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MITRE TECHNICAL REPORT

Transition Airspace Controller Tools (TACT) Visualization Aids for Radar Controllers

Concepts for Cognitive Assistance With Flow Control Tasks in Transition Airspace

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Christopher T. DeSenti

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Abstract

This document introduces and describes concepts being explored under the Transition Airspace Controller Tools (TACT) research effort at the MITRE Corporation's Center for Advanced Aviation System Development (CAASD). These concepts address identified difficulties radar controllers face while meeting flow restrictions in transition airspace. The tools provide controllers with cognitive assistance, through intuitive visualization, for complex tasks such as accurately meeting time-based metering schedules. This document serves as a primer for decision makers and stakeholders who seek to understand the functional value of TACT concepts; their applicability considering current National Airspace System (NAS) modernization activities; and the postulated effect of their use in an operational environment.

KEYWORDS: Transition Airspace, Metering, Time based, Spatial, Visual, Visualization, Cognitive, Marker, Ghosting

Preface

The contents of this material reflect the views of the author. Neither the Federal Aviation Administration nor the Department of Transportation makes any waranty or guarantee, or promise, expressed or implied, concerning the content or accuracy of the views expressed herein.

Acknowledgments

The contents of this document are based upon of the collective efforts of many individuals who participated in TACT research activities. The author would like to thank those individuals who participated on TACT research teams in 1998, 1999, and 2000, and also Diane Boone, Gene Wilhelm, and Mark Rockman for their managerial support. The author would also like to express great appreciation to Ellen Friedman, Joan Arnold, and Joseph Hetrick for their meticulous and professional guidance with this document.

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Executive Summary

Purpose

This document introduces and describes visualization concepts being explored as part of the Transition Airspace Controller Tools (TACT) research effort at The MITRE Corporation's Center for Advanced Aviation System Development (CAASD). The intent is to provide an overview for decision makers and stakeholders who seek to understand the functional value of the TACT concepts; their applicability considering current National Airspace System (NAS) modernization activities; and the postulated effect of their use in an operational environment. The material is also useful for understanding and interpreting the value gained by providing controllers with cognitive assistance by presenting intuitive visual information for performing complex tasks such as accurately meeting time-based metering schedules.

Environment

It is anticipated that TACT visualization concepts will reach a mature state of research and development during Free Flight Phase 1 (FFP1) which ends in 2002. Therefore, consideration of the FFP1 environment is part of continuing TACT research efforts. FFP1 will deploy key automation capabilities to a limited number of sites within the NAS for formal evaluation by aviation stakeholders and FAA operators.

The NAS environment by the end of 2002, and its future direction, will be largely influenced by the implementation and effectiveness of FFP1 capabilities in the preceding years. However, planning activities for the next phase of Free Flight have already begun, even though that phase is not fully defined at this point. Consideration of NAS modernization activities during this next phase will be part of continuing TACT research efforts, however, those considerations are currently beyond the scope of this document.

The Traffic Management Advisor (TMA) is the FFP1 capability most relevant to discussion of TACT concepts, which assist with flow restrictions in transition airspace. The transition airspace definition used for TACT research includes the high and low en route airspace sectors adjacent to the Terminal Radar Approach Control (TRACON). Transition airspace is that critical area where aircraft are being funneled from their routes of flight into often-congested airport areas. Developed at the NASA/Ames Research Center, TMA is designed to be a strategic traffic management tool. TMA is a sophisticated aircraft scheduling capability for using time-based metering as a means of delivering aircraft at a specified rate to the TRACON. It provides decision support capabilities to the Traffic Management Unit (TMU), and develops an arrival schedule by computing estimated and scheduled times of arrival to meter fixes and outer meter arcs. A meter list is displayed at the controller work station to communicate the scheduled meter fix times to the radar controller.

Transition Airspace Controller Tools (TACT)

The FFP1 implementation of TMA signals a desired shift in general Air Traffic Control (ATC) practices toward the increased use of time-based metering. The success of time-based metering for regulating traffic flows is dependent upon the radar controller, who must execute the control actions to absorb any needed airborne delay, and accurately deliver aircraft at their scheduled times.

The complexity associated with meeting flow restrictions in transition airspace was identified during early TACT research activities in 1998. Further efforts surveyed the process controllers use to meet time-based restrictions at Fort Worth Air Route Traffic Control Center (ZFW). The responses revealed that the controller tendency is to think spatially, indicating that controllers attempt to meet the time-based requirement by estimating the mileage spacing needed with preceding aircraft. In practice, once the first aircraft in a sequence crosses the meter fix, the crossing time is mentally logged and the degree of error in accuracy is noted. Then, the estimated Miles in Trail (MIT) with subsequent aircraft is re-evaluated and adjusted. The described process forces the controller to make mental estimations in the attempt to convert the time-based restrictions into mileage.

This observation raises the question as to the best way to display metering information to the controller. One difficulty inherent in the time-based metering is that it does not account for the natural tendency of human beings to relate to what is in their field of vision in a spatial manner, instead of in a time-based, temporal manner.

As evidenced by the fact that most Air Route Traffic Control Centers (ARTCCs) currently choose not to use time-based metering for flow control, the way of doing business that became a part of the operational culture is the use of MIT to meet flow restrictions. But that institutional and cultural skill orientation, reinforced through training and continuous practice, is not based on preference alone. Radar controllers work in a visual environment that promotes the use of their natural spatial perception skills. Time-based metering, although it can provide traffic management benefits, is counter-intuitive within the context and demands of the controller’s spatial/visual environment. In ARTCCs where TMA is scheduled for implementation, the impending reorientation of this skills base would require a significant paradigmatic shift in operational thinking for the controllers. The operational culture may very well resist this change.

One way to maximize the benefits of time-based metering in the NAS is to provide tools that address institutional barriers to time-based metering, while simultaneously providing enhanced decision support to increase effectiveness and address task complexity.

The Mileage Distance Marker (MDM) and Mileage in the Data Block (MDB) are TACT visualization aids to assist radar controllers with the complex task of managing streams of arrival traffic in transition airspace. The MDM does this by providing a highly intuitive, graphic means of displaying information to controllers to support them in meeting required flow restrictions such as meter fix times or MIT. With MDM the controller can display a marker that depicts to the controller the spatial magnitude of the adjustment needed for an aircraft to meet its time-based restriction. This display provides the controller with a means to make a cognitive adjustment of the temporal metering information so that it is intuitive in their spatial environment. The MDB concept provides similar cognitive assistance by displaying a positive or negative number in the aircraft's data block that represents a spatial increment (mileage adjustment) needed to meet the required restriction. The intention is to provide concepts that enhance the controller's ability to accurately meet scheduled times, while mitigating the increased cognitive workload associated with doing so.

FY2000 Research

TACT concept exploration prior to FY00 made use of a front-of-the-panel, non-interactive demonstration for gathering early input from individuals with operational ATC experience. This input was extremely important for identifying aspects of value, as well as potential problems with the concepts. The key limitation of that early research was that it provided for subjective feedback only, and did not offer the capability to gather objective performance information.

For FY00 the emphasis is on development of TACT concepts in a CAASD laboratory for Human-in-the-Loop (HITL) experimentation. The experimentation will use CAASD's 20x20 inch *DSR Clone* display with keyboard, and traffic and airspace based on real ARTCC operations for a high fidelity look and feel. Participant subjects will be active air traffic controllers contracted through the National Aviation Research Institute (NARI). All scenarios will be completely interactive, allowing the controller to verbally issue appropriate control instructions.

The goal of this approach is to gauge a measurable performance difference between aircraft delivery in metering environments both with and without TACT concepts. TACT HITL evaluations are scheduled to begin at CAASD during July 2000. These activities will result in an increased and more quantitative understanding of the functional application and utility of TACT concepts in a time-based metering environment. Inputs from controller participants will be used for future refinements to the display, behavior, and interface with TACT concepts.

Section 1

Introduction

1.1 Document Purpose

The purpose of this document is to introduce and describe concepts that address identified difficulties radar controllers face while meeting flow restrictions in transition airspace. This document discusses a subset of visualization concepts being explored as part of the Transition Airspace Controller Tools (TACT) research effort at The MITRE Corporation's Center for Advanced Aviation System Development (CAASD), as well as the research hypotheses on which they are based. This information is useful for understanding and interpreting the value gained by providing controllers with cognitive assistance through intuitive visualization for complex tasks such as accurately meeting time-based metering schedules.

The intent is to provide a basis for decision makers and stakeholders to understand the functional value of TACT concepts, their applicability considering current NAS modernization activities, and the postulated effect of their use in an operational environment.

It should be noted that TACT concepts discussed herein are in an early phase of the system development life cycle and require further study, evaluation, and development. The work is being conducted under MITRE/CAASD's Mission Oriented Investigation and Experimentation (MOIE) program.

1.2 Document Organization

The remainder of this document is divided into 4 sections. Section 2 discusses National Airspace System (NAS) modernization efforts being undertaken in Free Flight Phase One (FFP1). These efforts shape the environment and the context to which new concepts and research such as TACT can be applied.

Section 3 addresses TACT concepts and the research that identified their need and led to their development. Section 4 outlines current research efforts, and Section 5 provides a brief summary.

Section 2

Environment

To set a proper context for discussion of TACT concepts in an Air Traffic Control (ATC) environment that includes NAS modernization capabilities, this section will summarize selected aspects of that NAS environment, based on current plans, at the end of 2002. A number of documents have been published that provide broader and more in-depth descriptions of the future NAS. This summary, based on several of these source documents, is intended to provide only a high level overview of areas pertinent to the TACT concepts. For broader and deeper treatment of the expected modernized NAS environment, the reader is referred to these source documents [1, 2, 3, 4].

2.1 Free Flight

Free Flight is a conceptual vision for the NAS in which aircraft fly user-preferred trajectories under Instrument Flight Rules (IFR) while the system maintains a safe and efficient operating environment. Under Free Flight, air traffic restrictions would only be used to ensure separation, to preclude exceeding airport capacity, to prevent unauthorized flight through Special Use Airspace (SUA), and to ensure safety of flight. Restrictions would be limited to the extent and duration necessary to correct identified problem.

2.1.1 Phases of Free Flight

It is understood that the Free Flight vision will not be fully realized until a mature state of Free Flight implementation is reached. The NAS Modernization Task Force recommended that Free Flight be implemented in phases in order to mitigate risk while still providing highly desired capabilities at selected locations. The first of these phases, Free Flight Phase 1 (FFP1), is scheduled to be implemented by the end of 2002. FFP1 will deploy key automation capabilities to a limited number of sites within the NAS for formal evaluation by aviation stakeholders and FAA operators. Under this approach, referred to as Core Capabilities Limited Deployment (CCLD), each capability will be evaluated for operational suitability and benefits prior to committing to a wider deployment across the NAS. The next phase of Free Flight is not finalized at this point, although planning activities for it have already begun in response to RTCA recommendations. The time frame for this phase is generally agreed to be between 2003 and 2005. Although consideration for NAS modernization activities during this timeframe will be part of future TACT research efforts, those considerations are beyond the scope of this document.

2.1.2 Free Flight Phase 1 (1998-2002)

Free Flight represents a concept. FFP1 is an active FAA program representing an incremental step in the evolution toward Free Flight.

The goal of FFP1 is to provide near-term air traffic management capabilities that can safely yield early benefits to service providers and NAS users, while mitigating implementation risk through the limited deployment of low risk core capabilities at specified sites. These new technologies will be utilized in conjunction with new procedures and standards with the goals of increased responsiveness to airspace user routing and scheduling preferences, and enhanced efficiency of NAS operations, while maintaining today's high level of system safety.

The NAS environment by the end of 2002, and its future direction, will be largely influenced by the implementation and effectiveness of FFP1 capabilities in the preceding years. Those capabilities are as follows:

- User Request Evaluation Tool (URET)
- Traffic Management Advisor (TMA), Single Center (SC)
- Passive Final Approach Spacing Tool (pFAST)
- Surface Movement Advisor (SMA)
- Collaborative Decision Making (CDM)

Of the listed capabilities, TMA is most relevant to discussion of TACT concepts that assist with flow restrictions in transition airspace. TMA is a sophisticated aircraft arrival scheduling capability for using time-based metering as a means of delivering aircraft at a specified rate to the Terminal Radar Approach Control (TRACON). Developed at the NASA/Ames Research Center, TMA is designed to be a strategic traffic management tool. It provides decision support capabilities to the Traffic Management Unit (TMU), and develops an arrival schedule by computing estimated times of arrival (ETA) and scheduled times of arrival (STA) to meter fixes and outer meter arcs. A meter list is displayed at the controller work station to communicate the scheduled meter fix times to the radar controller.

TMA functionality as it relates to TACT concepts in transition airspace will be discussed further in Section 3.

Section 3

Transition Airspace Controller Tools

3.1 Background

In 1998, CAASD initiated the TACT research effort to explore problems associated with operations in transition airspace. Specifically, this research focused on the radar controller's role, including the complexities encountered in managing operations. The initial stages of this research included visits to six ATC facilities to observe, survey, and identify areas of complexity. Input from controllers regarding tasks performed and means of approaching them was instrumental in this early stage of problem identification. The underlying goal was to identify areas where visualization concepts might provide cognitive assistance for the radar controller, and where appropriate, initiate the development of such concepts.

The TACT team's research activities identified several issues of complexity, and subsequently identified visualization concepts to assist the radar controller with decision making processes related to managing those elements of complexity. The specific element on which this document will focus is the controller's task of meeting flow restrictions in transition airspace. In 1999, the TACT team published a report [5] outlining other elements of complexity as well as their initial research efforts.

3.1.1 Transition Airspace

Some researchers have referred to transition airspace as the "extended terminal area," relating it to the tactical and complex operations that commonly occur in terminal airspace. TACT research and surveys of transition airspace validate this characterization. It is indeed not uncommon for transition airspace operations to span the range from strategic to tactical and to contain complex traffic flows.

It is recognized that airspace configurations vary from facility to facility. However, for the purposes of TACT research, the definition of transition airspace includes the high and low en route airspace sectors adjacent to the TRACON. It is that critical area where aircraft are being funneled from their routes of flight into often-congested airport areas. A fuller discussion of the transition airspace definition used for TACT research is found in the Appendix.

Frequently transition airspace radar controllers must work toward multiple goals, adding to the overall complexity. They are often responsible for tasks such as merging streams of aircraft while simultaneously managing arrivals and departures for satellite airports, and absorbing airborne delay to meet flow restrictions into primary airports. This requirement to manage arrival flows represents a significant level of complexity added to the maintenance of required separation and other controller tasks, particularly in a time-based metering environment.

3.1.2 TACT Research and the Time-Based Metering Environment

While researching transition airspace operations, the TACT team learned that the metering task creates a great deal of operational complexity for the radar controller. With the FFP1 implementation of TMA signaling a general shift in ATC practices toward time-based metering, there exists a need for concepts that provide the controller with intuitive information and assist with the cognitive loads associated with flow control tasks. Such decision support concepts will allow the FAA to realize more of the potential benefits offered by time-based metering capabilities in the NAS.

A metering environment, as referred to in this document, is one in which aircraft are scheduled to be over a point in space, referred to as a meter fix, at a scheduled time of arrival (STA). The R-side controller is typically provided with a list that identifies the aircraft being metered, their STAs, and the aircraft's associated time delay. The R-side controller's task is to meet the prescribed STA, usually with ATC techniques such as vectors, speed control, and holding, to deliver the aircraft over the meter fix at its scheduled time. This task typically takes place in transition airspace. Currently the predominant method of restricting flows of arrival traffic is through distance-based MIT restrictions. The added complexity of time-based metering can lead to frustration on the part of the controller, and is a key contributor to the operational preference for using MIT for flow control.

One difficulty the time-based metering method presents is that it does not account for the natural tendency of human beings to relate to their field of vision in a spatial manner, instead of in a time-based, temporal manner. For a radar controller, this natural tendency is continuously reinforced through conditioning and training. Radar controllers operate in an environment that is heavily oriented to spatial perception. They work with a two-dimensional video map display precisely measured and scaled to facilitate the use of mileage increments. The majority of radar separation standards that controllers apply are distance-based. With constant reinforcement through continuous daily practice, controllers become very adept at working within this environment. Over time they develop a keen ability to anticipate and achieve specified degrees of spacing between aircraft.

Controllers at Fort Worth ARTCC (ZFW), who provide traffic sequencing to Dallas Fort Worth TRACON, are considered to be among the most skilled in a time-based metering environment due to their extensive experience with TMA. Initial TACT research, which surveyed the process some controllers use to meet time-based restrictions, supported the assertion that the controller tendency is to think spatially. When ZFW controllers were asked to describe the means by which they accurately meet meter times, responses indicated that controllers attempt to meet time-based requirements by estimating the mileage spacing needed with respect to the preceding aircraft. To convert meter time intervals to MIT, the controller must mentally estimate the relationship between an aircraft's assigned speed, controller assigned descent profile, vector heading, and the effect of observed wind components on the aircraft's ground speed. In practice, once the first aircraft in a sequence crosses the meter fix, the controller mentally converts the subsequent meter fix times to distances, estimating an MIT based on observed conditions that day. An aircraft's actual meter fix crossing time is mentally logged, the degree of error in accuracy noted, and the estimated MIT with subsequent aircraft is re-evaluated. The described process forces the controller to make multiple mental estimations in order to convert the time-based restrictions into mileage.

This observation raises the question as to the best way to display metering information to the controller. Miles In Trail, as a spatial means of flow control, is a natural extension of the controller's spatial skills. Time-based metering, although more accurate for scheduling, is operationally counter-intuitive within the context and demands of the controller's spatial/visual environment. Further evidence of this lies in the fact that most ARTCCs have made the operational choice not to use time-based metering as the method of flow control, even though they have had metering capability in the form of the Arrival Sequencing Program (ASP) since the 1980s. Though ASP does not offer the sophistication or accuracy of TMA for flow control, it is significant that most ARTCCs are choosing MIT over time-based metering.

At the institutional level, a significant element to consider is controller skill orientation. Since in most ARTCCs time-based metering is not an operational technique that is practiced for flow control, the way of doing business that became a part of the operational culture is the use of MIT to meet flow restrictions. In ARTCCs where TMA is scheduled for implementation, the impending reorientation of this skills base would require a significant paradigmatic shift in operational thinking for the controllers. The operational culture may very well resist this change.

3.2 Concepts

TACT concepts are geared toward providing assistance with cognitive loads associated with particular tasks for the radar controller by presenting a visual display of the task that supports the controller's role. The concepts being researched under TACT can essentially be split into two main categories:

1. Concepts geared toward assisting the radar (R-side) controller with the tasks of meeting time-based metering restrictions and/or MIT restrictions. These concepts will be referred to as R-side Restriction Assist concepts.
2. Concepts that assist the R-side controller with visualizing the anticipated spatial relationships between aircraft pairs during other types of operational circumstances, such as crossing traffic situations.

This document will focus on Restriction Assistance concepts, as they are the primary focus of TACT FY00 research. The concepts referred to in item 2 will be addressed in later research and documentation.

3.2.1 R-side Restriction Assistance Concepts

This section will discuss the Mileage Distance Marker (MDM) concept and its functional applicability to the time-based metering and MIT environments. This section also refers to and describes the TACT Mileage in the Data Block (MDB) concept. Both of these concepts were designed to assist decision making while improving performance efficiency and accuracy by delivering spatial information to the R-side controller. This spatial approach allows controllers to visualize and react to the information on a level they find intuitive, while simultaneously reducing the need to look away from their traffic to consult separate displays such as lists or timelines.

3.2.1.1 Mileage Distance Marker (MDM)

The MDM is a tool concept for assisting radar controllers with the complex task of managing streams of arrival traffic in transition airspace. The MDM does this by providing a highly intuitive, graphic means of displaying information to controllers to support them in meeting required flow restrictions such as meter fix times or MIT. The MDM allows the controllers to display a marker that visually indicates the spatial magnitude of the adjustment needed for that aircraft to meet its restriction (see Figure 3-1). For use in a metering environment, the MDM concept provides the controller with a means to make a cognitive adjustment of the temporal metering information in a way that is intuitive for their spatial environment.

It is important to note that the MDM does not generate the aircraft schedule for the metering environment. That role is fulfilled by a specialized scheduling capability such as TMA or ASP. The MDM's role is to convey the magnitude of the specified restriction to the controller in a spatial and visual manner.

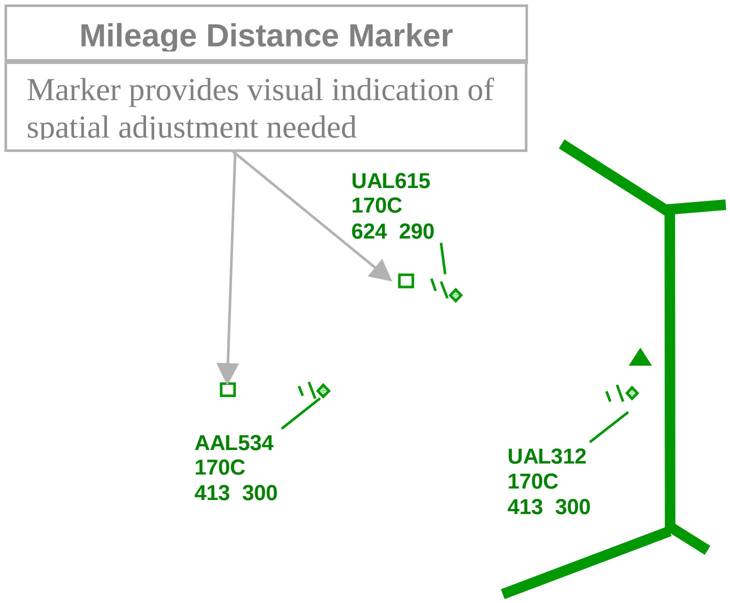

Figure 3-1. MDM Display

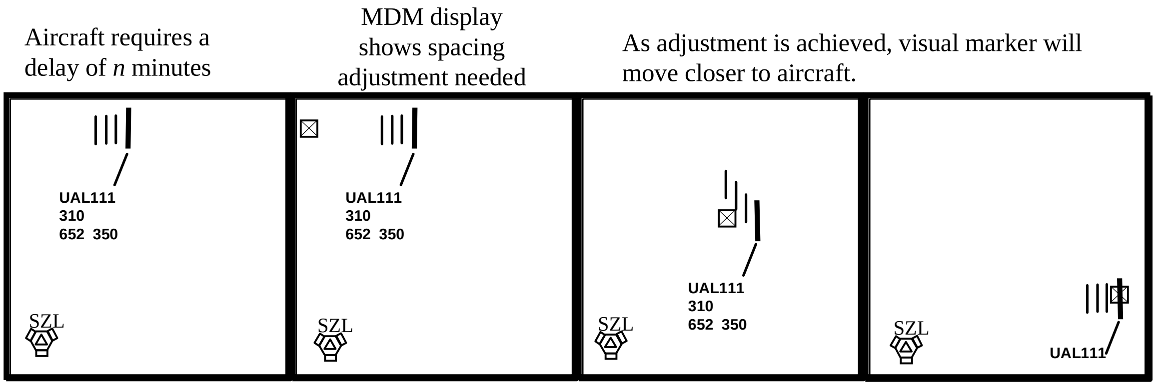

Figure 3-2. Sequential MDM Movement

The controller's goal is to merge the aircraft and the MDM marker. The MDM's spatially-oriented display instantly relays to a controller information relevant to the magnitude of correction needed to accurately meet the required restriction. As measures are taken (such as vectoring and/or speed control) to meet the required restriction, the marker and the corresponding aircraft will move closer together as seen in Figure 3-2.

TACT research has been very sensitive to the human factors implications of displaying a marker on the controller's display. Earlier TACT research work was performed with front-of-the-panel demonstrations to obtain feedback from individuals with operational experience as to the visual impact of the MDM display. This early developmental feedback was instrumental to addressing issues such as the potential for increased clutter caused by the marker display. The ability to adjust the brightness of the marker, as well as the ability to display markers only for aircraft individually selected by the controller, are examples of feedback that have been made part of the design. This type of feedback will continue to be gathered and considered as higher fidelity development progresses. Much consideration was also given to the operating environment in which the radar controller must perform. As mentioned previously, a wide variety of operational circumstances can occur in transition airspace, adding to complexity and creating a tendency for operations to range between strategic and tactical. Because of this, the radar controller's planning horizon must also range from strategic[1] to tactical.

[1] A distinction should be made here. It has become common to equate the term "strategic" to functions performed specifically by the D-side controller. However, this discussion acknowledges that both the D-side and R-side controllers, within their individual roles, have separate planning horizons that typically differ in magnitude, but which individually span a range between a strategic and a tactical mode of

When operations allow for the radar controller to work more strategically, the MDM makes it visually apparent when an aircraft requires adjustment in order to meet the given restriction. But more importantly, it provides intuitive feedback, in a visual and spatial manner, as to the size of the adjustment that needs to be made. This allows the controller to make early decisions as to the course of action most applicable given the operational circumstances. The visual display also provides feedback to the controller indicating when the aircraft is on target to meet its restriction. This reduces the possibility of over correction, which may result in additional transmissions and control actions.

During the tactical operations that are not uncommon to transition airspace, the MDM information is available, but does not advise or otherwise direct the controller's decision making. Therefore, the radar controller is free to establish other priorities and handle problems that arise; this may include actions that are sub-optimal for meeting the flow restriction, but are critical to other operational priorities. In cases such as these, the MDM does not restrict the controller's shift in priorities or actions. When circumstances permit, the MDM information facilitates recovering the flow schedule, and helps minimize effort and error in meeting the prescribed restrictions. Another important feature to consider in tactical operations is that the MDM is designed to allow radar controllers to assimilate pertinent information without requiring them to glance away from their traffic to scan lists or alternate displays, or to coordinate with others.

Finally, the MDM is not dependent upon the aircraft following a set, predetermined trajectory. Therefore, if control actions are needed for tactical purposes, the effects of those adjustments, as they relate to flow restrictions, will be immediately recognizable via the MDM display. This includes the size of adjustments needed to correct the situation, without requiring the controller to input additional information.[2]

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operation. In this case, "strategic" refers to actions or plans devised in advance of their implementation, as opposed to "tactical" actions, which tend to be reactionary to more immediate operational needs.

[2] The exception would be that case where the controller wanted to actually change the sequence of aircraft defined by the scheduler, in which case the scheduler (e.g. TMA) driving the MDM display would need to be updated to agree with the actual sequence set by the controller.

3.2.1.2 Mileage in the Data Block (MDB)

Like the MDM, the MDB concept also provides cognitive assistance by providing the radar controller with a spatial increment that represents the magnitude of the time-based restriction. As seen in Figure 3-3, the concept works by displaying a positive or negative number in the aircraft's data block that reflects the mileage adjustment needed to meet the required restriction. The number will count down or up, displaying zero when desired spacing is achieved. Placing information in the data block provides a valuable means of delivering information in a transition airspace environment without cluttering the radar scope, or requiring controllers to take their eyes off the traffic to assimilate a separate display. Observing the countdown display provides intuitive, continuous feedback to the controller, in a manner currently unavailable, to provide increased accuracy and ease to make control decisions for meeting flow restrictions. The use of a numeric spatial increment, and not a numeric time increment, is of particular importance here. Although a similar "countdown" function could be displayed using time increments, mileage is more intuitive to the controller. Using a time increment would still require the controller to estimate the spatial correction needed, or work in a "reactive" mode by simply taking control action, then waiting for the countdown display to provide feedback as to whether they chose the best action under the circumstances. As discussed previously, mileage increments can be easily visualized by the controller, and are an intuitive basis for decision making that already exists before a control action is chosen and implemented.

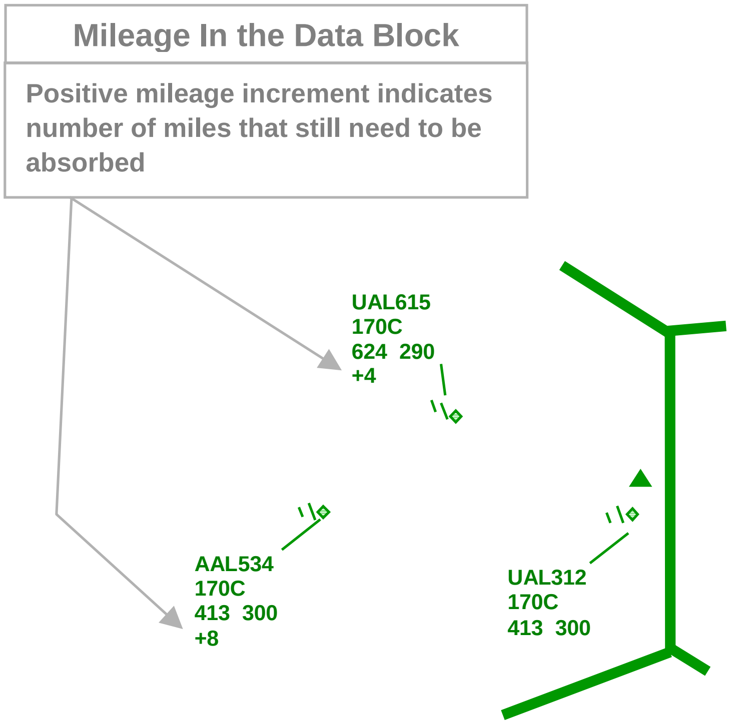

Figure 3-3. MDB Display

The underlying functionality of the MDB is identical to that of the MDM. The key difference between the MDM and MDB is the method of displaying information to the controller. It is not presumed that MDM and MDB would be used simultaneously, but rather each would be an option for the controller to access based on both preference and operational need.

3.2.2 TACT in the Miles In Trail Environment

MIT restrictions are used in a variety of ways to meet operational air traffic management needs. For example, they can be used on an inter-facility basis to restrict the flow of traffic into a downstream ARTCC, or on an intra-facility basis for purposes such as facilitating operations involving merging flows, or restricting the traffic flow to an acceptable rate into a TRACON.

Since the TACT research focus is operations within transition airspace, this discussion is limited only to MIT restrictions related to MITs that restrict the flow of traffic into the TRACON.

Currently, to set MIT restrictions as described, the Traffic Management Coordinator (TMC) will coordinate with the TRACON to set the Airport Acceptance Rate (AAR), that dictates the number of aircraft per hour the airport can accept. The TMC will often consult information provided by the ASP and use it to apply rule-of-thumb methods for estimating an appropriate static MIT increment that will restrict the inbound flow to meet the AAR. The number selected is typically applied in 5-mile increments such as 15, 20, or 25 MIT. It is generally not considered reasonable to expect controllers to gauge mileage accurately in increments smaller than 5 miles on a consistent basis, as the workload to achieve it could outweigh its value.

In an MIT application, the MDM display of information is essentially the same as in the metering application. This creates a degree of continuity between the two methods, rendering the difference between the two more seamless from an operational perspective. The MDM display method also allows the possibility for TMCs to specify MIT restrictions at more precise increments to meet their flow rate needs. With MDM, any specified mileage is equally easy to visualize. Therefore, a restriction of 18 MIT is just as feasible to attain as 20 MIT. Used in a static MIT environment the MDM would be supplied with the restriction and the correct distance correction marked by the MDM. Although the MIT display of information via the MDM marker is similar to the metering application, the calculation of the marker position in the MIT application is not driven by metering times. For MIT, the marker position is calculated based on the distance needed relative to the preceding aircraft.

In cases where, during MIT operations, the sequence of aircraft is not specified by a scheduler such as TMA, a proposed method for using the MDM would be for the controller to invoke the MDM for a pair of aircraft. In doing so, the first aircraft selected would be identified to the MDM as the preceding aircraft, and the second one selected would be identified as the in-trail aircraft. In this way, the controller would have the manual capability to define the aircraft sequence.

It should be noted that the aforementioned continuity between the MIT and metering display of information offers a potential means to facilitate the transition of controllers from the MIT environment to a time-based metering environment without requiring them to significantly change the way they think about their tasks.

Section 4

Fiscal Year 2000 Research Efforts

TACT concept exploration prior to FY00 used a JAVA development environment to build a front-of-the-panel, non-interactive demonstration. The demonstration was placed on a laptop computer to gather early input from individuals with operational ATC experience. This input was extremely important to identify aspects of value, as well as potential problems with the concepts. The key limitation of that early research was that it provided for subjective feedback only, and did not offer the capability to gather objective performance information.

For FY00, the emphasis is on development of TACT concepts, along with appropriate scenarios, in a CAASD laboratory for Human-in-the-Loop (HITL) experimentation. The experimentation will make use of CAASD's 20x20 inch *DSR Clone* (Display System Replacement) and keyboard interface, for a high fidelity look and feel. Participant subjects will be active air traffic controllers contracted through the National Aviation Research Institute (NARI). The airspace used will be based on available ARTCC Adaptation Controlled Environment System (ACES) data, while the air traffic scenarios will be based on System Analysis Recording (SAR) data recorded from ATC operations of the same ARTCC, and replayed for the controller using Dynamic Simulation (DYSIM). All scenarios will be completely interactive, allowing the controller to verbally issue appropriate control instructions. The scenario traffic volume will be altered to control the relative workload for experimentation purposes, but the actual traffic flow characteristics will remain unchanged from the SAR data.

To simulate a metering environment, aircraft will be scheduled to a designated fix by utilizing URET expected times of arrival. An emulated arrival scheduler will assign predetermined amounts of delay to scenario aircraft to yield the needed STAs. The scheduling information will be made available to the controller by a simulated meter list.

The experiment structure will use several separate scenarios to enable performance comparison between a baseline control scenario without TACT tools and an independent variable scenario, where a TACT tool concept is used by the controller.

The goal of this approach is to gauge a measurable performance difference between aircraft delivery in metering environments, both with, and without, TACT concepts. The experimentation will make use of recorded performance metrics captured at run time, as well as subjective feedback from operational participants. After data reduction and analysis of the quantitative results and the subjective feedback are performed, experimentation results will be compiled and documented.

TACT HITL evaluations are scheduled to begin at CAASD during July 2000. These activities will result in an understanding of:

- The functional application of TACT concepts in a time-based metering environment.
- The operational utility of TACT concepts.
- Necessary refinements to algorithmic integrity.
- How controllers interface with the concepts in a *DSR clone* environment.
- Necessary Computer Human Interface and functional refinements for future development and implementation.

Planning for activities and development beyond FY00 include the following:

- Spiral development of tools based on assessment of FY00 HITL evaluation results, HITL testing of modifications, new HITL tests in FY01, etc.
- Exploration of concepts for TACT collocation and/or integration with CAASD Problem Analysis and Resolution Ranking (PARR)[3] tool; write concept of use, determine modifications needed, implement in laboratory, learn lessons, and make modifications.
- Prepare for field evaluations: review candidate site operations to determine suitability for evaluating TACT, introduce TACT capabilities to site personnel, map needs of facility operations to specific TACT capabilities, select a site.

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3 PARR is an enhancement to URET that assists with strategic conflict resolutions.

Section 5

Summary

The planned implementation of TMA in many locations within the NAS signals a general shift in ATC practices toward time-based metering for flow control. TACT research in transition airspace indicated that the controller task of meeting flow restrictions is a significant contributor to transition airspace complexity. There is a need for concepts that provide the controller with intuitive information to support decision making for flow control tasks. Such decision support will allow the FAA to realize a greater portion of the potential benefits offered by time-based metering capabilities in the NAS.

As noted in Section 2, more accurate scheduling and increased traffic flow management of time-based metering with TMA are key benefits expected from the planned improvements in the NAS. At the operational level, it should be considered that TMA's scheduling capabilities primarily support the Traffic Manager, rather than the radar controller. The element of TMA utilized by the radar controller is essentially a meter list, which does not constitute a new capability at the controller's operational level. Hence, in the FFP1 environment, a controller performing the metering task may benefit from enhanced traffic flow management, but the controller is not given any specific capabilities that make the task of delivering aircraft accurately over the meter fix more manageable. A failure to offer tools to assist controllers with this task may result in a diminished return in capturing expected benefits from time-based metering. In light of the predicted increases in traffic volume in the coming years, compounded by the other complex characteristics of transition airspace, enhancements that provide cognitive assistance to the controller could prove to be beneficial to the continued evolution of the NAS.

A review was conducted of the process by which controllers perform time-based metering. It was found that the controller tendency is to mentally translate the time restriction into an estimate of the mileage correction needed to achieve the desired delay. This *cognitive model* helps in understanding why most ARTCCs currently choose not to use time-based metering as the means of conducting flow control, and why the use of MIT to meet flow restrictions is such a strong part of the operational culture.

The described mental translation process adds workload to the controller's metering task. The MDM and MDB concepts aim to make this translation somewhat seamless, and to deliver the information in a way that is intuitive to the controller, and supportive within a complex environment. Time-based metering is counter-intuitive within the context and demands of the controller's spatial/visual environment. In locations where TMA is scheduled for implementation, the impending cultural change of operational thinking required from the controller workforce is significant.

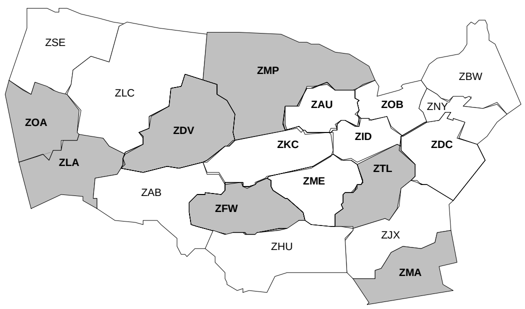
One way to maximize the benefits of time-based metering in the NAS is to provide capabilities that address institutional barriers to time-based metering, while simultaneously providing enhanced decision support to increase effectiveness and address task complexity.

The proposed MDM and MDB concepts are designed to work in partnership with the time-based aircraft scheduling capability for a metering environment. They assist the controller by making the maneuver size needed to meet the given restriction intuitively apparent by indicating the proper spatial adjustment needed in order to meet the flow constraints. Used as described, aircraft schedule times are the driver for MDM or MDB calculations, preserving time-based metering as the mode of operation, even though the adjustments required for specific aircraft are displayed to the controller in terms of spacing corrections. Therefore, controllers can quickly and easily conceptualize the size of the adjustments needed. In a given situation this is helpful for deciding what maneuver to utilize, or even what maneuvers are feasible, to achieve flow goals. Controllers using lateral maneuvers to achieve spacing with MDM or MDB need not perform repeated mental estimations to determine when they have enough spacing, how much more they need, or whether they are overcompensating. This information is intuitively and visually made apparent via the MDM or MDB. By providing an intuitive means for the controller to implement a time-based schedule, the MDM and MDB concepts enhance the effectiveness of the schedule delivery task, and therefore of the overall efficiency of operations.

Since the MDM and MDB concepts can be used in an MIT, ASP, or TMA environment, they could serve to enable the cultural/operational transition from MIT to time-based techniques, as well as accelerate it. Although TACT is still in early developmental stages, Figure 5-1 depicts how one might envision the role of TACT in the NAS after FFP1 implementation.

TMA scheduled implementation for FFP1

TMA not scheduled for FFP1



- MDM display provides spatial continuity between MIT and time-based flow restrictions to assist with operational acceptance of time-based metering.
- Time-based schedules are met more accurately via intuitive TACT display. Effectiveness is increased, while additional workload and complexity are curtailed.

- ASP may be used more effectively.
- MIT can be specified more precisely, and controller delivery accuracy of MIT restrictions is improved.
- Controller familiarity with TACT could facilitate easier future TMA acceptance.

Figure 5-1. Possible TACT Role During FFP1

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3. RTCA Select Committee for Free Flight Implementation, *Government/Industry Operational Concept for the Evolution of Free Flight, Addendum 1: Free Flight Phase 1 Limited Deployment of Select Capabilities*, December 1998, Washington, D.C.

4. RTCA Select Committee for Free Flight Implementation, *Government/Industry Operational Concept for the Evolution of Free Flight*, *Addendum 2: Free Flight Candidate Recommendations on Near Term Procedural Enhancements, 1998-2002*, December 1998, Washington, D.C.

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Appendix

TACT Definition of Transition Airspace

It is recognized that airspace configurations vary from facility to facility. However, for the purposes of TACT research, the definition of transition airspace, as seen in Figure A-1, entails aircraft operations that begin just prior to the top of descent point, where coordination for descent is conducted for inbound aircraft, and continues down to, and including, the coordination fix at the TRACON boundary. This airspace typically consists of the two en route sectors immediately outside the TRACON boundary—one high altitude sector typically owning airspace from 24,000 feet and above, and a low altitude sector that extends from 23,000 feet down to the surface. The area generally extends approximately 200 miles from the airport. Traffic flows also include aircraft climbing out from the terminal area to the en route phase of flight, satellite airport operations, and aircraft that pass to and from other adjacent sectors.

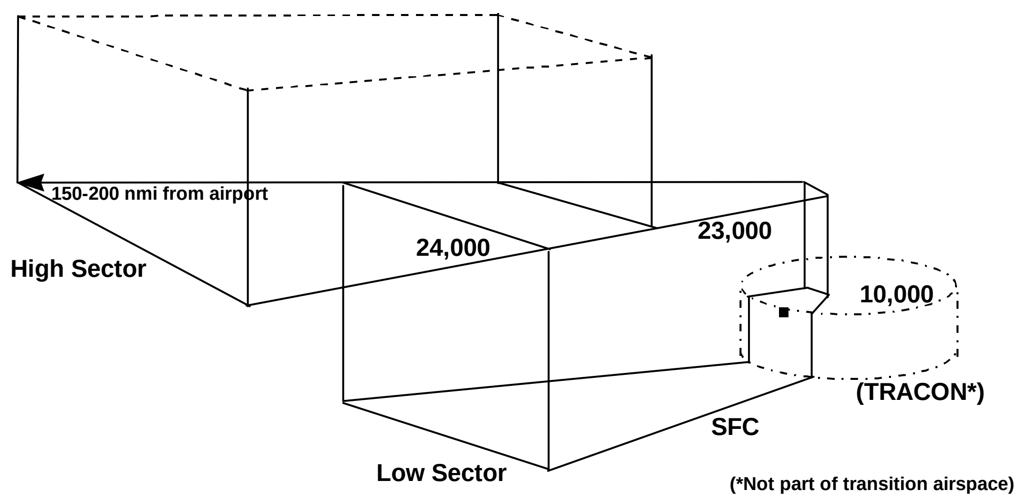

Figure A-1. Transition Airspace

Transition airspace is a complex air traffic control environment. An understanding that transition airspace operations bear distinct differences to operations in other en route domains is important for discussion of NAS modernization capabilities and TACT concepts. One cannot necessarily expect that a capability designed to address a broad, NAS-level problem, will be as effective at addressing a specific characteristic or area of complexity in transition airspace.

The TACT team observed that transition airspace contains a mixture of aircraft in differing phases of flight with a large volume of the traffic in either a climb or a descent. Aircraft maneuvering vertically add a particularly acute element of complexity to sector operations. To the controller, every altitude that the maneuvering aircraft will transition through toward a final or interim altitude becomes unusable for other traffic along a portion of the maneuvering aircraft's flight path, thus eliminating the option of vertical separation for a large block of the sector airspace. Increased controller attention is required to ensure lateral separation is maintained between other traffic and that airspace block, and to identify flight paths that provide for, or prohibit, unrestricted climbs and descents.

Glossary

AAR	Airport Acceptance Rate
ACES	Adaptation Controlled Environment System
ARTCC	Air Route Traffic Control Center
ASP	Arrival Sequencing Program
ATC	Air Traffic Control
CAASD	Center for Advanced Aviation Systems Development
CCLD	Core Capabilities Limited Deployment
CDM	Collaborative Decision Making
CHI	Computer-Human Interface
DSR	Display System Replacement
DYSIM	Dynamic Simulation
ETA	estimated times of arrival
FAA	Federal Aviation Administration
FFP1	Free Flight Phase 1
FY2000	Fiscal Year 2000
HITL	Human-in-the-Loop
IFR	Instrument Flight Rules
MDB	Mileage in the Data Block
MDM	Mileage Distance Marker

MIT Miles In Trail
MOIE Mission Oriented Investigation and Experimentation

NARI National Aviation Research Institute

NAS National Airspace System

PARR Problem Analysis, Resolution and Ranking

pFAST Passive Final Approach Spacing Tool

SAR System Analysis Recording

SC Single Center

SMA Surface Movement Advisor

STA Scheduled Time of Arrival

SUA Special Use Airspace

TACT Transition Airspace Controller Tools

TMA Traffic Management Advisor

TMC Traffic Management Coordinator

TMU Traffic Management Unit

TRACON Terminal Radar Approach Control

URET User Request Evaluation Tool

ZFW Dallas-Fort Worth ARTCC