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Exploring Concepts for FAA Traffic Flow Management Inter-facility Collaborative Routing

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Abstract

This paper describes research conducted by the Federal Aviation Administration (FAA) and the MITRE Corporation's Center for Advanced Aviation System Development in traffic flow management (TFM) operational concept exploration. These efforts aim to formulate concepts to increase the flexibility and efficiency of the future National Airspace System (NAS). Still on-going, the research uses a highly interactive process to define key operational, informational and functional needs and then postulates an operational concept to address the needs. The concept involves an enhanced process for FAA inter-facility collaborative routing. Expected to be operational about 2005, it assumes the availability of new TFM decision support capabilities and infrastructure to support real time data exchange and decision making among FAA facilities.

1.0 Introduction

The FAA's Traffic Flow Management Research and Development (R&D) office has been pursuing a number of research and development initiatives that are directed towards improving the effectiveness of traffic flow management decisions. The approach involves improving current flow management decision making processes, within the FAA and between the FAA and the airspace user community, through increases in information exchange and collaboration. Some aspects of this information exchange and collaboration will be accomplished by the introduction of new decision support tools. Information exchange capabilities will provide FAA and user community decisions makers, such as the air carriers, with a common picture upon which to define and respond to problems. Decision support capabilities under development and evaluation will provide their users with an improved ability to identify and resolve traffic flow problems in a strategic time frame.

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) has been assisting the FAA in the definition and initial development of capabilities to help FAA traffic managers. This research focuses on the early identification of potential flow management problems, the development and evaluation of problem mitigation strategies, and in assessing the effectiveness of the strategies to be implemented. The capability definition work has included working with FAA traffic managers and members of the airspace user community to determine how collaboration can be used to improve on how flow strategies such as miles-in-trail restrictions and aircraft rerouting are applied. The research reported in this paper is the result of one such effort.

Improving collaboration between the FAA's local and national flow management operations has the potential to enhance the National Airspace System's efficiency. Potentially, these changes could result in the following benefits:

- A more efficient flow management decision making process
- Increased prevalence of flow management strategies that are system-oriented in emphasis
- Improved user contingency planning based on increased awareness of FAA flow management plans and decisions
- A reduction in the overall volume of restrictions applied at the local and national levels to manage flow problem situations

1.1 Research Approach

The research conducted by the FAA and CAASD to establish a concept of operation for inter-facility collaborative routing involves several activities. These include:

- A detailed examination of current Air Traffic Management (ATM) flow management operating practices and decision making
- Human factors techniques for eliciting input from subject matter experts
- Software prototyping of capabilities to support the emerging concepts

Direct observations of flow management task performance, decision processes and specialists' usage of available operational data were made by CAASD at several FAA Air Route Traffic Control Centers (ARTCCs) and the Air Traffic Control System Command Center (ATCSCC). These observations helped to clarify the current paradigms for flow problem analysis and decision-making, and to bring key information and functional needs associated with traffic flow problem identification and the reroute planning process into focus.

In addition to observations of current flow management operations, traffic management specialists at Kansas City ARTCC served as subject matter experts, providing iterative feedback on initial, and later, on more detailed and mature concepts for collaborative routing. The feedback sessions and evaluations were conducted at the FAA/MITRE field laboratory at Kansas City ARTCC. Software prototypes of proposed functions and information were used extensively for concept, capability, and task visualization purposes.

During the sessions, a combination of facilitated demonstrations and hands on use of the prototypes were used to capture feedback. The demonstrations consisted of preplanned narrated operational activity sequences with task modeling. Recorded traffic and weather data, rather than artificial scenarios, were used to illustrate the new concepts. Comments were elicited from the field participants using structured questions and discussion. The collected data, consisting of verbal feedback, was analyzed and used to revise the concepts and the supporting prototypes.

For these activities, information requirements, functional needs and descriptions of the human tasks implied by the new concepts were emphasized. Considerations that are traditionally a focus of intensive human factors analyses, e.g., use of color and information display design, received less attention since concept exploration should be completed before key design decisions are made.

To ensure that the explored concepts represented a broader orientation than the perspective of a single ARTCC, the FAA assembled a team of local and

national traffic managers and representatives of user groups to provide feedback on the emerging concept. The team was integrated with the Kansas City traffic management specialists and participated in the same type of demonstrations and evaluations.

As a result of these activities, the operational need as well as the information and functional needs associated with TFM inter-facility collaborative routing were defined and a concept was formulated. A related concept produced by this research, which is more oriented to local traffic management's use of CRCT capabilities for reroute planning, is available in the reference.

2.0 Research Results

2.1 Operational Need—A Summary

Today, traffic flow problems are rarely confined to a single facility. Furthermore, the planning and decision making processes used to remediate flow problems are often more tactical than strategic, making implementation inefficient. The ability for multiple facilities to share a common picture of flow problem situations and planning activities that may affect the facilities directly or indirectly is not available. This forces local facilities and the ATCSCC to coordinate planning and strategies to resolve flow problems primarily by voice communications. To a considerable extent, this requires the participants to verbally describe the situation and proposed strategies, and to mentally synthesize the information. These activities are workload intensive and can result in untimely decision making and strategy implementation, as well as misunderstandings.

Traffic managers also lack methods to evaluate the potential effects of flow management actions before they are actually adopted. As a result, they may implement a traffic management strategy without fully knowing if the action will resolve the problem, and what likely effects the strategy may have on other airspace resources. In an attempt to overcome this limitation, they often implement more constraints than may be required to alleviate the problem.

2.2 Assumptions

The concept is dependent on the implementation of new decision support capabilities and communications infrastructure improvements. Collectively, the capabilities are referred to as "Collaborative Routing Coordination Tools" (CRCT). CRCT consists of the following components:

- Flow problem recognition capabilities, including:
  - Modeling future aircraft positions
  - Calculating projected sector loads
  - Calculating projected loading for other airspace resources
- Flow problem analysis capabilities, including:
  - A capability to define an airspace volume, such as a severe weather area or a sector, where traffic flow needs to be managed in some way
  - A capability to analyze projected traffic flow over a resource (fix, airway, etc)
  - A capability to allow the traffic manager to easily identify the aircraft involved in the flow problem
  - A capability to define group or individual aircraft reroutes to reduce traffic flow or avoid static or dynamic situations
- A flow strategy analysis capability that:
  - Enables the traffic manager to evaluate the potential effects of aircraft reroutes on sector volume before they are implemented
- Communication improvements that provide:
  - Real time electronic inter-facility information exchange
  - The ability to electronically distribute flow management information to aircraft operators
  - Electronic capabilities to allow the distribution of aircraft reroutes to the appropriate air traffic control operational position

2.3 Concept Overview

Key features of the operational concept for FAA inter-facility flow management collaborative routing include:

- The ability of local and national traffic managers to observe in real time the same situation and planning data used in the decision making process for identifying and resolving flow problem situations
- The ability to evaluate the potential effects of candidate flow management actions before they are implemented

In the concept, the following roles and responsibilities are assumed for local and national traffic management:

- The ATCSCC is responsible for:
  - Facilitating collaborative problem solving and decision making with local traffic management units when flow problems arise
  - Serving as the primary FAA interface with airspace users to keep users informed of planned or implemented FAA flow management actions
  - Serving as the primary FAA interface for receiving and handling user inputs and requests
  - Creating and distributing large scale traffic flow management plans
  - Assessing and managing the system level effects of flow management actions
- Local traffic management is responsible for:
  - Actively participating in collaborations with other local facilities and the ATCSCC
  - Coordinating information about local conditions and problems with the ATCSCC
  - Monitoring the local effects of flow management actions
  - Adjusting internal ARTCC traffic to maintain sector volume at acceptable levels, while maintaining the overall plan defined by the ATCSCC
  - Communicating the selected flow management strategy to the sector level

2.4 Scenario

For the purpose of this scenario, aircraft rerouting is the strategy selected by traffic flow management to manage predicted traffic congestion near a large line of convective weather. It is acknowledged that rarely in the operation today is a single strategy adopted. Usually, flow management strategies consist of combinations of actions, for example, miles in trail restrictions, ground delays, and reroutes. However, the use of CRCT's capabilities in the future to define aircraft reroute plans, and evaluate the plan's likely results before it is implemented, may lead to an overall reduction in the use of multiple constraints needed today to assure acceptable sector loading.

In this illustration, local and national traffic managers, along with interested airspace users, will participate in the decision process, collaborating to develop a resolution strategy for a flow problem situation caused by weather. The following steps are taken during the process:

- Identifying and analyzing the flow problem situation
- Developing the reroute strategy
- Evaluating the reroute strategy
- Implementing the reroute strategy

2.4.1 Identifying and Analyzing the Flow Problem Situation

Based on National Weather Service (NWS) forecasts, a line of thunderstorms with tops to 45,000 feet will be associated with a cold front extending from central Minnesota across Minneapolis, and Chicago ARTCCs, and into the southern sectors of Kansas City ARTCC, by mid afternoon. This line of thunderstorms is expected to disrupt the major east-west traffic flows across the Midwest.

At 12:00 PM, the ATCSCC, users, and all ARTCC traffic management units (TMUs) in the coterminous United States hold a conference using a combination of electronic visual collaboration (e.g., chalkboards) and voice communications. All facilities have a common display that depicts the set of data (lists,

graphical information) being discussed during the planning session.

The ATCSCC makes available a display depicting the path of the forecast weather over time based on NWS information (Figure 2-1). The participants agree, based on the data, sectors in the southern part of Minneapolis ARTCC, the western sectors of Chicago ARTCC, and much of Kansas City ARTCC will have reduced capacity due to the weather. Based on the NWS forecast, the Kansas City ARTCC sectors nearest the southern terminus of the line of thunderstorms are expected to experience aircraft inflight deviations and volume increases caused by aircraft operator initiated routings. These events make it likely that the area will experience unacceptable sector volume levels. As a result, it will be necessary to replan several major traffic flows through Memphis and Ft. Worth ARTCCs to manage the expected congestion at Kansas City ARTCC.

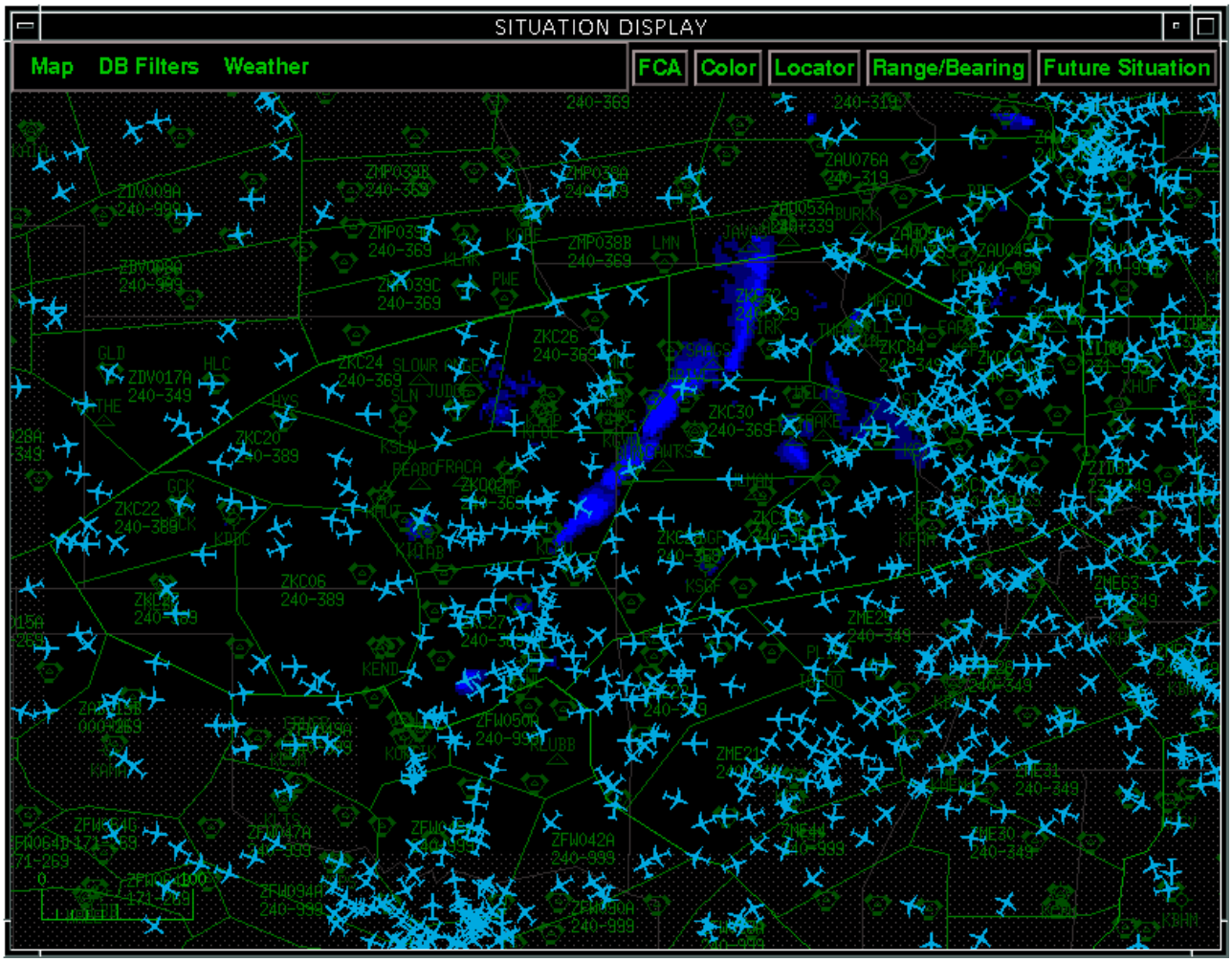

Figure 2-1. Depiction of Future Projection of Convective Activity

The ATCSCC examines Kansas City ARTCC projected sector, fix and route demand data for 3 hours, based on current and planned flight data. The ATCSCC does this to confirm the necessity for a reroute plan to manage the east-west flows. The analysis indicates the Kansas City sectors are likely to be heavily loaded during the time period under analysis. The ATCSCC also examines future aircraft positions projected for the next 3 hours, showing patterns of fluctuation and density in the areas of interest. This information is distributed to conference participants via the chalkboard (Figure 2-2).

2.4.2 Developing the Reroute Strategy

As a result of discussion among the conference participants, there is a consensus that Memphis and

Fort Worth ARTCCs are the best options for re-routing much of the east-west traffic flow, and for reducing the predicted unacceptable traffic loads in the southern sectors of Kansas City ARTCC. To identify areas where sector capacity would permit additional traffic resulting from the reroutes, the Command Center uses CRCT to assess the projected demand over selected fixes, routes, and sectors in Fort Worth and Memphis ARTCCs.

Projections of current and planned traffic over Oklahoma City, OK (IRW) from FL280 through FL550 for the next 3 hours indicate that traffic is likely to be moderate to heavy (Figure 2-3). However, the projections at flight levels 280 through 550 over the Dallas Fort Worth (DFW) area, for the same time period, appear to be light to moderate (Figure 2-4). Farther south, over Waco TX (ACT), traffic appears to be light for the same time period and altitudes. The ATCSCC distributes this demand data to all participants to examine.

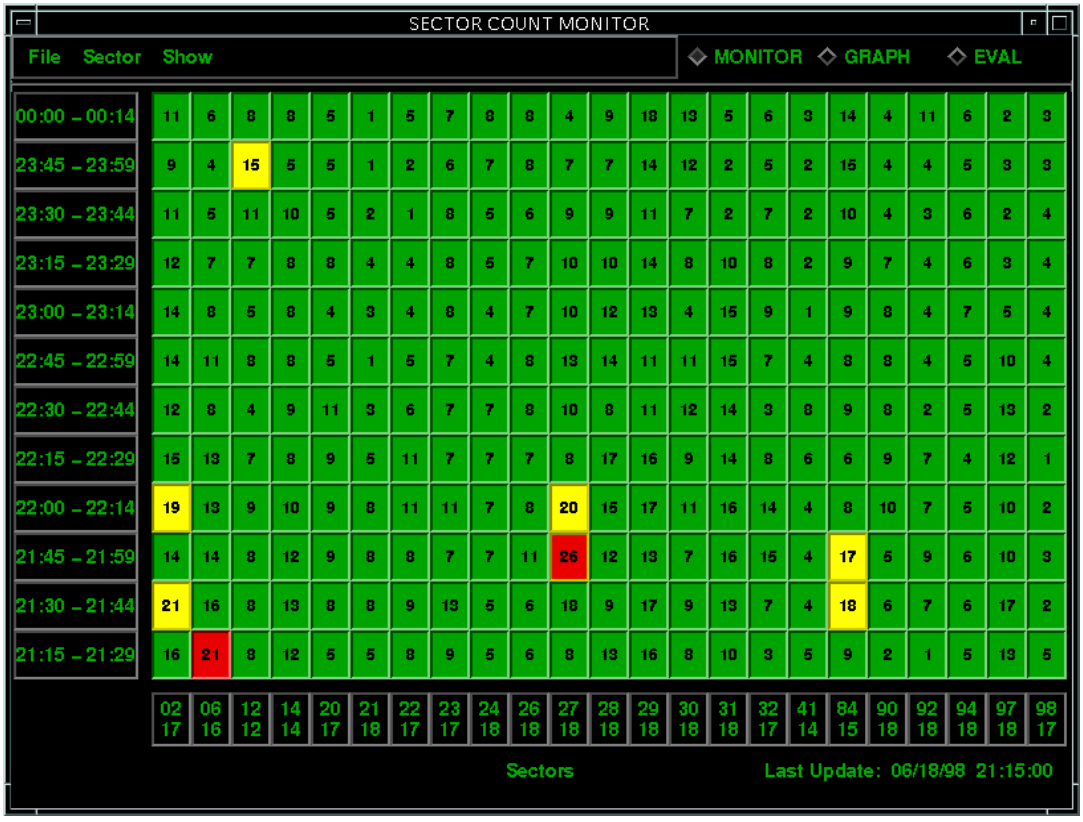

Figure 2-2 Three Hour Sector Count Predictions for Kansas City ARTCC

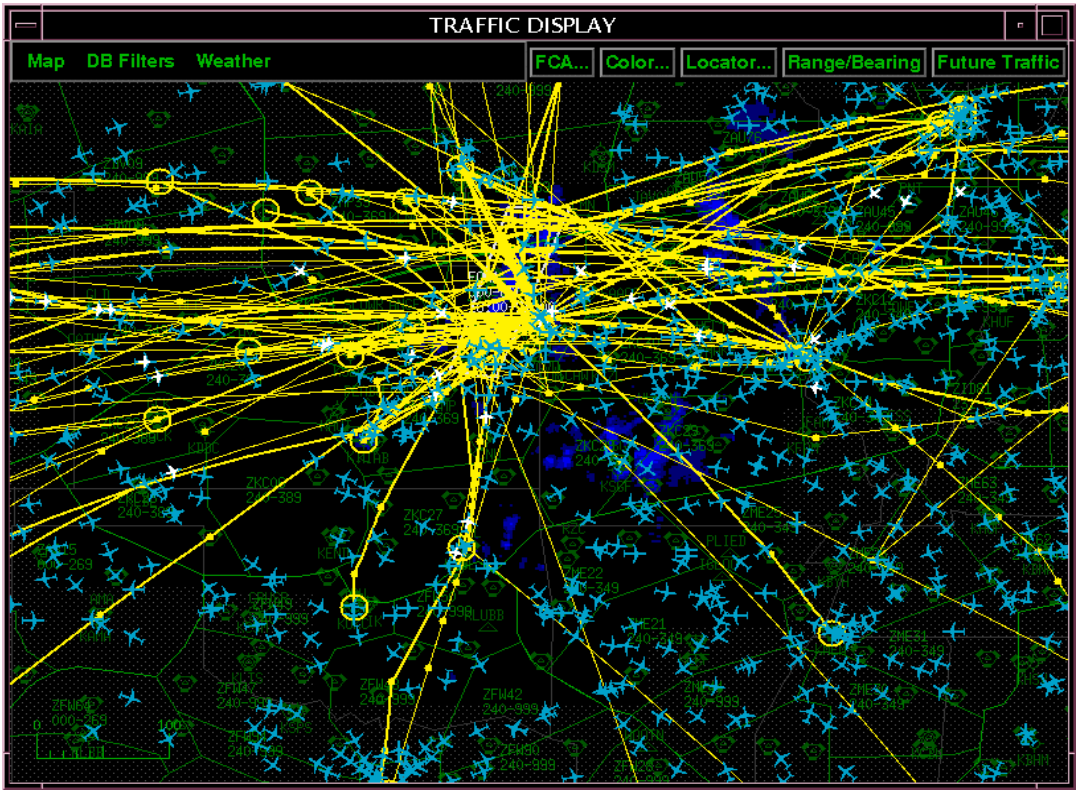

Figure 2-3 Projections of Current and Planned Traffic Over IRW

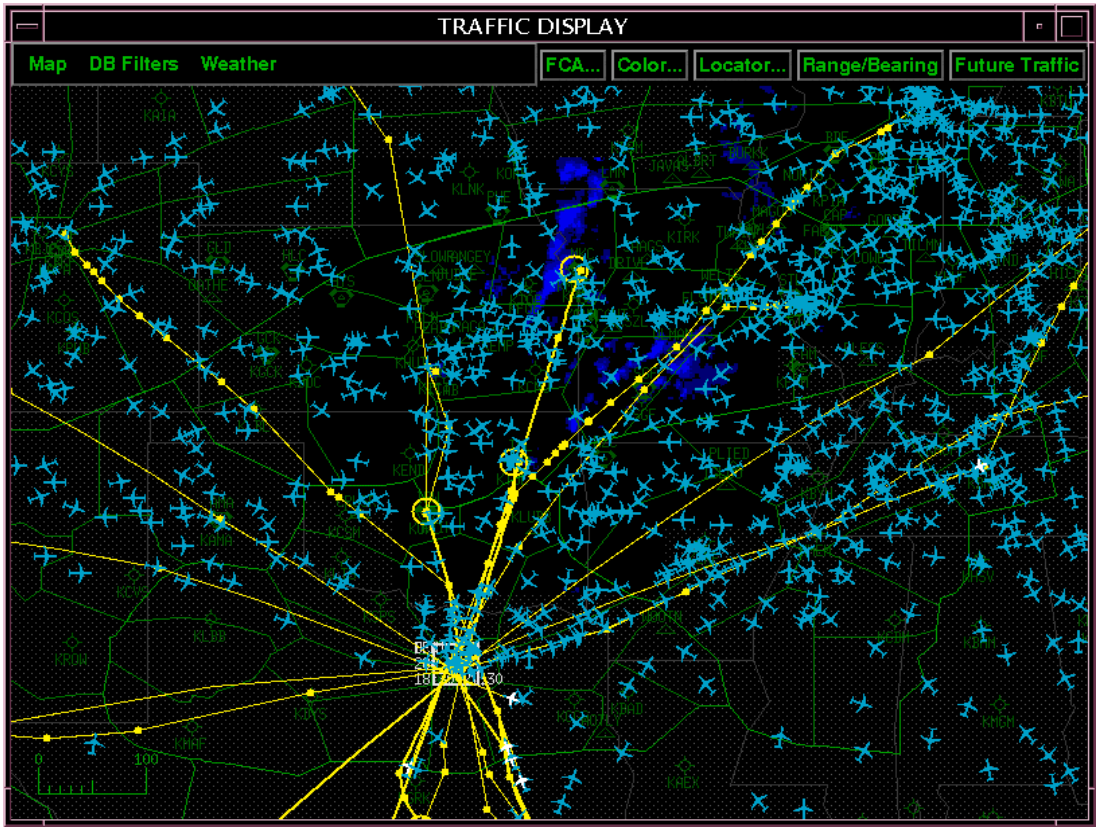

Figure 2-4 Projections of Current and Planned Traffic Over DFW

The Fort Worth ARTCC TMU assesses whether any intra facility situations (e.g., military activity, equipment outages) might interfere with the facility's ability to accept the reroutes. After conferring with the Area Supervisors of the affected areas of specialization, the Fort Worth ARTCC traffic management coordinator concludes that only a small amount of additional traffic may be taken via IRW due to light to moderate turbulence in the area and a scheduled military operation. The other areas indicate that no problems are expected, if additional traffic is routed into their airspace. The Memphis TMU performs a similar assessment.

Based on inputs from the Fort Worth and Memphis TMUs, the ATCSCC uses CRCT to define three major east-west routes traversing Fort Worth ARTCC and Memphis ARTCC airspace. Based on destination airports, the routes are defined by CRCT in both graphical and alphanumeric formats.

For westbound flights, one route is projected for airports in the Albuquerque and Los Angeles ARTCCs. The second would route traffic into the Oakland ARTCC airports; the third would send traffic into the Denver, Salt Lake City, and Seattle ARTCC airports. The ATCSCC plans the flow that is predicted to contain the fewest aircraft through the IRW area.

The proposed routes may be summarized as follows:

- Albuquerque and Los Angeles ARTCCs: via Nashville, TN, (**BNA)**-Sidon, MS **(SQS)**-Shreveport, LA **(SHV)**-Waco, TX **(ACT)**-Wink, TX **(INK)**
- Oakland ARTCC: via **BNA**-El Dorado, AR **(ELD)**-Dallas-Fort Worth, **TX (DFW)**-Abilene, TX **(ABI)**-Albuquerque **(ABQ)**
- Denver, Salt Lake City, and Seattle ARTCCs: via Bowling Green KY, (**BWG)**-

Little Rock AR **(ALT)-**Oklahoma City, OK **(IRW)-**Amarillo, TX **(AMA)**.

The routes laterally separate the major flows, and reduce aircraft convergence at common fixes for aircraft destined to different airports. Additionally, aircraft-specific routes could be constructed to take advantage of advanced aircraft navigation systems. By flying route offsets from the above routes, additional lateral separation is created along the same route. Aircraft-specific routes could be created using latitude/longitude coordinates to describe the route. These features are especially useful to the local TMUs, because they allow shifting some aircraft away from potentially congested areas, while maintaining the general flow created by the ATCSCC.

The routes would apply to all aircraft (except Chicago O'Hare (ORD) traffic) whose current or planned route of flight would take them through the impacted area until 2030Z. Aircraft departing Atlanta ARTCC internal airports or operating through Atlanta ARTCC airspace could join the routes at or near Memphis (MEM), ELD, or SQS.

Chicago O'Hare arrival and departures for Minneapolis, Denver, Salt Lake City, Oakland, and Seattle ARTCC airports are routed north of the weather activity. Chicago O'Hare traffic bound for ARTCCs south and west of this area are routed via PXV, BNA or MEM and the remainder of the weather avoidance route.

Eastbound flights, once clear of the departure terminal area, will fly the above routes until clear of the severe weather area near BWG or BNA. All participants in the conference observe the routes on the chalkboard.

2.2.3 Evaluating the Strategy

The ATCSCC uses CRCT to assess the impacts of the reroutes on sector volume. This is accomplished by grouping the traffic by destination ARTCC, and defining specific reroutes for the resulting aircraft in each flow. Once the ATCSCC finishes defining the reroutes, CRCT automatically alerts the ATCSCC if the reroutes cause unacceptable sector loading in any of the sectors traversed by the new routes. The results are available to all collaboration participants. When the reroutes are modeled CRCT indicates a Fort Worth ARTCC sector threshold would be exceeded for 30 minutes. An adjustment in the reroute traversing that sector is made by the Fort Worth TMU by splitting off the San Diego traffic to a route defined by a series of latitude/longitude fixes rather than NAVAIDS. All conference participants observe the reroute plan in advance.

2.4.4 Implementing the Strategy

The reroute strategy is implemented as follows: For air carrier flights that do not have flight plans filed, the ATCSCC notifies the appropriate Airline Operations Control (AOC) and informs AOC staff of the routes to file and the reason for the action. For flights already having filed flight plans, but not yet departed, the route amendments are entered into the Air Traffic Control (ATC) system and the change is reflected in the filed flight plan at the appropriate control position. The air carrier operators are automatically notified that these amendments have occurred. For already departed flights, the flight plan amendments are transmitted to the appropriate sector controller, who re-clears the aircraft.

3.0 Summary

The concept for inter-facility collaborative routing envisions changes in the way national and local traffic management develop reroute strategies for flow problem situations, and communicate these reroutes to the appropriate users and control positions. In the proposed process, all participants in the collaboration will have the same planning information at the same time. The participants will share an understanding of the location and rationale of the constraint and its expected effect on the traffic. Finally, and perhaps most importantly, the potential effects of the reroute plans will be evaluated before the reroutes are put into effect. This could potentially increase the precision of the FAA in assigning TFM reroutes, thereby reducing the overall number of reroutes applied.

4.0 Status of CRCT

The FAA is currently conducting a field evaluation of the operational concept for inter-facility collaborative routing. Besides confirming the concept's operational validity and benefits, the evaluation is also focussed

on identification of its associated architectural and technical implications. During the evaluation, traffic managers from FAA facilities will refer to information provided by CRCT as they jointly develop and implement aircraft routing flow management strategies.

After the completion of the field evaluation, the FAA will determine the next steps for the concept and for CRCT.

References:

Carlson, L. S., and L. R. Rhodes, April 1998, *Operational Concept for Traffic Management Collaborative Reroute Coordination Tools*, MP 92W0000106, The MITRE Corporation, McLean, VA.