs, and Monitor Alert Facelift functions (NAS and Center Monitors, and the Time In Sector Display) revolved around HCI issues related to function-level concepts evaluated in past FFP2 CRCT evaluations and analyses. Therefore, past evaluation results enabled CAASD to make both functional and HCI-related comments that reflected operational feedback. This activity is detailed in Reference 11 and the supplemental deliverables it describes.

## 2.5 Design Results of Re-engineering Activities

CAASD, WJHTC, and operational personnel have all provided input to VNTSC regarding the design of the user interface for FCA and Rerouting functions. Following the re-engineering activity of early FY03, described in previous sections, VNTSC released mockups of the Multiple FCA Filters functionality for ETMS 7.7. The latest version of the design, completed in March 2003, is seen in Figure 2-4. The software will be deployed in the fall of 2003.

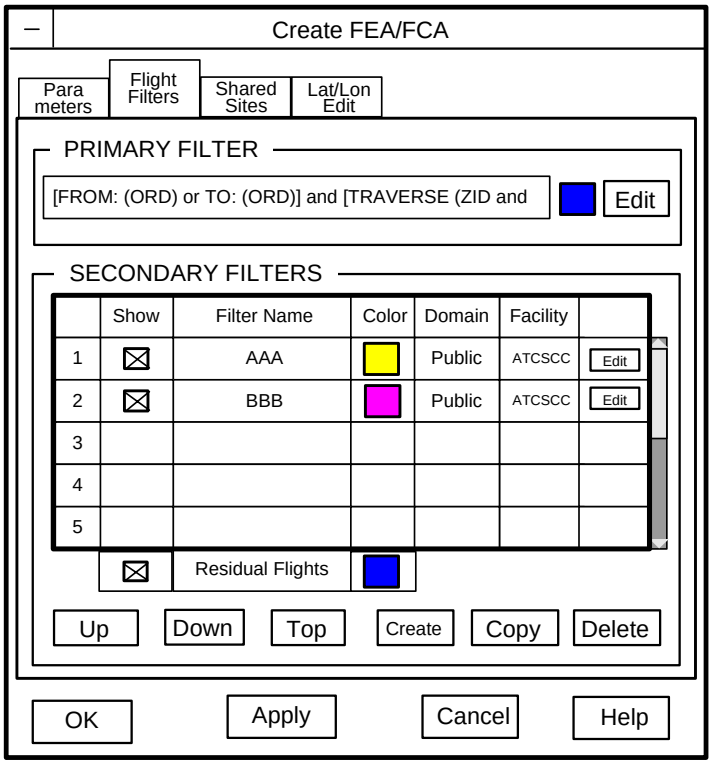


**Figure 2-4. VNTSC Mockup for Multiple FCA Filters**

A number of the features in the design are functionally consistent with the design of the interface in the CAASD mockups. For example, the textual summary of filters (seen in the box under "PRIMARY FILTER"), the activation of a Graphical User Interface (GUI) to specify the primary filter or any secondary filter by clicking an Edit button in the appropriate row, and the "Residual Flights" row (which captures flights in the primary but not in any secondary filter), are all features common to CAASD's evaluation mockups and the ETMS 7.7 FCA Filters design.

Although Reroute Modeling will not be implemented in ETMS 7.8, integration is progressing between the FCA and the existing ETMS Create Reroute functionality. Some features that integrate the FCA and Rerouting functionality are expected to be deployed in ETMS 7.8. The proposed design for the Create Reroute functionality as of July 2003 can be seen in Figure 2-5. The figure is excerpted from a briefing developed by WJHTC Human Factors personnel in ACB-220, and was discussed at two July 2003 meetings hosted by WJHTC.

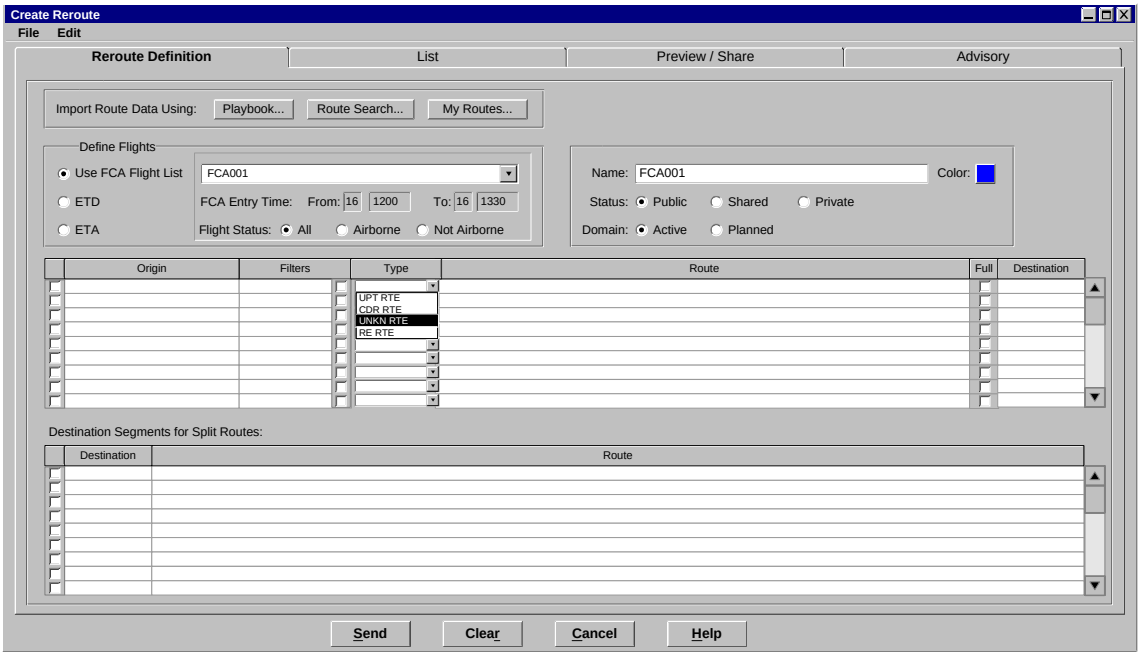


**Figure 2-5. ETMS 7.8 Create Reroute Mockup as of July 2003**

The July 2003 WJHTC meetings were held to discuss user interface enhancements to the Create Reroute functionality suitable for implementation in the near term, i.e., ETMS 7.8, to be released in spring 2004. CAASD participated in both meetings, and in related discussions both before and after the meetings. CAASD offered general comments from the operational and Human Factors perspectives, as well as presenting the FFP2 CRCT evaluation results,

and updated/summarized versions of the integrated interface mockups and scenarios. Most attendees were VNTSC and operational personnel, including RAT WG representatives, and few had previously been briefed on the topic.

During this series of discussions, components of the recommended FCA-Rerouting integration were deemed potentially suitable for ETMS 7.8, possibly as incremental steps toward fuller integration in future releases. For example, in this design, when specifying a reroute, the operator may select an existing FCA to "use" for the reroute. This option filters the reroute list so that only those flights that will pass through the FCA (in addition to meeting any origin, destination, or other filters defined in the "grids" in Figure 2-5) are subject to the reroute advisory. This feature integrates the FCA and Rerouting functionality in a way that should achieve the usability benefits expected based on the FY02 FFP2 CRCT evaluation and the NGOMSL modeling.

In WJHTC's proposed design, when a reroute advisory is created with an attached FCA, the advisory name will be the same as that of the FCA (in this case, FCA001). This is consistent with the results of the FY02 FFP2 CRCT evaluation, where TMCs unanimously agreed that automatic assignment of the same name to an FCA and its associated reroute was an important feature to implement in ETMS. It had been concluded based on the FY02 evaluation that this feature, depicted in Appendix A, would represent a reasonable step toward fuller integration of FCA and reroute functions[5].

The current Create Reroute functionality features the option to generate a list of affected flights for dissemination to applicable FAA facilities and airspace users. Beginning in ETMS 7.8, this list will dynamically update on request of the operator, to reflect flights being removed from or added to the reroute list. This concept, also evaluated in FY02 and depicted in Appendix A, is similar to the dynamic nature of the FCA functionality. This correspondence of the FCA and Reroute Lists' behavior represents another step toward integration.

## 2.6 Re-engineering Activities for FFP2 CRCT Functions to be Implemented After FY03

The user interface enhancements described in the previous section represent steps toward the integration deemed important based on the FY02 FFP2 CRCT evaluation. The FY02 Evaluation Report[5] documents the FAA recommendation, based on CAASD's evaluation results, that as the Reroute Modeling functions are implemented, they be closely integrated with the existing Create Reroute function, possibly accompanied by further integration with FCA capabilities. Although full integration of Create Reroute, Reroute Modeling, and FCA remains a potential future development, initial steps were taken in FY03 toward the design of these integrated functions.

Figures 2-2 and 2-3 presented and described earlier, show CAASD's updated mockups of the integrated Flight Set Definition Window, used to demonstrate fully-integrated functions that could be deployed in the future. It is excerpted from the briefing delivered to the FCA WG in January 2003, posted to the CDM website in April 2003, and presented during the first July 2003 WJHTC meeting.

In addition to assisting with near-term HCI re-engineering, these mockups support post-FY03 HCI development, specifically the integration of reroute modeling into ETMS. The full CAASD briefing from which Figures 2-2 and 2-3 are excerpted, indicates that the information entered in the integrated definition window could serve multiple purposes. All of the following purposes could be served by a functionality designed similarly to Figures 2-2 and 2-3, which could be accomplished via enhancements to Figure 2-4 or 2-5:

- generating the FCA list and analysis information
- generating the list of flights to be rerouted and the appropriate route(s) for each one—known as the RAT List
- generating the RAT advisory message sent to affected FAA facilities and airspace users
- serving as input to Reroute Modeling, which would generate estimates of the airspace demand and airspace user impact if the reroute were implemented.

Initial discussion took place in FY03 regarding accomplishing all these functions from a single integrated interface. This discussion is expected to continue as reroute modeling is implemented in ETMS.

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**Section 3**

# Conclusion

Operationally mature FFP2 baseline CRCT functions are being incrementally technology transferred by CAASD and deployed in ETMS, starting with the deployment of the FCA in 2001. CAASD's FY02 evaluation led to the conclusion that an operational need exists for integration between the FCA and Rerouting functions. In FY03, as part of this technology transfer and deployment process, much progress has been made toward the important goal of integrating these functions.

During FY03, CAASD supported the integration and other HCI re-engineering activity by providing input and guidance to WJHTC and VNTSC regarding the operational, functional, and user interface issues surrounding FCA multiple filtering capabilities and FCA-Rerouting functional integration. CAASD's presentation of the FFP2 CRCT evaluation results and integrated mockups, and participation in meetings of relevant working groups, have given WJHTC and VNTSC input on the operational need for an integrated FCA-Rerouting capability as well as other HCI enhancements. The cognitive modeling results supported the operational evaluation results, showing the extent to which the integrated functions deemed helpful by TMCs can increase the usability of the interface, potentially resulting in more widespread use of the functionality in future ETMS releases.

Based on informal feedback from operational stakeholders, the re-engineering conducted by WJHTC and VNTSC with CAASD input has resulted in an improved user interface for the newly-deployed CRCT functionality. The approach taken in FY03—ongoing communication among all stakeholders and provision of mockups, operational evaluation results, and modeling results—should be continued for future joint WJHTC/VNTSC/CAASD activities, as the remainder of the FFP2 CRCT technology is transferred to ETMS.

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**Appendix A**

# Excerpts from Concepts Evaluated Using CRCT CDEP in FY02

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**Appendix B**

# Excerpts from Flight List Concepts Evaluated Using Mockups in FY02

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**Appendix C**

# Detail of NGOMSL Cognitive Modeling Analysis

NGOMSL (Natural Language GOMS) is a member of the GOMS (Goals, Operators, Methods, and Selection Rules) family of cognitive modeling. GOMS models provide a road map of events that must happen at the cognitive level in order to complete a specified task. Much like a program that is able to provide directions between two points, GOMS determines how a human will go about accomplishing a given task based on their goals. Each GOMS model consists of Goals, Operators, Methods, and Production Rules.

Cognitive models like GOMS assume that humans accomplish tasks through the use of goal stacks. These goal stacks consist of top level goals, for example "Accomplish Goal: Turn on the television" and subgoals necessary to accomplish the top level goal like "Accomplish Goal: Find the remote." Each goal is accomplished by employing various Operators.

Operators are cognitive, perceptual, or mental actions needed to accomplish a Goal. For example, a mental (M) Operator would be used to recall the channel a program is on. A perceptual (P) Operator would be used to scan a list of programs in a channel guide. Each operator has an empirically validated execution time associated with it. For example, research has shown that it takes a human about 500 ms to recall something from long-term memory. The set of Operators used to accomplish a Goal are organized through the use of Methods.

Methods describe how a series of operators are used to accomplish the goal. In the task of turning on the television the following Method describes the use of the needed Operators.

- Accomplish Goal: Change the channel
    - Method for Goal: Change the channel
    - Step 1 Reach for the remote (physical operator – 1500ms)
    - Step 2 Recall channel desired (cognitive operator – 500ms)
    - Step 3 Press buttons for channel 14 (physical operator – 560ms)
    - Step 4 Return with goal accomplished

By adding up the execution time for each of the operators described in the method above, it is possible to derive how long it would take for the average person to change the channel on the television using a remote control (2560ms).

The final element of GOMS models is Selection rules. Selection rules are IF – THEN statements inserted into the model when decisions must be made. For example, "IF location of remote is known, THEN pick it up, ELSE search for remote."

In constructing the models described in this research, a variant of GOMS modeling known as NGOMSL (Natural Language GOMS) was chosen. NGOMSL can be used to predict expert behavior, predict the amount of time it will take to accomplish a task, predict how long it will take to learn a task using a specified interface, and measure the cognitive workload imposed by the use of a specified interface.

An excerpt from one of NGOMSL cognitive models is depicted below. Note the far right column contains the Methods and Selection Rules necessary to accomplish the goals and subgoals related to the task of rerouting flights using the Integrated Interface. The operators necessary to accomplish each step of the method are listed in the far left column. The first operator listed is "P", which indicates the use of the physical operator of pointing to an object using a mouse. The second column, "Oper Time", shows that the empirically validated value for pointing to an object using a mouse is .8 seconds.

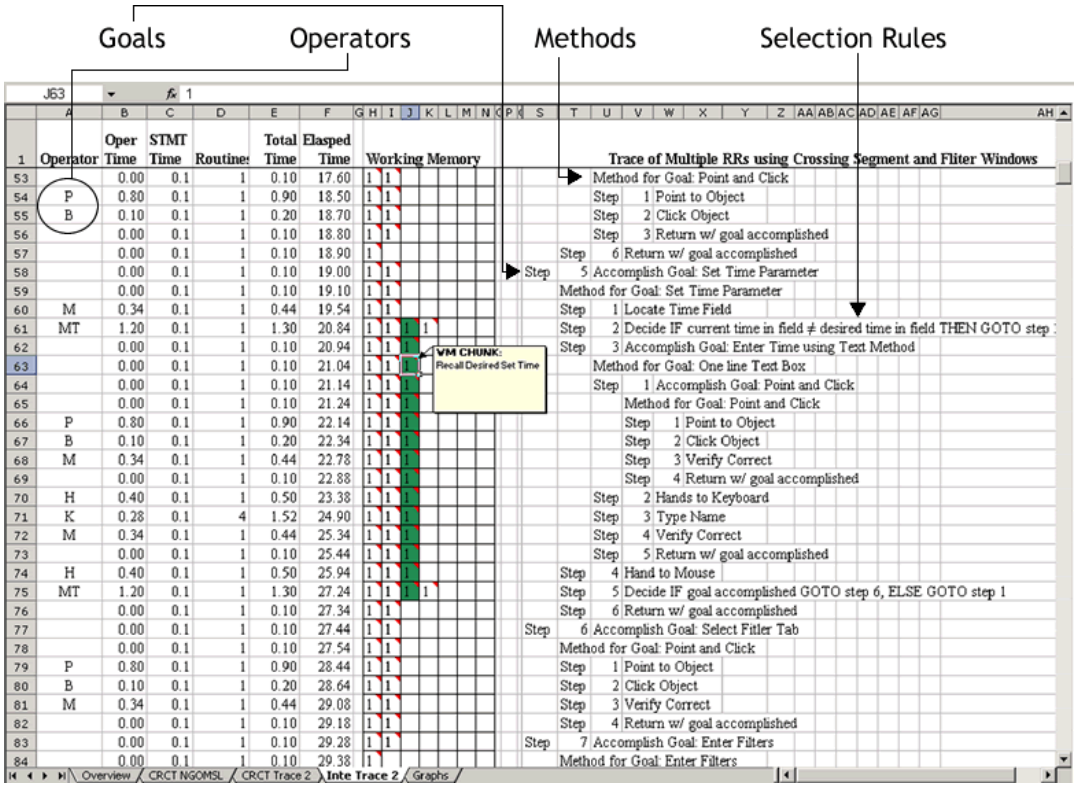


**Figure C-1. Excerpt from NGOMSL Model of Rerouting Task**

The “Routines” column refers to the number of times the operator will have to be executed. For example, naming an FCA “KSAV” requires the K, or Keystroke operator to be used three times, once for each letter. The value shown in the “Total Time” column is the operator time multiplied by the number of routines plus a statement time of .1 seconds. Statement times are corrective figures added to the model to make their predictions more conservative.

The working memory column depicts how many working memory (WM) chunks are used in each step of the method listed on the same row. WM is often referred to as the “workbench” of human cognition. It is a short-term (about 30 seconds), limited capacity storage device humans use in completing cognitive tasks. Because of the small temporal and storage capacity of WM, it often acts as a bottle neck in cognitive processing and can be a major driver of cognitive workload.

Measuring WM usage in the model provides an indication of cognitive workload and can provide information on how the interface can be redesigned to make WM usage more efficient. WM can be impacted by goals and facts that have to be held in memory in order to accomplish a task.

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# Glossary

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| **ARTCC** | Air Route Traffic Control Center |
| **ATCSCC** | Air Traffic Control System Command Center |
| **CAASD** | The MITRE Corporation's Center for Advanced Aviation System Development |
| **CDEP** | Concept Demonstration and Evaluation Platform |
| **CDM** | Collaborative Decision Making |
| **CRCT** | Collaborative Routing Coordination Tools |
| **ETMS** | Enhanced Traffic Management System |
| **FAA** | Federal Aviation Administration |
| **FCA** | Flow Constrained Area |
| **FEA** | Flow Evaluation Area |
| **FFP2** | Free Flight Phase 2 |
| **GOMS** | Goals, Operators, Methods, and Selection rules |
| **GUI** | Graphical User Interface |
| **HCI** | Human-Computer Interface |
| **K** | Keystroke |
| **m** | Mental |
| **NAS** | National Airspace System |
| **NGOMSL** | Natural Language Goals, Operators, Methods, and Selection rules |
| **ORD** | Chicago O'Hare Airport |
| **P** | Perceptual |
| **RAT** | Reroute Advisory Tool |
| **RR** | Reroute |
| **TFM** | Traffic Flow Management |
| **TFM-I** | TFM Infrastructure |
| **TMI** | Traffic Management Initiative |

| | |
|---|---|
| **TMC** | Traffic Management Coordinator |
| **TMS** | Traffic Management Specialist |
| **TUT** | TFM User Team |
| **UPT** | User Preferred Trajectory |
| **VNTSC** | John A. Volpe National Transportation Systems Center |
| **WG** | Work Group |
| **WJHTC** | William J. Hughes Technical Center |
| **WM** | Working Memory |
| **ZDC** | Washington ARTCC (Washington, DC Center) |
| **ZID** | Indianapolis ARTCC (Indianapolis, IN Center) |
| **ZJX** | Jacksonville ARTCC (Jacksonville, FL Center) |
| **ZKC** | Kansas City ARTCC (Kansas City, MO Center) |
| **ZNY** | New York ARTCC (New York, NY Center) |
| **ZTL** | Atlanta ARTCC (Atlanta, GA Center) |