The Miles-in-Trail Impact Assessment Capability

Paul Ostwald[*], Tejal Topiwala[†], and James DeArmon[‡]
Center for Advanced Aviation System Development (CAASD)
The MITRE Corporation, McLean, VA 22102 U.S.

Abstract

Miles-in-Trail (MIT) restrictions are one of the most commonly used traffic management initiatives. They are most often used to manage arrival flows into airports. Traffic managers often use MIT restrictions to protect a destination airport, particularly when capacity has been reduced due to weather or during periods of high volume. They also use MIT restrictions to smooth out flows to support merging streams. Currently, traffic managers must rely largely on experience to determine if a proposed MIT restriction will have the intended effect on traffic demand, as no tool is available to specifically assess the impact of proposed MIT restrictions. The inability to assess the impact of such a widely used traffic management initiative can sometimes result in inefficient restrictions that increase impacts on flights as well as controller effort. The MITRE Corporation's CAASD has developed a prototype MIT Impact Assessment (MIA) capability which allows traffic managers to evaluate the impact of proposed MIT restrictions on resources and flights before implementing them. This paper proposes an operational concept for arrival MIT restrictions using the MIA capability. This paper also provides an analysis to identify the type of situations when the proposed MIA capability can be used in the future to employ less restrictive MIT restrictions and to determine the impact of MIT restrictions on flying times.

I. Introduction

TRAFFIC Managers (TMs) play an important role in the National Airspace System (NAS) by monitoring and managing traffic flows and system resources, primarily airspace and airports. This role is generally more strategic than the tactical services provided by air traffic controllers, and is referred to as Traffic Flow Management (TFM). TMs employ a number of different actions called Traffic Management Initiatives (TMIs) that include ground stops, ground delays, rerouting, and Miles-in-Trail (MIT) restrictions. MITs are typically placed on the boundaries between facilities, and they specify a minimum spacing for flights in a stream that must be imposed by Air Traffic Control (ATC).

Automation support is available for use by TMs and includes the Enhanced Traffic Management System (ETMS)[1]. The Federal Aviation Administration (FAA) has a program called TFM-Modernization (TFM-M) that will provide a modern infrastructure and platform for additional capabilities for use by TMs in the future. One of the capabilities planned for TFM-M is a MIT Impact Assessment (MIA) capability that allows TMs to evaluate MITs prior to their implementation. It is envisioned that by having the MIA capability, in conjunction with the other automation support capabilities available, TMs will be able to more effectively plan, implement, and monitor MITs. Today, with more limited automation support, MITs are often set conservatively – sometimes in place for longer periods of time or with more restrictive spacing values than might be used if an MIA "what-if" modeling capability were available. This paper presents a proposed concept of operations for how traffic managers can establish arrival MIT restrictions in the future when the MIA capability is available to support this process.

As part of the process to acquire funding for the TFM-M program, the FAA has prepared a Benefits Basis of Estimate (BOE)[2]. The MITRE Corporation's CAASD contributed portions of the Benefits BOE, including the section on the MIA capability. This paper also presents some of the analysis done by CAASD that supported the benefits estimate for the MIA capability. This discussion will focus on measuring the impact on flights that have been subjected to MIT restrictions. Some portion of these impacts may be reduced when the MIA capability is

[*] Multi-Disciplinary Systems Engineer, Lead, Enterprise Engineering and Transformation, CAASD, 7515 Colshire Drive, Mail Stop FAAT
[†] Multi-Disciplinary Systems Engineer, Lead, Terminal TFM System Engineering & Evolution, CAASD, 7515 Colshire Drive, Mail Stop N450
[‡] Multi-Disciplinary Systems Engineer, Principal, Terminal TFM System Engineering & Evolution, CAASD, 7515 Colshire Drive, Mail Stop N450

available resulting in benefits to the NAS users, i.e., the air carriers and the flying public. This paper does not focus on other potential benefit areas – such as increased productivity of traffic managers and controllers.

II. Background on MIT Restrictions

MITs are used daily throughout the NAS to help manage a variety of situations at a number of system resources. MIT restrictions are used to organize traffic flows and protect congested resources. If the protected resource is an airport, the MIT restriction can be called an Arrival MIT restriction. If the protected resource is an en route sector or fix, then the MIT restriction is referred to as an En Route MIT restriction. In the en route environment, MIT restrictions are also used to organize traffic flows of rerouted flights. If the protected resource is a departure fix or route, then the MIT restriction is referred to as a Departure MIT restriction.

An examination of the FAA's National Traffic Management Log (NTML) from January through early May 2004 found about 485 MIT restrictions on average each day. This number closely matches the 480 average daily MIT restrictions found by Metron Aviation in May 2004[3]. The vast majority of these restrictions, almost 86% in the period of the NTML examined, have a destination airport specified – indicating that the restriction applied only to arrival flights to the specified airport that otherwise met the criteria specified. The other required criteria include a location where the restriction applies (typically a fix or section of a boundary between two facilities) and the time period during which the restriction is active. Additional criteria, which are optional, include an altitude range and a subset of flights (e.g., "Only Jets"). Also required is a spacing value in nautical miles, which defines the distance at which successive flights should cross the specified location.

Further review of the NTML data revealed that the 8 destination airports most frequently specified comprised over 60% of the total MITs, and the top 15 specified airports comprised almost 80% of the total MIT restrictions.

Studies have been undertaken over many years to examine various aspects of MIT usage. An analysis done back in 1996 by Solomos and Cooper[4] investigated the possibility of easing or removing various MIT restrictions in the Chicago area. They stated that "unused arrival capacity at the airport may exist if current en route restrictions remain unchanged for the southeast arrival fix." While this situation has likely changed over time, this type of question is often raised when examining MIT usage.

A more recent study found an increase in en route delay for flights involved in en route or arrival MIT restrictions of 1.1 minutes over those flights not involved in any MIT restriction[5]. While factors other than MITs may contribute to this difference, it is reasonable to attribute some portion of this increase in delay to the impact of MITs.

These impacts on flights are often easy to see visually. Figure 1 below shows flight paths of arrival flights that landed at Chicago's O'Hare Airport (ORD) between 18:00 and 19:00 Z on 2 April 2004. MIT restrictions were in place on several of the first tier centers (center boundaries are shown with solid lines, ZAU is in the middle; "first tier" means immediately adjacent) during this time period. This data was obtained from the ETMS. Note in particular several places where a "signature of an impact" due to vectoring has been pointed out – these maneuvers are likely employed to help achieve the specified spacing of the MIT restrictions that were in place at several of the center boundaries. Steve Green, of the National Aviation and Space Administration (NASA), also noted the use of vectoring in his 2000 paper[6]: "… spacing adjustment typically involve vectors. Although speed control can help fine-tune spacing … it is often too little to establish spacing because of performance mismatches and limited range within a sector."

A Free Flight Program Performance Metrics report from December 2003[7] stated "MIT restrictions can unnecessarily starve the runway, in which case the actual arrival rate would be less than the demand, even during times when the demand is less than the airport capacity." These claims were confirmed by a Free Flight Program study covering the period of May 2002 – October 2003, examining periods when MITs were in use and the demand was less than the Airport Arrival Rate (AAR). While the mean differences between predicted demand and the number of actual arrivals were small, the differences increased when larger MITs were in use (to greater than 0.5 aircraft per 15 minute interval), indicating the MIT restrictions do have a negative impact if employed during periods when demand is less than capacity. The report further stated that "decreases in the use of MIT restrictions or more judicious or timely use … should allow the airport to better meet the demand." Note that some of these MIT restrictions may be in place to help manage arrival sectors and to facilitate merging of multiple flows as the flights proceed towards their destination airport – these factors also need to be considered.

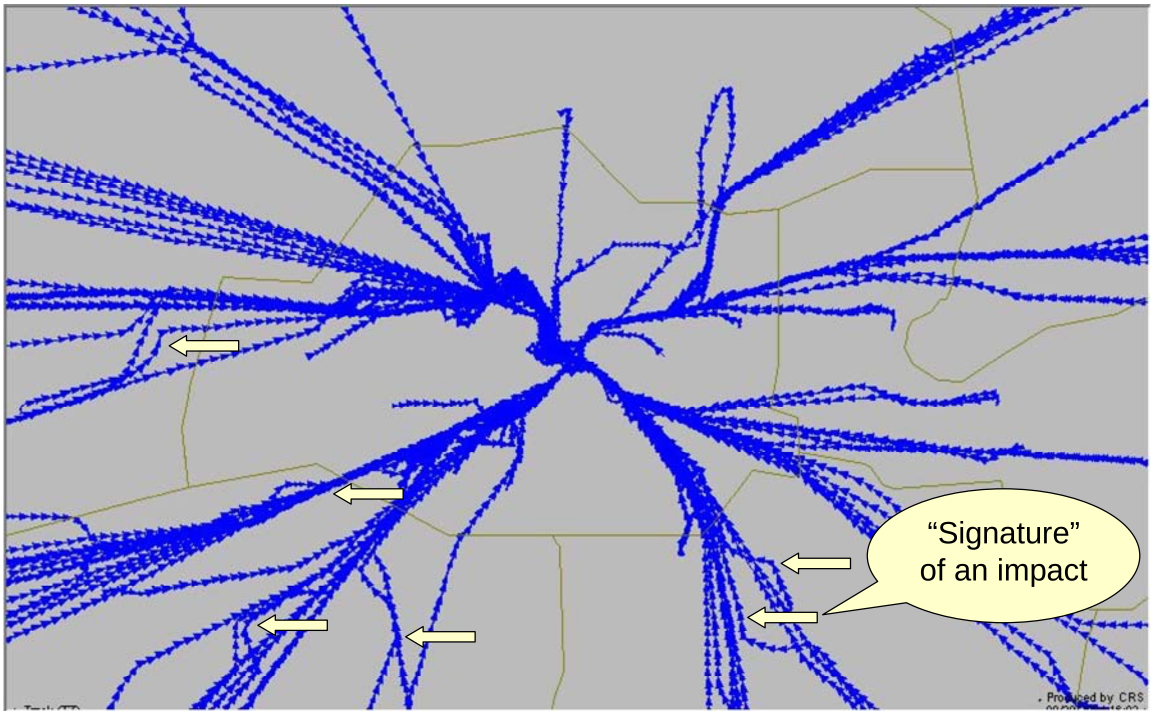

Figure 1. ORD Arrival Flight Paths, 2 April 2004

Studies have also investigated the "compliance" rate for MITs and the spacing achieved relative to the specified spacing. One study examined ORD arrivals during March 2005[8] and estimated a "compliance" rate of about 85%. This analysis used an assumption for "compliance" of the measured spacing being the same as or greater than the specified spacing. The Metron Aviation study mentioned previously measured the spacing of flights relative to the specified spacing. They found that approximately 85% of flights subject to MITs had the same as or larger than the specified spacing[9]. Note that some occurrences of larger than specified spacing can occur when "natural spacing" occurs during periods of low demand (but when an MIT was in place).

Together, these studies indicate that when MITs are in place, they are generally followed and have an impact on some of the flights subjected to the MIT. There is also some evidence to indicate that on occasion MITs may be overly constraining.

III. MIT Impact Assessment Capability

By modeling ahead of time the impact of proposed MIT restrictions on the protected resource, the MIA capability will help traffic managers better identify those situations where MITs are truly needed. With such a tool, a flow manager can tailor each MIT, accurately setting start time, stop time, spacing value, and thus the affected flight set. The use of the MIA capability is anticipated to reduce the overall number, duration and spacing values of MIT restrictions employed, leading to greater efficiency in flight operations.

The MIA capability discussed in this paper will support the planning of MIT restrictions by TMs. Additional capabilities to support communication and execution of MIT restrictions are also needed. Such a capability will allow a traffic manager to transmit MIT restrictions to controllers. In addition, an en route automation capability could help integrate MIT information on a controller display. For instance, a flight subject to a MIT restriction could be identified to the controller along with the delay that that the flight will need to absorb in the current sector.

There is recent evidence to suggest that provision of additional tools to traffic managers can lead to a reduction in use of MITs. The introduction of the Traffic Management Advisor (TMA) tool has already had an impact on reducing the number of MITs employed. The "Free Flight Program - Performance Metrics to Date - December 2003 Report"[10] documents a 24% reduction in a metric that measures the restriction value (this metric is defined as the duration of an MIT times the specified spacing value) of MITs that ZLA (Los Angeles Center) imposes on ZOA (Oakland Center) for Los Angeles International Airport (LAX) destined traffic, after deployment and use of TMA in ZLA. TMA helped provide better situational awareness leading to this reduction, particularly during periods of low demand.

IV. Proposed Concept of Operations for Arrival MIT Restrictions

A concept of operations has already been proposed for the MIA capability for use in evaluating MIT restrictions when they are used in conjunction with reroutes[11]. The purpose of this section is to describe a proposed concept of operations for MIT restrictions that are used to organize traffic flows into airports: Arrival MIT restrictions. Future work will develop the concept for en route MIT restrictions and departure MIT restrictions.

This discussion uses arrival flows destined to ORD as an example.

The ZAU TM uses the currently available capability, Flow Evaluation Area (FEA), to monitor the demand on ORD airport and its four arrival fixes: KRENA, PLANO, KUBBS, and BEARZ (figure 2).

The FEA Capability provides demand at selected resources in 15 minutes intervals (figure 3). The capacity of ORD airport for this day is 25 aircraft in a 15 minute interval. As a rule of thumb, the capacity of each arrival fix is 9 aircraft in a 15 minute interval.

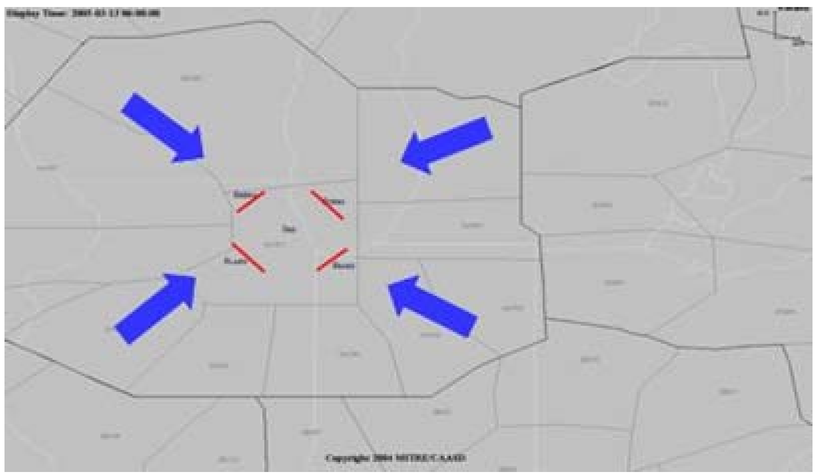

Figure 2. ORD and Arrival Fixes

The ZAU TM notes that there are several time periods when the demand at ORD airport meets or exceeds a capacity of 25 flights per 15 minute interval. For most of these time periods, the demand at BEARZ also meets or exceeds a nominal capacity of 9 flights per 15 minute interval.

As a step towards reducing the demand at ORD and at BEARZ, the ZAU TM further analyzes the demand at BEARZ by reviewing the demand at the key traffic flows through ZID (Indianapolis Center) fixes, OKK and FWA, and the ZOB (Cleveland Center) boundary (figure 4).

As expected, the demand at OKK is higher than the demand at FWA or ZOB. The ZAU TM estimates that a 15 MIT restriction at OKK and 30 MIT restrictions at both FWA and ZOB will reduce the demand at BEARZ (depicted in figure 5). The ZAU TM enters these as trial MIT Restrictions to evaluate the impact of these MIT restrictions on the predicted demand.

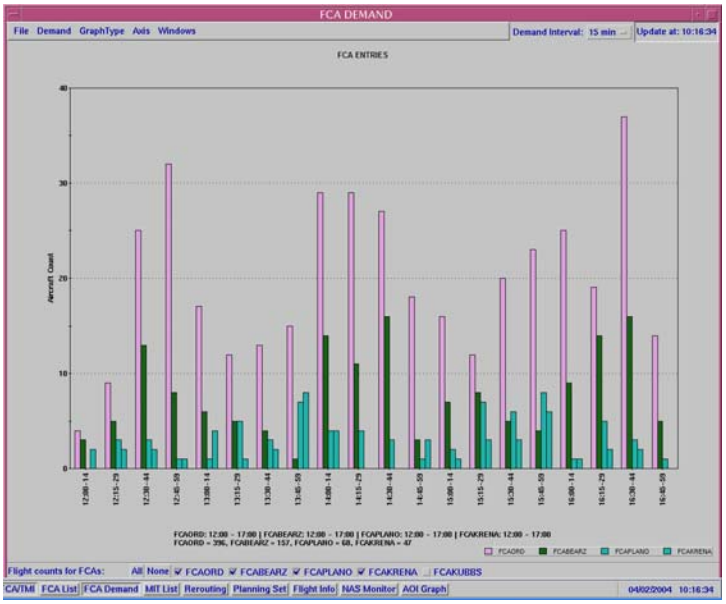

Figure 3. Predicted Demand at ORD and Arrival Fixes

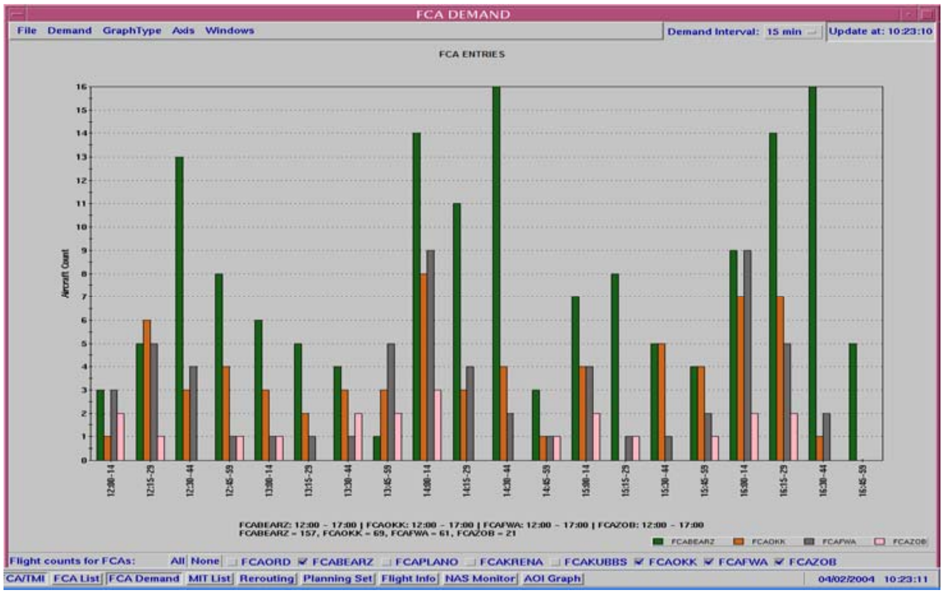

Figure 4. Predicted Demand at BEARZ, OKK, FWA and ZOB Flows

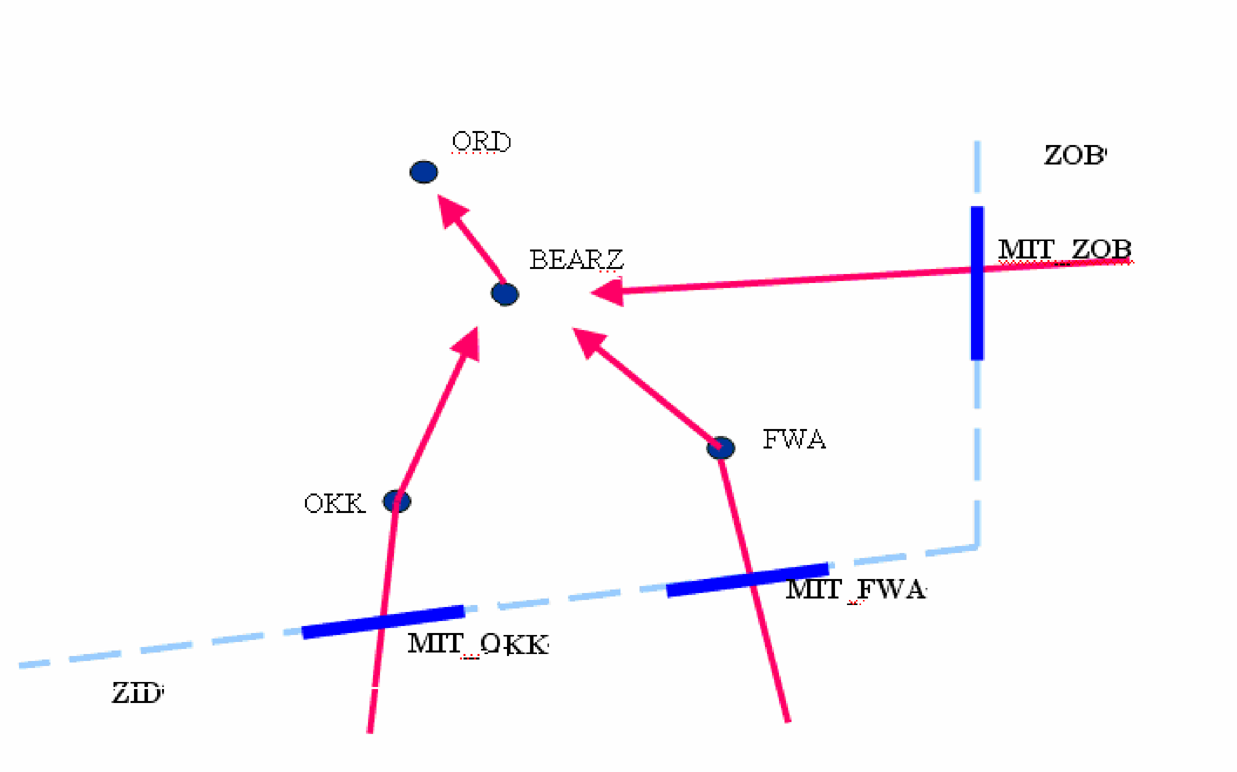

Figure 5. Trial MIT Restrictions at OKK, FWA, and ZOB

The MIA capability provides impact assessment for the trial MIT restrictions in two ways:

1. the change in predicted demand at BEARZ (figure 6) and
2. the flights involved in each MIT restriction and the predicted delay for each flight (figure 7).

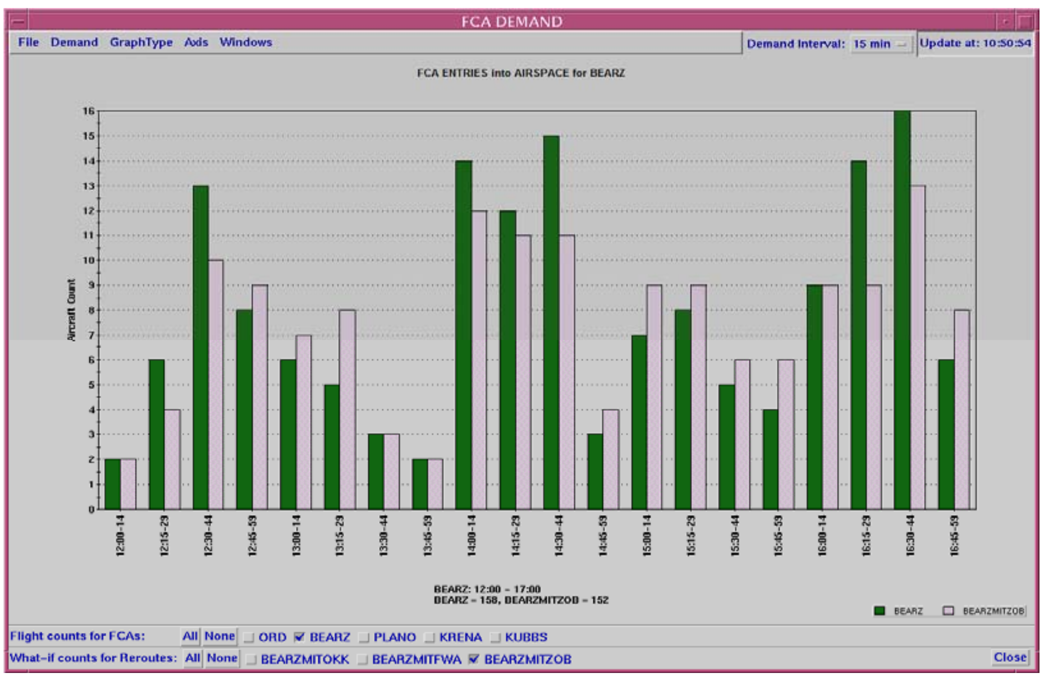

Figure 6. Change in Predicted Demand due to Trial MIT Restrictions

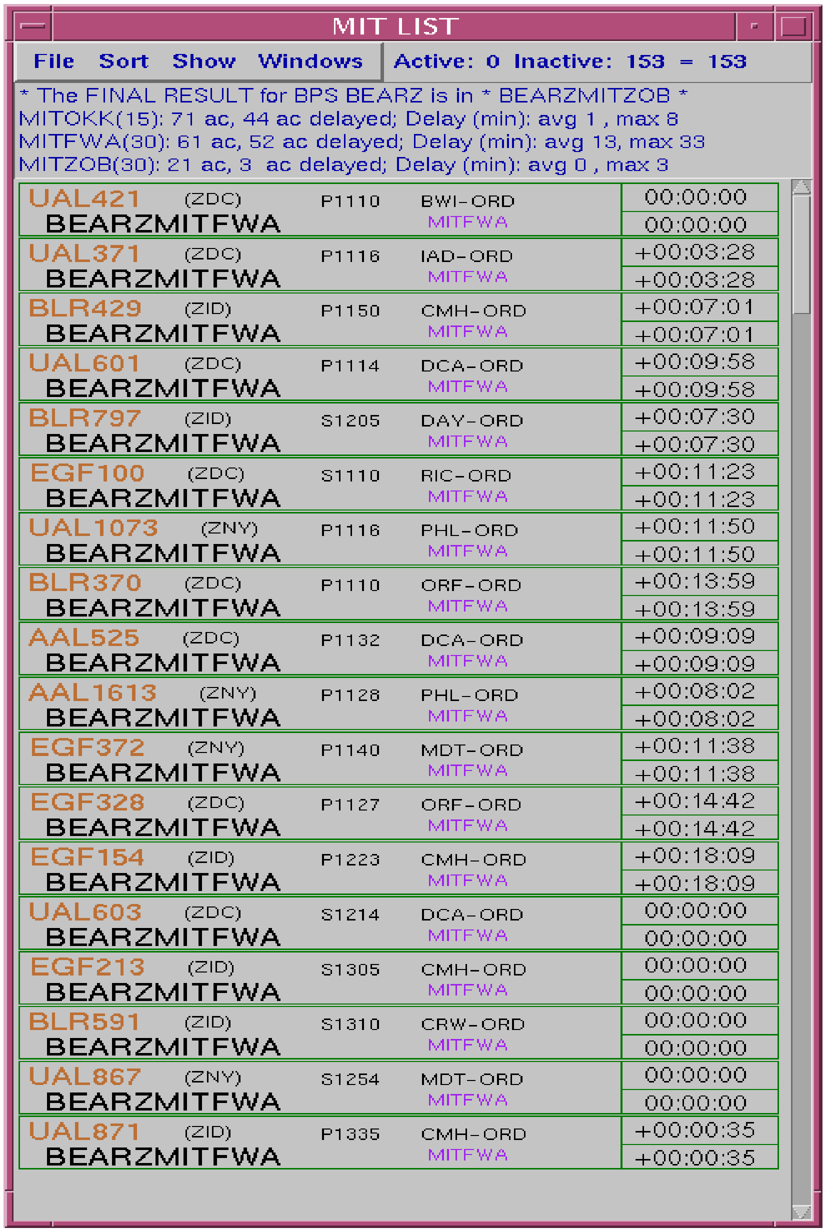

Figure 7. Predicted Flight Delays due to Trial MIT Restrictions

For each 15 minute interval, Figure 6 provides the demand at BEARZ (in green) and the demand at BEARZ modified with Trial MIT restrictions (in pink). The Trial MIT restrictions do reduce the demand at BEARZ and for the initial two hours from 1200-1400Z, the demand at BEARZ is close to acceptable levels. For now, it does not appear that the Trial MIT restrictions are sufficient to reduce demand between 1400-1445Z and 1615-1645Z.

Figure 7 provides the list of flights impacted by the Trial MIT Restrictions and the delay each flight would need to absorb. For instance, Figure 7 indicates that 44 flights will need to be delayed to meet the Trial MIT restriction at OKK and will have an average delay of 1 minute. If a flight is pre-departure, the flight can absorb some or all of the delay on the ground. Note that in Figure 7, all of the flights listed are pre-departure (aircraft identification is in brown).

The ZAU TM is satisfied that the Trial MIT Restrictions will reduce demand at BEARZ sufficiently for the initial two hours. (The ZAU TM will need to monitor demand and adjust MIT restrictions as needed.) The ZAU TM initiates a telecon with TMs in the Air Traffic Control System Command Center (ATCSCC), ZID, and ZOB. In addition, the ZAU TM shares the FEA demand and Trial MIT Restrictions analysis with the participants. Based on the analysis, the ATCSCC TMS approves the MIT Restrictions. The ZID TM may need to do further analysis to determine if the MIT restrictions should be passed back to ZDC (Washington Center) and ZTL (Atlanta Center). This will depend on two major factors:

1. Can the predicted flight delays be absorbed in ZID airspace? For instance, AAL525 is predicted to be delayed approximately 9 minutes. The ZID TM will need to assess if this airborne delay can be easily absorbed in ZID airspace or is it better to pass back this delay to ZDC and have some of this delay be absorbed on the ground.
2. Can the internal ZID departures (including those from Indianapolis, Cincinnati, and Dayton airport) be easily merged into the ORD flows? Based on this analysis, the ZID TM may determine that MIT restrictions will need to be passed back to ZDC and or ZTL.

V. Pursuing a Benefits Analysis

The proposed concept for the MIA capability is anticipated to reduce the number, duration, and spacing of MIT restrictions, thus improving the efficiency of flight operations. A benefit analysis for the MIA capability was originally undertaken to support the FAA's Benefits BOE for TFM-M. That document[12] describes the full process employed, including roll-up to annual benefit estimates and the dollar estimates made through 2016 for the MIA capability. This paper will focus on two areas that provided a foundation for the estimates contained in the BOE: the identification of "periods of opportunity" and the measurement of the direct impact on flying times for flights subjected to MIT restrictions today.

The "period of opportunity" portion of the analysis attempts to identify those time periods during which MITs were employed that had potential for employment of less restrictive MITs if additional tools such as the MIA capability were available. These less restrictive MITs are envisioned to be of shorter duration and/or have a smaller spacing value specified (e.g., 15 nm instead of 20 nm). The purpose of the analysis was to gain an understanding from today's usage of MITs so that for similar situations in the future when an MIA capability is available (which may be even more common due to increases in traffic), an estimate could be made of the potential for benefit. Since other enhancements to the NAS, such as the TMA tool currently being deployed also help manage arrival flows, the analysis of both situations where TMA was in use and where it was not deployed was undertaken.

The second portion of the analysis attempted to measure the impact on flying times of flights subjected to MIT restrictions, and in particular, any impact present during identified "periods of opportunity." Some portion of such impacts, if they exist and can be estimated, represent the potential for direct benefit to the users if use in the future of the MIA capability results in employment of less restrictive MITs. Note also, for flights that depart close to the point of application of an MIT the impact may be a delay in the departure time as opposed to or in addition to an impact in flying time. Impacts in departure times due to MIT restrictions were not investigated during this analysis, but do represent an interesting area for future analysis.

Note that other potential for benefits exists: if use of the MIA capability in the future results in fewer MITs being employed, there may be reductions in communication and coordination, and in the number of maneuvers issued to aircraft to comply with MIT restrictions. These impacts were also not investigated during this analysis.

VI. Methodology and Results

MIT related data from the FAA's NTML was obtained for most of 2004. Examination of the NTML data identified ORD as the arrival airport most frequently specified in MIT restrictions. ORD was selected for inclusion in the analysis. LAX was also selected for this study due to the use of TMA for arrival traffic to LAX and since use of MIT restrictions is also common on LAX arrivals flows – it is in the top 15 airports specified in MIT restrictions.

Data from the FAA's Operations Network (OPSNET) was obtained for ORD and LAX during 2004 to gain insight into the daily situation at those airports. This data was used to select several "good weather" days for more in-depth analysis. The criteria consisted of looking for days when MITs were used during large portions of the day but no other significant TMIs (Ground Delay Programs (GDP) or Ground Stops (GS)) were used for the airport. MIT restrictions are typically used every day during a variety of weather conditions. While MITs are also used during "bad weather", these can be complex situations where a number of traffic management tools may be in use. Due to the difficulty in identifying the individual contribution of MITs during these situations, "good weather" days were used for this analysis. The premise was that these were typical "good weather" days, and that many such days occur each year. If benefits could be shown on such days, they could be implied for many other similar "good weather" days. Specifically, April 2nd and September 1st were selected for ORD and March 16th and June 24th were selected for LAX.

The FAA's Aviation System Performance Metrics (ASPM) database was accessed to obtain information on activities at ORD and LAX during the selected days. Specifically, ASPM data for arrival demand, arrival capacity (the target arrival rate) and actual arrival operations counts were obtained. This data was available for 15-minute time intervals. Data was extracted from the NTML for ORD and LAX to determine the specific MIT restrictions used on the selected days. Examination of these MITs and correlation with ASPM data during their periods of use resulted in categorizing them into three groups:

1. MITs employed during periods when the demand exceeded the target arrival rate of the airport and the actual arrivals met or exceeded the target arrival rate. This group represents the busiest arrival traffic periods. It is likely that the MIA capability would often be used during such periods in the future, typically in conjunction with TMA if present, to help assess any MITs employed.

2. MITs employed during periods when the demand exceeded the target arrival rate of the airport, but the actual arrivals were under the target arrival rate. This group represents a "period of opportunity" since the demand exceeded the target rate but the MIT may have been too restrictive and over-controlled the flow. There is the potential for benefits in the future during such periods if use of the MIA capability helps TMs establish more effective MIT restrictions.

3. MITs employed during periods when the demand does not exceed the target arrival rate of the airport. This group also represents a "period of opportunity" since these MITs do not appear to be needed strictly from an airport perspective. There is the potential for benefits in the future during periods like these if use of the MIA capability helps TMs establish more effective MIT restrictions.

"Periods of opportunity" (groups two and three above) were identified for both airports throughout the days studied. However, this initial portion of the analysis only considered the arrival airport. There are situations when MIT restrictions are used primarily for other purposes, such as to "smooth out the flow," and not in response to the demand on an airport. When flights arrive in "bunches" they can be more closely spaced than desired, and MITs are a widely established technique used to mitigate this occurrence. It is expected that the use of MIA capability will not obviate this use in totality. Thus, additional analysis was done to analyze flows over arrival fixes.

ETMS data was also obtained for these selected days. From the ETMS data, track positions were obtained for arrival flights destined to the selected airport on the chosen days. The arrival fixes at ORD and LAX were analyzed during these same days. The previous analysis mentioned above provided the information on the duration and categorization of the MITs, ETMS data was used to obtain actual flight counts over each arrival fix on the days selected, and the NTML data was used to determine when the aircraft were affected by MITs.

Using ETMS data, actual traffic over arrival fixes was examined during periods when MITs were employed, and traffic counts per 15-minute period over those fixes were obtained. Periods when 9 or more flights crossed the fix were identified as periods when the MIT was likely used to manage the heavy traffic flow over the fix. These periods were removed from the previously determined "periods of opportunity." The criterion for heavy traffic is based on a nominal aircraft speed of 400 knots and a spacing of 10 nautical miles, resulting in 10 flights per 15 minutes over a fix. A value of 9 was used to include those periods when this level existed for most of the 15-minute period. The other periods, when 8 or fewer flights crossed the arrival fix during a fifteen minute period, were still considered in the "periods of opportunity" – the arrival airport was not busy or the target arrival rate was not met and the arrival fix was not busy based on the simple criterion presented above. Note that this criterion is used for analysis purposes only – it does not reflect an actual process used by TMs. It was intended as an easy way to consider the situation at an arrival fix in the analysis. A substantial number of periods were found when MITs were in effect but when traffic over the arrival fix was not "heavy" based on the criteria specified above. Many of these periods were found to "align" with the previously identified "periods of opportunity" at the airport. Periods were also found when the arrival fix was busy – these periods were removed form the "periods of opportunity" identified earlier. Table 1 contains the results of this portion of the analysis. The first column identifies the airport, date, and fix studied. Four types of 15-minute periods are reported: "non_MIT" are when an MIT restriction was not active for the fix, "MIT" are when a restriction was active. The MIT periods were further broken down based on the groups defined above: "MIT_1" are for those periods identified as group one, "MIT_2_3_OP" are for those in groups two and three (the "period of opportunity"). Note that this data also reflects the fix analysis discussed above: if a "period of opportunity" was found to occur when the arrival fix was busy, it was removed from the "MIT_2_3_OP" category and added to the “MIT_1” category. Also shown are the number of periods per day, the resulting hours per day, a breakdown of the MIT periods by percent, the number of flights found for the periods, and the average number of flights per hour.

Table 1. Results of “Periods of Opportunity” Analysis

Airport, Date, Fix	Type of Periods	Number of Periods	Hours per day	% of MITs	Number of Flights	Flights per Hour	Ratio:MIT_1 to MIT_2_3_OP
LAX_0316_AVE	non_MIT	54	13.50		59	4.4	
	MIT	42	10.50	100%	86	8.2	
	MIT_1	13	3.25	31%	39	12.0	1.9
	MIT_2_3_OP	29	7.25	69%	47	6.5	
LAX_0624_AVE	non_MIT	39	9.75		24	2.5	
	MIT	57	14.25	100%	119	8.4	
	MIT_1	6	1.50	11%	31	20.7	3.0
	MIT_2_3_OP	51	12.75	89%	88	6.9	
ORD_0402_OKK	non_MIT	42	10.50		16	1.5	
	MIT	54	13.50	100%	147	10.9	
	MIT_1	31	7.75	57%	125	16.1	4.2
	MIT_2_3_OP	23	5.75	43%	22	3.8	
ORD_0402_FWA	non_MIT	42	10.50		11	1.0	
	MIT	54	13.50	100%	92	6.8	
	MIT_1	31	7.75	57%	82	10.6	6.1
	MIT_2_3_OP	23	5.75	43%	10	1.7	
ORD_0402_ZOB	non_MIT	42	10.50		12	1.1	
	MIT	54	13.50	100%	80	5.9	
	MIT_1	31	7.75	57%	69	8.9	4.7
	MIT_2_3_OP	23	5.75	43%	11	1.9	
ORD_0901_OKK	non_MIT	59	14.75		67	4.5	
	MIT	37	9.25	100%	97	10.5	
	MIT_1	19	4.75	51%	81	17.1	4.8
	MIT_2_3_OP	18	4.50	49%	16	3.6	
ORD_0901_FWA	non_MIT	59	14.75		43	2.9	
	MIT	37	9.25	100%	61	6.6	
	MIT_1	19	4.75	51%	50	10.5	4.3
	MIT_2_3_OP	18	4.50	49%	11	2.4	

MIT restrictions were in place from 9.25 to 14.25 hours per day on the days studied. The identified “periods of opportunity” ranged from 4.5 to 12.75 hours. Overall, on the days studied the resulting “periods of opportunity” ranged from 43% to 89% of the time an MIT was being employed with an overall average of 64%.

The average number of flights per hour data tends to reinforce the claim that the “periods of opportunity” do represent periods that would have potential for employment of less restrictive MITs if additional tools such as the MIA capability were available. The number of flights per hour during these periods ranged from only 1.7 to 6.9, while the number during the MIT_1 periods was substantially higher, ranging from 8.9 to 20.7. A column is also show containing the ratio of flights per hour for MIT_1 to MIT_2_3_OP: the ratio ranged from just under 2 to just over 6 times the flights per hour, further illustrating the lower number of flights subject to the MITs during the “periods of opportunity.”

The southeast (SE) arrival flow into ORD was selected for delay analysis because ORD has a significant proportion of the MIT restrictions that are implemented across the NAS and the SE arrival flow into ORD is frequently congested. There are 3 major flows into ORD from the SE: OKK, FWA, and ZOB. These flows are depicted below, in Figure 8.

.

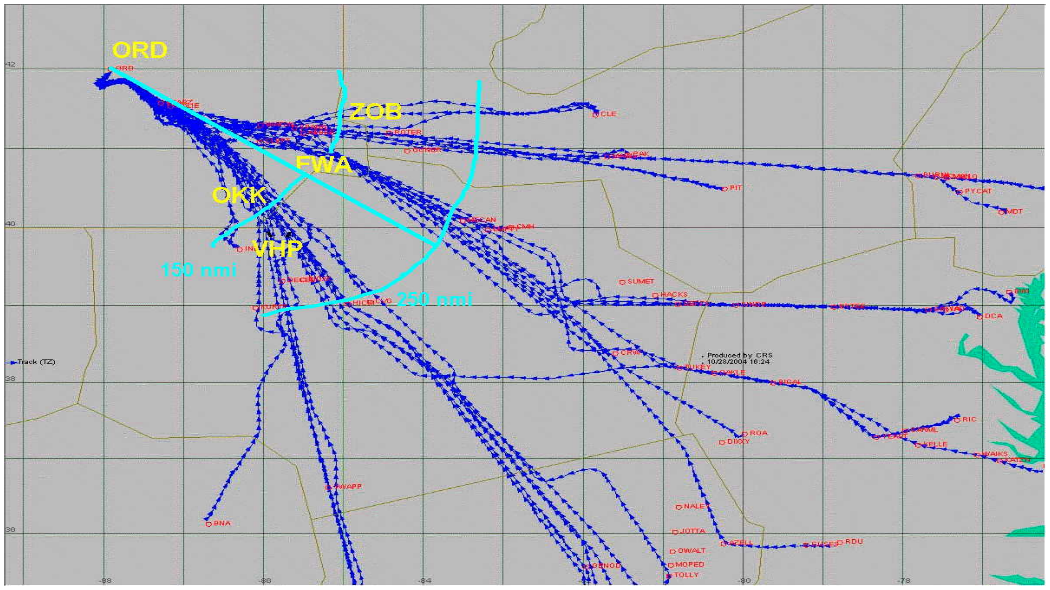

Figure 8. SE Flows into ORD

Flight crossing times are determined for arcs 150 nmi and 250nmi from ORD using ETMS track messages. The error in flight crossing time is driven by the error in the track position and time provided in the track message. The ZAU/ZID and ZAU/ZOB facility boundaries are approximately 150 nmi from ORD, and when MIT restrictions are active, flights will be delayed before they reach the arc 150 nmi from ORD. Therefore, flights during an MIT period may take longer to traverse the distance between the outer arcs and 150 nmi arc than flights during a non MIT period. Flight travel times are computed between the arc at 250 nmi and the arc at 150nmi from ORD. Flight travel times are then grouped according to flow: OKK, FWA, and ZOB.

The north arrival flow over AVE into LAX was also selected for delay analysis because it is frequently congested and MITs are often in place. Flight crossing times are determined for arcs 150 nmi and 250 nmi from LAX using ETMS track messages. The ZOA facility boundary is approximately 150 nmi from LAX. This is depicted in Figure 9.

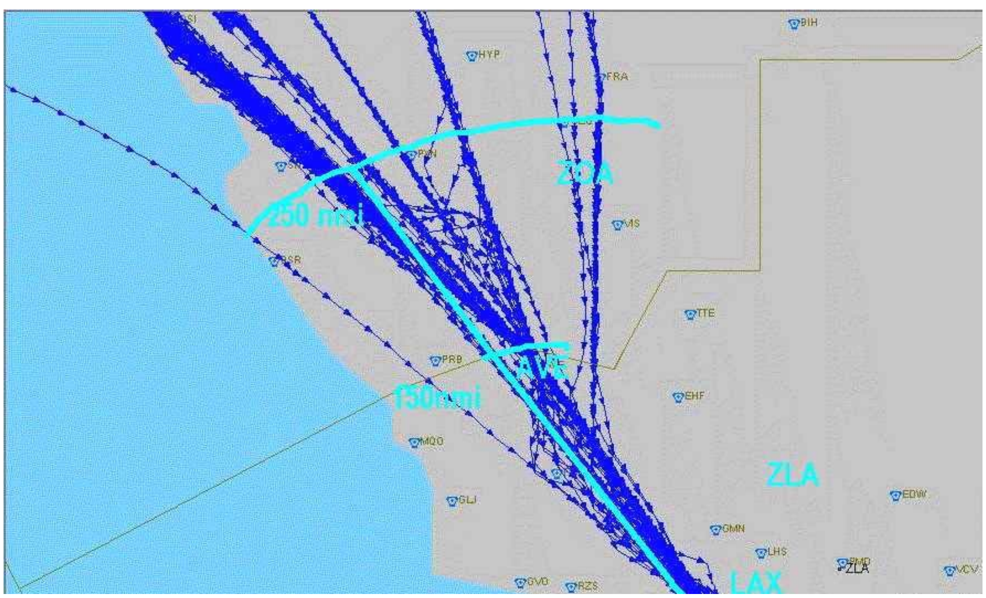

Figure 9. LAX Arrivals over AVE

Table 2 compares the mean flight travel time during MIT intervals, Non-MIT intervals, and OP intervals for each flow between the 250 nmi and 150 nmi arc for both LAX and ORD airports. OP intervals are intervals of opportunity when an MIT restriction is in place but is not needed based on the following conditions:

1. Airport arrival demand, actual arrivals, and target arrival rate for the interval meet the criteria for potential benefits as discussed above
2. All arrival fix counts for that interval are less than 9

Table 2 also provides number of flights involved during MIT, Non-MIT, and OP intervals for each flow. (All flights for which aircraft type information was available were identified to be Jets based on FAA Order 7110.65 Appendix A. For a small percentage of the flights no aircraft type information was available.) In addition, for each flow an ANOVA test was computed to determine if there was a statistical significance in the difference between flight travel times during MIT versus Non-MIT intervals and Non-MIT versus OP intervals.

Table 2. Mean Flight Travel Times for Selected LAX and ORD Flows

Airport, Date, FIX	MIT/NonMIT/OP	Num of flights	Flight Travel Time (sec)	Num of 15 min intervals	Statistical	
					MIT/Non MIT	Non MIT/OP
LAX0316(AVE)	MIT	86	810	42	Yes	**Yes**
	Non MIT	59	782	54		
	OP	47	813	29		
LAX0624(AVE)	MIT	119	837	57	No	**Yes**
	Non MIT	24	813	39		
	OP	88	841	51		
ORD0402 (OKK)	MIT	147	971	54	No	No
	Non MIT	16	943	42		
	OP	22	955	23		
ORD0402(FWA)	MIT	92	886	54	No	No
	Non MIT	11	855	42		
	OP	10	884	23		
ORD0402 (ZOB)	MIT	80	830	54	No	No
	Non MIT	12	808	42		
	OP	11	823	23		
ORD0901(OKK)	MIT	97	901	37	Yes	**Yes**
	Non MIT	67	858	59		
	OP	16	894	18		
ORD0901(FWA)	MIT	61	892	37	No	*Yes*
	Non MIT	43	901	59		
	OP	11	867	18		

There was a statistical significance in the flight travel times between Non-MIT periods and OP periods for both days (0316 and 0624) analyzed for LAX and for one day (0901) and one flow (OKK) for ORD. Although the most likely contributor of the difference in flight travel times between Non-MIT periods and OP periods is the absence or presence of MIT restrictions, the winds aloft affecting the flights may also be different and contribute some to the flight travel time differences.

The average delay for a flight involved in an MIT restriction is computed by taking a weighted average of the difference in mean flight travel time during OP intervals and during Non MIT intervals for the selected flow. Table 3 provides the average delay per flight for the days and flows that had a statistical significance in the flight travel times between Non MIT periods and OP periods.

Table 3. Average Delay Per Flight

Date	Diff(OP-Non MIT) Flight Travel Time (sec)	Num of OP Flights	Diff(OP-Non MIT) Flight Travel Time*Num of OP Flights
LAX0316(AVE)	31	47	1457
LAX0624(AVE)	28	88	2464
ORD0901(OKK)	36	16	576
Total		151	4497
Average Delay Per Flight		30 sec	

This analysis indicates that for LAX (over both days) there were 340 flights subject to MIT restrictions and there may be opportunity to reduce delays for 135 of those flights during the periods of opportunity using a tool such as the proposed MIA capability. There may also be an opportunity to reduce delays for some flights for ORD, however, the number of such flights is much smaller. In addition to reducing delays, the MIA capability will provide benefits by improving the common situational awareness of the center and ATCSCC TMs in planning MIT restrictions.

It should be noted that this analysis only looked at delays for a flight that were within a 100 nmi of the facility boundary. Many of the MIT restrictions are passed back to adjacent facilities. For instance, when ZAU imposes MIT restrictions on flights going to ORD from ZID to ZAU, ZID will in turn often impose MIT restrictions on ORD flights from ZDC (Washington Center) and ZTL (Atlanta Center). Therefore, flights may absorb delays for an ORD restriction long before arriving at the ZAU/ZID boundary. In addition, this analysis only measured airborne delay due to an MIT restriction. If a flight is not airborne at the time an MIT restriction is initiated, the flight may absorb the MIT delay on the ground. The subject of future analysis will be to determine the total delay, both airborne delay and ground delay, for a flight subject to one or more MIT restrictions.

VII. Conclusions

MIT restrictions are a frequently employed TMI, used daily for many situations throughout the NAS. They are useful to help manage resources and to smooth flows, particularly arrival flows into the larger airports. They do impact some of the flights subject to the MIT restrictions – for airborne flights vectoring to achieve the required spacing induces small amounts of increased flying time for these flights.

A limited set of tools are currently available to support traffic managers as they establish MIT restrictions. An MIT Impact Assessment capability has been designed and is intended for future implementation in the FAA’s TFM-M program. This capability is specifically intended to support traffic managers as they employ MIT restrictions for a variety of situations. A proposed concept of operations was presented for how this tool can be used for arrival MIT restrictions. It is hypothesized that use of this tool will help establish more efficient restrictions in the future – some restrictions being of shorter duration and/or with less restrictive spacing values that those employed today for similar situations. These more efficient restrictions in the future have the potential to reduce the impact on flights resulting in benefits to the NAS users.

Analysis of today’s use of MIT identified “periods of opportunity,” times when if similar situations occur in the future when the MIA capability is available, more efficient MITs might be established. This analysis was limited to two airports and two days – but “periods of opportunity” ranging from about 4 hours to over 12 hours were found on each day. The impact on flights during these periods was also examined. While the results were not statistically significant from every period (sometimes due to small sample sizes), several periods were found where impacts averaged about one-half minute per flight and were statistically significant.

There are several activities that should be undertaken in the future to further research the use of MIT restrictions and to gain additional insight into how the MIA capability can be used in the NAS and what additional benefits it might provide. These activities include:

- Develop a concept of use for MIA application to en route and departure MIT restrictions,
- Investigate the impact of MITs on departure flights,

- Expand the analysis to include a larger number of airports,
- Further study the use of the MIA in conjunction with TMA and Time-Based metering (TBM), and with other tools and in a wider variety of situations including those during bad weather,
- And research the potential productivity benefits for traffic managers and controllers under these proposed concepts of use.

Acknowledgments

The authors thank Mr. Anthony Chambliss and Mr. John Mayo III of the MITRE CAASD for their valued support and review. The authors also thank Dr. Mark Rockman and Dr. Ellen Chernivsky of MITRE CAASD, who previously developed an analysis of MITs upon which the "period of opportunity" approach presented in this paper is based. The project was funded by the Federal Aviation Administration (FAA). The authors thank Ms. Linda Yok for her efforts in preparing this manuscript.

References

1. Enhanced Traffic Management System Functional Description, v 8.0, Report No. VNTSC-DTS56-TMS-002, Volpe National Transportation Systems Center, Cambridge, MA, 2005.
2. "Benefits Basis of Estimate (BOE) for Traffic Flow Management Modernization (TFM-M)," The Federal Aviation Administration, 2005.
3. Meyers, T. A., Klopfenstein, M., Mintzer, J., Wilmouth, G., Sud, V., "A Preliminary Analysis of the Impact of Miles-in-Trail Restrictions on NAS Flight Operations," *6th US/Europe Air Traffic Management R&D Seminar*, Baltimore, MD, USA, 2005.
4. Solomos, G. H., and Cooper, W. W., "Analysis of MIT Restrictions into ORD from the Southeast (Volume 1)," The MITRE Corporation, MP96W0000203V1, McLean, VA, 1996.
5. Meyers, Klopfenstein, Mintzer, Wilmouth, Sud, *op cit.*
6. Green, S. M., "En route Spacing Tool: Efficient Conflict-free Spacing to Flow-Restricted Airspace," *3rd US/Europe Air Traffic Management R&D Seminar*, Napoli, Italy, 2000.
7. "Free Flight Program Performance Metrics to Date," The Federal Aviation Administration, 2003.
8. White, K., "A Study of Chicago O'Hare's March 2005 Restrictions Using an MIT Analysis Tool," *24th Digital Avionics Systems Conference*, Washington, D.C., USA, 2005.
9. Meyers, Klopfenstein, Mintzer, Wilmouth, Sud, *op cit.*
10. "Free Flight Program Performance Metrics to Date," *op cit.*
11. Wanke, C., et al, "Decision Support for Complex Traffic Flow Management Actions: Integrated Impact Assessment," *Proceedings of the 2002 AIAA Guidance, Navigation, and Control Conference*, Monterey, CA, USA, 2002.
12. "Benefits Basis of Estimate (BOE) for Traffic Flow Management Modernization (TFM-M)," *op cit.*