MTR 99W0000106

MITRE TECHNICAL REPORT

Integrated Impact Assessment Capability Concept Exploration Transition Report

September 1999

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Center for Advanced Aviation System Development
McLean, Virginia

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Sponsor:	FAA	**Contract No.:**	DTFA01-93-C-00001
Dept. No.:	F045	**Project No.:**	02991204-O3

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Abstract

As part of the daily management of the National Airspace System, FAA traffic management specialists implement traffic management initiatives such as aircraft reroutes, miles-in-trail restrictions, ground stops, and Ground Delay Programs. The effectiveness of these traffic management initiatives could be improved if traffic management specialists had decision support capabilities that would allow them to simultaneously evaluate the effects of collections of traffic management techniques and airspace user actions before they are implemented.

This report summarizes the results of Concept Exploration research performed by CAASD, during fiscal year 1999, on a capability to assess the impact of proposed collections of traffic management initiatives on the National Airspace System.

KEYWORDS: Traffic Flow Management, Concept Exploration, Integrated Impact Assessment, Collaborative Decision Making, Strategy Evaluation

Acknowledgments

The authors are grateful to several persons at CAASD for their contributions in developing the operational concept for an integrated impact assessment capability and in identifying issues and areas for further research. Thanks go to Jim DeArmon for his significant guidance and for being a sounding board for concept ideas. Thanks also go to Mark Huberdeau who provided invaluable air carrier perspective. Without the efficient support of Michelle Bradshaw the production of this paper would not have gone so smoothly.

Table of Contents

List of Figures

List of Tables

Section 1

Introduction

The Center for Advanced Aviation System Development (CAASD) of the MITRE Corporation has been providing Concept Exploration (CE) support to the Traffic Flow Management (TFM) Research and Development Branch of the Federal Aviation Administration (FAA). Integrated impact assessment is one of the capabilities being addressed by CAASD as part of this support.

The primary purpose of CE research is to establish the technical and operational viability of a concept and its potential benefits. Results from CE research will provide the FAA with a basis for decision making on the commitment of funding for further development of the subject capability. Transition criteria have been defined by the FAA for use in evaluating whether or not a capability should be transitioned from the CE phase to the Concept Development (CD) phase, for which funds are allocated for further research and development. Transition criteria addressed by CAASD as part of CE of an integrated impact assessment capability are presented in Table 1-1. FY99 activities were focused on the Requirements/Operational Concepts criteria and Open Issues component of the Wrap-up criteria.

1.1 Purpose

This report summarizes the results of research performed during the past fiscal year on a capability to assess the impact of proposed collections of Traffic Flow Management (TFM) initiatives on the National Airspace System (NAS). It discusses operational needs, presents a candidate operational concept, identifies significant operational issues, and identifies research and development needs which should be addressed as part of the CD phase for the integrated impact assessment capability.

1.2 Scope of Concept Exploration for an Integrated Impact Assessment Capability

The scope of CAASD's CE for an integrated impact assessment capability has been limited to establishing the needs and basic requirements for the capability for the 2005 time frame.

Research and development for some of the decision support capabilities discussed in the strawman operational concept have taken place as part of the CE/CD activities performed by CAASD for a stand-alone miles in trail (MIT) restriction (Abrahamsen et al., 1998) impact assessment capability and a stand-alone collaborative routing capability (Carlson and

Rhodes, 1998). The results of this research and development work are not addressed in this report.

1.3 Audience

The intended audience for this report includes TFM service providers, system developers, and FAA sponsors of TFM research and development.

1.4 Background

As part of the daily management of the NAS, FAA traffic management specialists implement TFM initiatives such as aircraft reroutes, MIT restrictions, ground stops, and Ground Delay Programs (GDPs). The specific details of these initiatives are based on the characteristics of the situation, the traffic management specialist's knowledge of the airspace and its routine traffic patterns, and the traffic management specialist's knowledge of TFM initiatives in effect at that time.

Today, with the exception of GDPs, the traffic management specialist develops these initiatives without the benefit of any decision support aides to assess their potential effect on NAS-wide operations. For instance, while a set of reroutes is designed to eliminate some known sector congestion, it could simultaneously create congestion in one or more downstream sectors. This new problem leads to the establishment of other "ripple" TFM initiatives. This phenomenon occurs on a regular basis today. A clear need exists to explore the concept of an integrated impact assessment capability.

Table 1-1. Concept Exploration Transition Criteria Addressed by CAASD

Concept Exploration Transition Criteria	CAASD Concept Exploration Results
Requirements/Operational Concepts	
Problem definition/clarification	Sufficient understanding of the problem to determine a need for a solution and the feasibility of implementing a solution in the 2005 timeframe
Initial operational needs document	Consensus on operational need subject capability will address
Operational concept - strawman	Capability for demonstrating and evaluating alternative concepts
	Preliminary participant roles and responsibilities, information exchange requirements and desired behaviors/interactions
	Preliminary operational, functional, data and system interface requirements
Cost/Benefits Analysis (CBA)	
Initial description of benefits	Narrative on anticipated FAA and user community benefits from implementing subject capability
Benefits estimate - preliminary	Benefits presented in primarily qualitative terms, from both the FAA and user community perspectives (limited quantitative results anticipated in time available)
Wrap-up	
List of open issues	Technical and operational issues which need to be addressed by a more robust evaluation capability, or when a specific technical implementation approach is selected
CD Phase Plan	Recommendations for evaluations and additional development during Concept Development Phase

Section 2

Problem Clarification

2.1 Integrated Impact Assessment Problem Definition and Clarification

In today's NAS, a variety of TFM initiatives are applied in order to maintain a balance between demand imposed by airspace users, and the capacity available from NAS resources such as airports, sectors, airways, and fixes. Demand is defined by scheduled and unscheduled use of the airspace, and varies on a minute-by-minute basis. The capacity of NAS resources also varies on a minute-by-minute basis, due to such phenomena as weather or changes in airport capabilities.

For the most part, today's TFM initiatives are applied with benefit of only limited understanding, beyond that of the traffic management specialist's personal experience, of how the initiatives individually and collectively will affect the en route traffic flows or the ability of airports to respond to the resulting changes in arrival and departure traffic. This a priori decision making frequently leads to TFM initiatives that are inefficient, ineffective, or counterproductive. For example, an excessive MIT restriction can result in departure delays at feeding airports that cause sufficient airport gate or ramp congestion to interfere with arrival traffic. If the effect on arrival traffic is severe enough, ground stop initiatives may have to be implemented.

With the exception of GDPs, MIT restrictions, ground stop initiatives, and reroute initiatives are frequently developed with only limited discussion or collaboration with airspace users. Traffic management specialists are not always able to take into account airspace user preferences or their willingness to help in mitigating the problem, because of current limitations in information exchange capabilities.

Research and development efforts are underway today to provide decision support tools that will provide traffic management specialists with the ability to evaluate the potential impact of a single TFM initiative on a NAS resource. The Flight Schedule Monitor (FSM) is an example of such a tool. It allows traffic management specialists to evaluate the potential effect of airport-specific GDP proposals. An estimate of the delay imposed by a proposal can be quickly determined, allowing for refinement of the proposal before it is implemented as a TFM initiative. The Collaborative Routing Coordination Tool (CRCT) set of capabilities, currently being researched, is another example. It will allow a traffic management specialist to determine the potential effects of proposed reroutes, including identifying sector capacity versus demand over time.

Neither capabilities, however, take into account existing TFM initiatives; nor do they allow for the simultaneous evaluation of other proposed initiatives. Therefore, the "perfect" reroute plan defined through the use of CRCT could adversely affect the arrival flow anticipated for the "perfect" GDP defined through the use of FSM.

2.2 Initial Operational Needs

The effectiveness of FAA TFM initiatives could be improved if traffic management specialists had decision support capabilities (procedures as well as automation tools) that would allow them to simultaneously evaluate the effects of collections of traffic management initiatives and airspace user actions before they are implemented. Initiatives such as reroutes, MIT restrictions, ground stops, and GDPs would have to be accommodated along with user initiated actions such as schedule changes, flight cancellations, and diversions.

Based on work completed to date, a decision support capability to assess the impact of a combination of TFM initiatives should do the following:

- Have access to accurate and timely airspace user demand data that takes into account active (at the time of the evaluation) and proposed flights, filed or historical routes (for flights not filed), and proposed departure schedules
- Take into account active and proposed NAS characteristics (for example, sectorization and sector thresholds)
- Take into account existing TFM initiatives
- Allow the traffic manager to define, in terms acceptable to the airspace user, a single or collection of TFM initiatives for evaluation
- Allow for the input of airspace user oriented preferences or exemptions
- Provide for a rapid evaluation response
- Provide output in the form of quantitative metrics that are appropriate for the resources affected
- Provide for the sharing of output to support collaboration with other FAA facilities and airspace users

Section 3

Candidate Operational Concept

3.1 Assumptions About the Operating Environment in 2005

This operational concept makes the following assumptions about Air Traffic Management (ATM) operations in the target time frame, 2005:

- The ATM automation system accepts airspace user flight intent information and places the data into a database accessible by other automation systems, in particular, the Integrated Impact Assessment Tool (IIAT).
- Most, if not all, automation tools available to the Command Center are also available to other TFM facilities.
- Given a time of arrival at an airport or a location in airspace, TFM and airspace users use (independent) automation systems to help estimate the time of departure to achieve the time of arrival, given forecasted weather, capacity, and demand conditions.
- Weather forecasting is more accurate than today – in particular, the location, size, strength, movement, and duration of convective activity.
- Although air carrier schedules are published, at the beginning of each day airspace users send any known changes in flight intent to the ATM automation system, and, throughout the day, send revisions in flight intent as the information is known to the airspace user. This includes changes in flight route, altitude, and speed, as well as changes in departure time, arrival time, and times at specified fixes or waypoints. Specific related terminology used in this paper includes the following:
  - *Replan* – to make changes in flight route, altitude, time of departure, or time of arrival to an airport or fix; replanning is done by the air carrier prior to departure.
  - *Reroute* – to make changes in flight route or altitude after departure. The changes can be requested by the airspace user (pilot or Aeronautical Operational Center [AOC]) or the FAA (controller or traffic manager).
- Flights generally are not required to fly Air Traffic Control (ATC)-preferred routes, as are known today. Airspace users are able to fly any path, subject to such ATM constraints as closed airspace or TFM initiatives implemented to manage demand-capacity imbalances in the NAS.

- The FAA does not initiate rerouting, except for reasons of safety or if a flight is not conforming to the TFM constraints.
- The IIAT is intended for use by traffic managers and is not necessarily envisioned for use by the AOC.

3.2 Scenario

The scenario given below describes a flight day in 2005 when a weather system, worse than anticipated in the early morning, is predicted to begin six hours hence and interrupt east-west traffic flows in the contiguous United States (CONUS). With input from traffic managers at the affected en route centers, the Command Center specialist uses an automated capability, called the IIAT, to evaluate the impact on the NAS of various TFM strategies, taking into consideration any TFM initiatives already planned. Used in this way, the IIAT is a "what if" tool, testing out a strategy and calculating how well the strategy plays out according to a set of defined metrics.

The Command Center specialist evaluates the IIAT results for each strategy, and, with input from the local traffic managers, selects the strategy that best meets TFM's objectives for the day. Throughout the day, airspace users are kept informed of the situation in the NAS and of strategies being considered by TFM personnel. Airspace users adjust their own plans as needed, and inform the ATM system of any replans or other schedule changes.

Additionally, the IIAT is used to develop a temporary organized route structure around an impassible weather system, and to evaluate individual airspace user requests for replanning.

Although the subject of this operational concept is a capability to help assess the impact of implementing multiple TFM strategies, this scenario describing how the tool is applied also implies a concept for the following:

- How the users of the capability (traffic managers at the national and local TFM facilities) and airspace users (primarily AOC personnel, such as flight dispatchers) interact
- Roles and responsibilities of national and local traffic managers, as well as of the AOC
- The decision support systems they use
- Operating procedures that may not be in place in today's environment

The scenario description is organized so that the situation, actions, and interactions are described on the left. Any comments or questions associated with the scenario are listed on the right. Furthermore, the following convention has been used to enhance readability of the scenario: solid horizontal lines separate time frames, while dashed horizontal lines separate activities within the time frame.

Events	Comments
1000Z. GDP is created for EWR Due to planned maintenance on runway 22R at Newark Airport (EWR), a GDP will be in effect at EWR for arrivals originally scheduled between 1400Z and 2400Z. This GDP has been announced for several days, and all air carriers have already made plans for the incurred delays to EWR. The Command Center runs the software for the GDP, and the software issues a Controlled Time of Arrival (CTA) for each affected flight to EWR. In turn, the air carriers have an opportunity to manage these allocated arrival slots. That is, considering the carrier's business objectives for today and following procedures agreed to by the airspace users and the FAA, the carrier's AOC personnel decide which among its flights to assign to the arrival slots allocated by the GDP software. The AOC uses in-house software to calculate a departure time range for each flight affected by the GDP, and submits these time ranges to the ATM software. The time range represents the earliest departure time and the latest departure time that enables the flight to fly the desired route and achieve the CTA. In turn, the ATM software issues a departure time that is within the time range submitted by the AOC. The AOC incorporates this information and submits revised flight intent information to the ATM automation system.	This scenario is hypothesizing how departure times are calculated once an airspace user is issued a CTA.
1100Z. Initial CCFP shows no severe weather The **Collaborative Convective Forecast Product** (CCFP), prepared by a team of air carrier meteorologists and ATM weather providers, has been published on the ATM website. At this time, the CCFP indicates moderate precipitation in the midwest throughout the day; no convective activity for CONUS is forecast.	
1430Z. IIAT generates FCAs Weather conditions in the midwest have changed. Airline meteorologists have been conferring with the ATM weather provider. The CCFP team now forecasts popcorn storms to form from Wisconsin to Oklahoma. A line of such storms is threatening	

to develop in a few hours, severely impacting traffic through Minneapolis Center and Kansas City Center. According to the ATM weather provider, severe weather is forecasted to last from 1730Z to 2100Z, with a near-line of impenetrable storm cells from 1900Z-2030Z. The weather system is predicted to move east southeast. The **CCFP team publishes the revised weather forecast on the ATM website**.	
The Command Center specialist prepares the weather forecast for input to the Integrated Impact Assessment Tool. The **IIAT creates a Flow Constrained Area (FCA)** for the beginning of the weather system. Since movement and growth information are included in the forecast, the IIAT is able to create an FCA for the forecast for every 15 minutes for which the weather system is in effect. An FCA is a four-dimensional outline encasing that portion of airspace whose capacity is severely reduced, due to such reasons as lightning activity. The IIAT generates a set of FCAs, each applicable for a 15-minute time frame (or as adaptable by the Command Center).	In an advanced version of IIAT, there will be no need for pre-processing of the weather forecast. The tool will have access to the database containing the weather forecast.
A **Command Center specialist evaluates the set of FCAs** to see whether, based on the specialist's analysis, the FCAs need to be refined in size, shape, location, and time parameters. If needed, the specialist can alter these details about the FCA. After consulting with the CCFP team, the Command Center specialist makes a small change in the shape and location of the FCAs in the 1900Z-2100Z timeframe. An example of the resulting set of FCAs is illustrated in Figure 3-1.	This would be a new role for the Command Center.

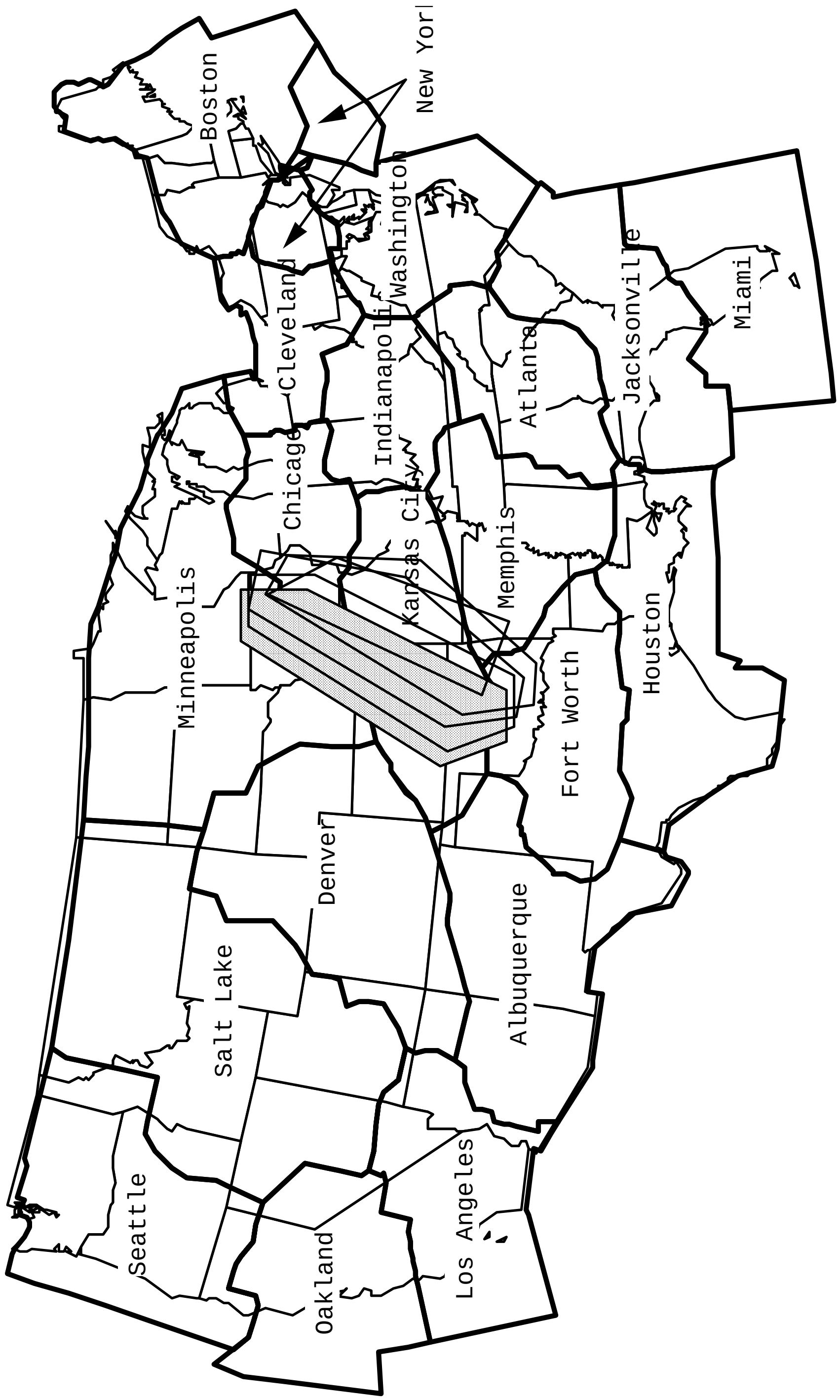

Figure 3-1. FCAs Constructed Around Severe Weather as Forecasted for 1900Z-2030Z at 1130Z

The Command Center places a two-dimensional depiction of the FCAs on the ATM website. Furthermore, **the data specification of the set of FCAs is made accessible electronically**. (Electronic access to the FCA specifications allows air carriers to input the FCAs into their flight planning and flight following systems, and allows flight service providers to incorporate the information into their real-time systems.)	Would airspace users in fact find the electronic availability of this capacity information useful? How would they incorporate the information into their in-house automation systems?
1435Z. **IIAT is used to develop a route restriction** The airspace users likely will replan several flights to the north and south of the weather system, causing a higher than usual demand for those airspaces. In case the replanning causes congestion, as expected, the **Command Center is responsible for developing candidate *TFM-designated routes***, which are temporary recommended flight "corridors" created as the need arises to organize traffic flows around severe weather systems, closed Special Use Airspaces (SUAs), and other airspaces with severely reduced capacity.	In this scenario, these TFM-designated routes (similar to today's en route "SWAP routes") are created and coordinated among all affected TFM facilities very early in the day, and are tailored to the situation and needs of that day.
To do this, the Command Center specialist consults with the affected TMUs to **identify today's objectives for the TFM-designated routes**, and translates the objectives into "rules" for the IIAT. For example, a high priority objective today is to avoid placing a TFM-designated route over the North departure fixes of Dallas-Fort Worth airport. Likewise, the Minneapolis TMU makes a similar request to minimize impact on departures from Minneapolis airport. The Command Center specialist uses the IIAT to analyze the latest estimates of flight intent, as supplied by the airspace users, and to identify traffic flows. The **IIAT identifies several candidate TFM-designated routes and determines the appropriate number of routes** according to the specified rules. As requested by the Command Center, the IIAT lists the three sets of routes best meeting today's objectives.	This idea of TFM-designated routes is similar in many respects to the notion of using tracks to manage oceanic traffic in the Pacific and North Atlantic today. There are lessons to be learned from that experience that could help refine how TFM-

The Command Center communicates these results with the TMUs, and, after consulting with them, selects route set R – consisting of three routes for eastbound traffic and two for westbound traffic – as illustrated in Figure 3-2.

designated routes are generated as well as to work on the operational issues associated with using TFM-designated routes.

It is a conjecture that TFM-designated routes, as described here, would be good solutions for managing an en route demand-capacity imbalance. Additional research would need to be done to estimate the feasibility.

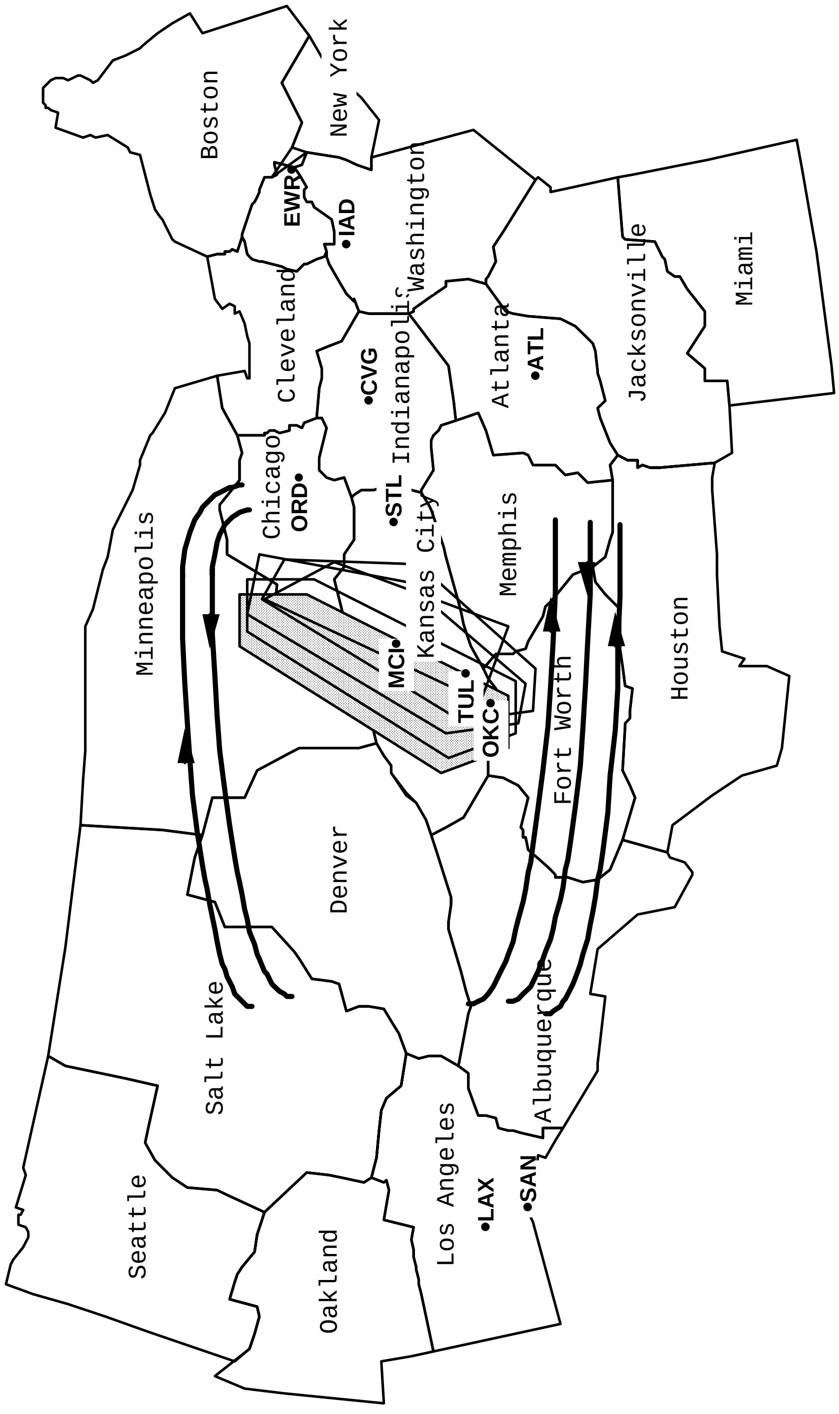

Figure 3-2. Today's TFM-Designated Routes

1445Z. IIAT is used to identify metered entry points

It is likely that in addition to TFM-designated routes, the Command Center will need to establish **rate** requirements along those routes or implement MIT restrictions. If so, there likely will be delays in departure for those flights choosing the TFM-designated routes.

In case MIT restrictions will become necessary, **the Command Center uses the IIAT to identify *metered entry points***, locations on each TFM-designated route where a flight can enter the route in an orderly manner. These points are used by the IIAT in its calculation of impact on the NAS. (See Figure 3-3.) Information used by the IIAT to determine the metered entry points could include the following:

- Paths of flights prior to traversing the TFM-designated route
- Path crossing complexity
- Spacing needs of the metered entry points in order to maintain safety and achieve the MIT spacing
- Altitude restrictions, such as for direction
- As with the location and shape of the TFM-designated routes, the Command Center confers with the TMUs in refining the location of the metered entry points.

The **Command Center publishes the set of TFM-designated routes, and the associated metered entry points and altitudes on the ATM website**. The Command Center message states that if the weather materializes as forecast and if demand remains great, the all flights in this airspace will be required to fly the TFM-designated route set R.

Research needs to be done on how to determine necessary and sufficient TFM-designated routes and metered entry points – for example, how many, where located, start of route, end of route, and so forth.

Other research includes the following:

- whether secondary routes to deliver traffic to the metered entry point would become necessary
- safe and effective ways of merging the traffic from the secondary routes
- safe ways to change altitudes once on a TFM-designated route (for example, to take advantage of available capacity or favorable winds)

	Or, is it possible to have a Free Flight-like environment prior to traversing the TFM-designated route? In this scenario all airspace users traversing the affected airspace would be *required* to fly the TFM-designated routes.

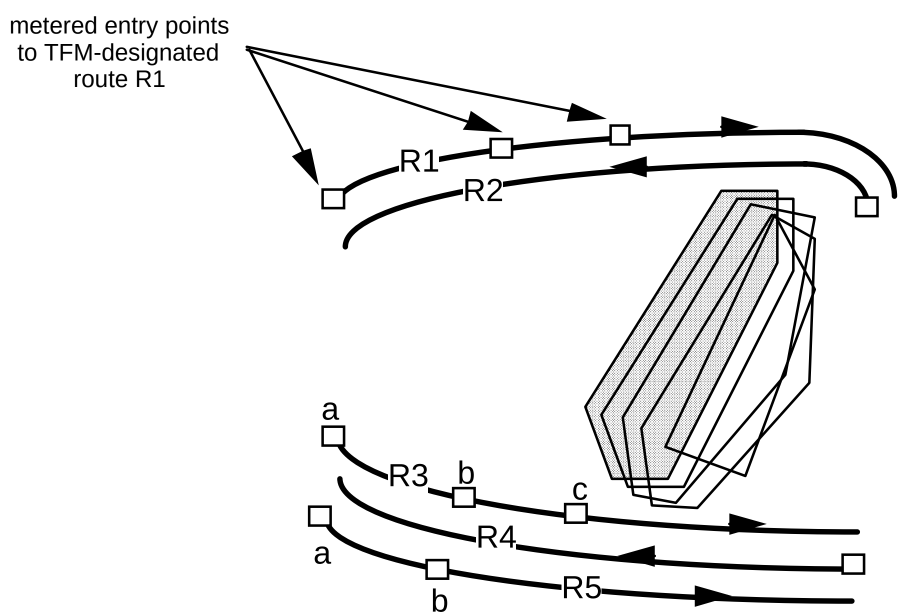

Figure 3-3. Examples of Metered Entry Points for a TFM-Designated Route

1446Z. **Command Center and TMUs consider various strategies** In the meantime, Minneapolis Center **TMU uses the IIAT to help estimate the en route center's sector capacity over time** based on the weather forecast. The traffic manager at the TMU has the capability to adjust the capacity predictions, as necessary – for example, in accordance with the skill mix of the day's staffing of controllers.	It is proposed that the IIAT perform the task of capacity estimation. However, whether done by IIAT or by another automation system, it seems reasonable that capacity calculation could become automated. Further research on such a capability would be needed.
Minneapolis **TMU begins to consider initiatives** to help manage the additional volume of traffic through Minneapolis Center airspace. Among the options Minneapolis TMU considers[1] are the following: • Use of the selected TFM-designated routes • Spreading the overflight demand to Minneapolis Center through a combination of MIT restrictions or delayed departure times • Call-for-departure restrictions for internal and first-tier departures for Minneapolis Center • Coordination with Nav Canada for increased use of their airspace for rerouting and replanning options • Reconfiguration of Minneapolis airspace to accommodate the anticipated changes in traffic flow	
Minneapolis TMU communicates these initial thoughts to the Command Center. Similarly, other en route center TMUs have been considering some initiatives to manage unusual traffic demand through their sectors, and they communicate their ideas to the Command Center. The **Command Center publishes all the centers' considerations about today's TFM strategies on the ATM website,** for information purposes only.	Is this a reasonable division of responsibility between local and national TFM facilities?

[1] All TFM initiatives that impact other en route centers are coordinated with the Command Center.

1447Z. **Airspace users respond to weather forecast with schedule adjustments**

Also in the meantime, air carrier ABC's **AOC has been monitoring the ATM website**, noting the CCFP weather forecasts and corresponding FCAs. The AOC has also studied the possible initiatives that each en route center TMU has been considering for managing currently projected demand through its airspace. The carrier's experience has been that when it is proactive in replanning flights, the results are more satisfactory than when the changes to the schedule are left to ATM to decide. Hence, ABC re-examines its business objectives for that day and explores replanning some flights.

ABC has a hub at Chicago O'Hare (ORD) where its operations represent 40% of the arrival and departure traffic. **The air carrier makes the following adjustments to its schedule** for flights that would otherwise be adversely impacted by the reduced capacity in the midwest:

- Replan 60% of its east-west traffic to fly the airspace in which the TFM-designated route set R is located
- Replan 20% to fly outside the airspace for TFM-designated routes, including Canadian airspace (as negotiated between the Command Center and Nav Canada)
- Since some of ABC's airframes are capable of flying at altitudes greater than the FCA ceiling, replan these few flights to fly above the FCA ceiling
- Release some flights at their scheduled departure but fuel for additional minutes of airborne holding, if needed
- Delay departure of 30% of its O'Hare arrivals coming from the west that were originally scheduled to arrive in the 1730Z-1830Z time frame
- No action as yet on canceling, but consider cancellation of as many as 20 flights, if needed

At this time, it is not known whether TFM-designated routes will be implemented, only that they are being considered as a strategy. Airspace users are not asked to state a preference for a TFM-designated route or a metered entry point. In their replanning, airspace users are stating their intended flight path, in case the situation improves to the point where TFM-designated routes are not necessary.

Would airspace users prefer to state a preference (or set of ordered preferences) for

	TFM-designated routes – for example, first choice is R1a at FL 350, second is R3b at FL 370, etc.? If so, at what time in the process would this be useful?
ABC sends changes in flight intent to the ATM automation system. The **Command Center notes the large number of voluntary adjustments** that ABC has made to its fleet schedule. Similarly, other air carriers adjust their fleet schedules and notify the Command Center of their intended changes.	Would the airspace users and traffic managers want to have a system where "good deeds" are remembered and rewarded, as is shown later in the scenario? This scenario suggests that airspace users submit changes in flight intent whenever they know about them. In reality, would it be more practical to establish known times for changes to be submitted – for example, on the hour?

1515Z. IIAT is used to evaluate candidate TFM strategies

The IIAT, which is continuously running, updates its demand estimates with the revised flight intent data. **The Command Center and en route center TMUs independently review the new demand/capacity projections on the IIAT**. While the air carriers' own early initiatives have spread demand across time and to less congested airspace, demand estimates through Minneapolis and Fort Worth Centers are still high.

In a conference session requested by the Command Center, these **TMUs reconfirm the need for TFM initiatives**, including implementing the set of TFM-designated routes identified earlier today, delaying some departures, doing FAA-initiated rerouting (if necessary)[2], and implementing MIT restrictions.

In addition, some TMUs have requested ground stops for the time period during which the storm is expected to be over their en route centers' airports. These include the following airports and time frames:

Kansas City (MCI)	1900Z-2030Z
Tulsa (TUL)	1900Z-2030Z
Oklahoma City (OKC)	1900Z-2000Z
St. Louis (STL)	2000Z-2100Z

[2] In the 2005 time frame, it is assumed that the flight routes identified in the flight plan are the routes the carrier wants flown, and that it is preferable to delay departure as long as needed rather than have the FAA determine an alternate route. Thus, in general, traffic managers will not need to require that flights be rerouted (while airborne) except to get them onto the TFM-designated routes, in those cases where the airspace user has not altered the flight plan to do so.

The **Command Center use the IIAT to evaluate the impact of the ground stop initiatives**. Examples of candidate metrics used by the IIAT are shown in Table 3-1. The Command Center inputs the following information into the IIAT:

- Details about the only other TFM initiative in place or planned for the day, the GDP at EWR
- The names of the airports for which a ground stop is desired and times of the ground stops

As expected, the IIAT indicates severe delays across the NAS. (A capability of the IIAT that the Command Center did not invoke at this time is to calculate revised arrival times and departure times for affected flights. This will be done at the next step.)

Table 3-1. Examples[3] of Metrics Used by the IIAT to Measure Impact of a TFM Strategy on the NAS

How well this initiative would keep sectors, airports, or fixes from being saturated, but still keep demand at close to capacity
The ability of arrival airports to manage to the resulting arrival rates
Delays in minutes for flight arrivals to key selected cities
Delays in minutes for flight departures at key selected cities
Level of any resulting ground congestion at key airports

[3] These are suggestions of some metrics to help traffic management personnel. Are these useful metrics? Research needs to be conducted to identify the correct metrics and to determine how to calculate them.

Next, the **Command Center uses the IIAT to evaluate different strategies for managing heavy traffic flows around the thunderstorm**. The strategies being considered include variations in MIT restrictions for flights intending to fly the airspace with the TFM-designated reroutes. The strategies selected for evaluation are the following:

- No MIT restriction along any of the TFM-designated routes
- The same MIT along each TFM-designated route – for example, 15, 20, or 25
- Varying the MIT restrictions among the routes (for example, 20 MIT along R1, 30 along R2, etc.)

Constraints or guidelines used by the IIAT in evaluating the strategies include the following:

- The GDP at EWR, developed at 1000Z
- Planned short-term ground stops to selected midwest airports, as described above

Although in this scenario the IIAT is evaluating various MIT restrictions (constrained by the GDP and ground stop initiatives), the IIAT is able to evaluate several kinds of TFM strategies.

Generally, the **procedures used by the Command Center to apply the IIAT** are the following.

1. If a **GDP** is to be implemented, the Command Center inputs such GDP data as the following:
    - Which flights to the GDP-affected airport have assigned CTAs
2. If a planned **ground stop** is to be implemented, the Command Center inputs such ground stop data as the following:
    - The ground stop-impacted airport
    - The times during which the ground stop is in effect
3. If TFM-**designated** routes are being used, for those flights whose intent is to fly in the airspace where TFM-designated routes are in effect, the **IIAT "matches" an airspace user's intended flight route as close as possible to one of the TFM-designated routes**. The matching is done according to algorithms jointly agreed to by the airspace users and the FAA. Examples of considerations built into the algorithms could include the following:

It is suggested that for an advanced version of IIAT, the airspace users be able to state preferences in TFM-designated routes, along with one or two alternate choices. Rules developed by the airspace users and the FAA on equitable methods of granting user requests would then need to be developed.

This scenario states

- Time flown
- Distance flown
- Airspace user's intended cruise altitude
- Altitude restrictions, if any
- Fuel consumption
- Airspace user request

4. If MIT restrictions are being evaluated as part of the strategy, the following **data are input into the IIAT for each TFM-designated route**:

   - MIT restriction, including the following:
     – the number of miles in trail
     – associated segment of the TFM-designated route
   - For example, 30 MIT between R1a and R1b, 20 MIT between R1b and R1c, etc.
   - Start time of MIT restriction
   - Stop time of MIT restriction

5. For flights traversing the TFM-designated route, the **IIAT** calculates **a time of arrival at a metered entry point** for the TFM-designated route. These time-at-metered-entry-points are based on the following:

   - Rules of engagement (including rules of fairness), agreed to earlier by the airspace users and the FAA
   - The assumption that airspace users want to keep the same sequence of arrivals and departures for flights that fly the TFM-designated routes with the exception of flights to airports for which a GDP or planned ground stop will be in effect
   - In the case of a GDP, the IIAT gives priority to any flight that has been issued a CTA (by the GDP software)
     – Therefore, the IIAT attempts to assign a time-at-metered-entry-point such that a flight's CTA can be achieved
   - In the case of a planned ground stop, the IIAT delays departure of a flight to ensure that it does not arrive at the affected airport during the period for which the ground stop

that the order in which the IIAT is operated is following: first, information about all known constraints or planned TFM initiatives (for example, GDP, ground stops); next, the strategy being evaluated. The order in which constraint information is entered affects the outcome of IIAT. For example, suppose the GDP information is input before the ground stop information; then the result would be different from inputting ground stop information first. In this scenario then, the IIAT can only evaluate one strategy at a time. It is suggested that an advanced version of IIAT be capable of evaluating combinations of several strategies.

is in effect. Furthermore, the IIAT assigns a departure time that allows for some airborne holding near the ground-stopped airport so that demand will be available when the ground stop is lifted.

6. The **IIAT calculates a revised departure time** to enable the affected flight to achieve its time-at-metered-entry-point.
7. The **IIAT calculates a revised time of arrival**.
8. The **IIAT calculates values for each of the impact metrics**.

1530Z. **Command Center selects TFM strategy**

The IIAT has finished evaluating each strategy. The Command Center studies the results and selects the following strategy:

- TFM-designated route set R from 1800Z to 2030Z
- R1: 25 MIT restriction from metered entry points a to b,
  20 MIT restriction from metered entry points b to c,
  15 MIT restriction thereafter[4]; from 1915Z to 2000Z
  R2: 15 MIT restriction from 1915Z to 2000Z
  R3: 20 MIT restriction from 1900Z to 2030Z
  R4: 15 MIT restriction from 1900Z to 2000Z
  R5: 20 MIT restriction from 1900Z to 2030Z

For each strategy involving a MIT restriction, the IIAT has calculated the times-at-metered-entry-point, expected arrival time, and departure time for each affected flight.

This information is communicated to each affected airspace user. Figure 3-4 shows an example of the resulting changes to ABC airline's schedule at this point, including the matched TFM-designated route, the time-at-metered-entry-point, the entry altitudes, the revised departure time, and revised arrival time.

[4] The greater spacing at the beginning of the TFM-designated route is to enable flights to merge onto the route at the metered entry point at the spacing necessary for traffic on the remainder of the route to be able to maintain the required MIT.

from LAX :

flight number	departure time before IIAT processing[5]	departure time after IIAT processing	TFM-designated route & metered entry point, entry altitude	time-at-metered-entry-point	arrival time before IIAT processing	arrival time after IIAT processing	arrival airport
…							
ABC001	**1700Z**	**1800Z**	**R3a FL350**	**1900Z**	**2200Z**	**2310Z**	**IAD**
ABC135	1715Z	1830Z	R5a FL330	1930Z	2045Z	2220Z	ATL
ABC246	1745Z	1740Z	R3a FL370	1835Z	2245Z*GDP	2245Z*GDP	EWR
ABC567[6]	1800Z	n/a	n/a	n/a	2130Z	2130Z	ORD
…							

from SAN:

flight number	departure time before IIAT processing	departure time after IIAT processing	TFM-designated route & metered entry point, entry altitude	time-at-metered-entry-point	arrival time before IIAT processing	arrival time after IIAT processing	arrival airport
…							
ABC369	**1630Z**	**1705Z**	**R5a FL310**	**1810Z**	**2030Z**	**2140Z**	**CVG**
ABC478	1650Z	1800Z	R5a FL330	1855Z	1950Z	2055Z	MCI
ABC690	1800Z	1905Z	R3a FL390	2010Z	2130Z	2155Z	ATL
…							

Figure 3-4. ABC Airline’s Schedule after IIAT Processing

[5] Because the AOCs submitted flight intent changes earlier in the day, in response to the weather forecast, some of these departure times are different from the published departure times.

[6] The AOC replanned flight ABC567 through Canadian airspace, thus avoiding any airspace containing the TFM-designated routes.

1545Z. AOCs respond to TFM strategy

ABC's AOC has been waiting for these revisions, and studies the IIAT results for flights departing from Los Angeles (LAX) and San Diego (SAN) airports. The AOC notes the following:

- ABC flights for Newark, for which a GDP is in effect, have received times-at-metered-entry-point to enable them to arrive at Newark at the time assigned by the GDP software. In the case of flight ABC246, this has meant an earlier departure time of five minutes (but not earlier than the original departure time, as listed in the *Official Airline Guide* publication).
- Flight ABC478 from San Diego to Kansas City, for which a planned ground stop is in effect from 1900Z to 2030Z, has been delayed so that it would arrive after the planned ground stop was no longer in effect.

For the ABC246 flight to EWR, is the earlier departure time (even by five minutes), as calculated by the IIAT, operationally acceptable to the airlines?

In addition, the AOC is concerned that flight ABC001, a high priority flight from Los Angeles to Washington Dulles (IAD), is to incur an arrival delay of 70 minutes, with a time-at-metered-entry-point of 1900Z on route R3, as shown in Figure 3-4. Because of replanning done earlier in the day, ABC001's departure time had already been pushed up from the published departure time. ABC001 has a high percentage of full fare passengers who need to connect to an ABC flight to Europe. An additional delay of 70 minutes would cause the passengers to miss this connection.

Upon further inspection, the AOC notes that flight ABC369 from San Diego to Cincinnati (CVG) has been given a time-at-metered-entry-point of 1810Z on route R5. In comparison to the rest of the air carrier's fleet needs, flight ABC369 is not considered a high priority flight today since most of its passengers have Cincinnati as their final destination.

Using ABC's in-house software, the AOC finds that if it could **exchange TFM-designated routes and times-at-metered-entry-point** between the two flights, ABC001 could arrive at IAD in enough time for the Europe-bound passengers to make their connection. The AOC phones the Command Center to find out whether the exchange could be made.

The **Command Center uses the IIAT to evaluate the AOC's**

Note that the in-house software used by the air carrier to evaluate changes in flight intent could, in fact, be a version of the IIAT.

Implied in the Command Center's evaluation is the notion that the Command Center approves an air carrier request, in this case to exchange IIAT-allocated routes and time slots. Is this process acceptable to the airspace users as well as to the Command Center?

request, finds that there is available arrival capacity at IAD and that the exchange would not contribute to en route congestion, and therefore grants the AOC's request, giving the requested arrival times at IAD and CVG. ABC makes the changes in assigned TFM-designated routes and the times-at-metered-entry-point, and calculates revised departure times. Then ABC sends the revised flight intent information to the ATM automation system. The ABC-initiated changes are shown in Figure 3-5.

from LAX :

flight number	departure time before IIAT processing	departure time after IIAT processing	TFM-designated route & metered entry point, entry altitude	time-at-metered-entry-point	arrival time before IIAT processing	arrival time after IIAT processing	arrival airport
ABC001	**1700Z**	**1710Z**	**R5a FL310**	**1810Z**	**2200Z**	**2220Z**	**IAD**
ABC135	1715Z	1830Z	R5a FL330	1930Z	2045Z	2220Z	ATL
ABC246	1745Z	1740Z	R3a FL370	1835Z	2245Z*GDP	2245Z*GDP	EWR
ABC567	1800Z	n/a	n/a	n/a	2130Z	2130Z	ORD
…							

from SAN:

flight number	departure time before IIAT processing	departure time after IIAT processing	TFM-designated route & metered entry point, entry altitude	time-at-metered-entry-point	arrival time before IIAT processing	arrival time after IIAT processing	arrival airport
…							
ABC369	**1630Z**	**1755Z**	**R3a FL350**	**1900Z**	**2030Z**	**2230Z**	**CVG**
ABC478	1650Z	1800Z	R5a FL330	1855Z	1950Z	2055Z	MCI
ABC690	1800Z	1905Z	R3a FL370	2010Z	2130Z	2155Z	ATL
…							

Figure 3-5. ABC Airline's Schedule after Managing to Its Allocated Metered Entry Point Slots

1800Z. Command Center manages unexpected available capacity

The weather system is not materializing as was expected earlier in the day. That means that there will be more capacity available in the midwest this afternoon than predicted. The changes in weather forecast and in capacity are published in the ATM website.

The Command Center remembers that some air carriers, including ABC, had early in the day voluntarily made significant alterations in their schedules to decrease congestion in the midwest. The TFM-designated route restriction will not be lifted. Rather, the **Command Center telephones the AOCs of these air carriers and, applying rules developed by the airspace users and the FAA, offers these air carriers the extra capacity**. ABC AOC uses its in-house software to determine how it can use the available capacity, then communicates changes on flight intent to the ATM automation system.

What is a fair and acceptable way[7] to:

- notify airspace users about extra available capacity?
- determine who gets to use the available capacity?

Is offering available capacity to airspace users a sufficient incentive for the users to cooperate early or to voluntarily make schedule adjustments in order to spread demand across space or time?

[7] See (Chambliss, et al., 1998) for an alternate treatment for managing the unexpected availability of en route capacity.

3.3 Key Operational Concepts

The following are key concepts about an integrated impact assessment tool, as described in the scenario:

- Although in the 2005 time frame it is expected that flights fly "off routes", that is, along paths developed by the airspace users to best satisfy their business needs, this scenario suggests that when a situation warrants it, flights can be restricted to fly FAA-specified routes, called *TFM-designated routes*. Furthermore, it might be necessary to maintain a rate of delivery along the routes, in the form, for example, of MIT restrictions. It is anticipated that MIT restrictions will be placed on flights only flying the TFM-designated routes, not, for example as is done today, on all traffic heading for a particular airspace boundary.
- The IIAT is envisioned to evaluate the impact of MIT restrictions along these routes.
- Analogous to the idea of airspace users managing GDP-allocated arrival slots at an airport, this scenario introduces the notion of time "slots" at en route resources called *metered entry points* on a TFM-designated route; these slots are allocated by the integrated impact assessment tool in the form of a time-at-metered-entry-point. When it is required to fly the TFM-designated route and when MIT restrictions are in place, the airspace user decides which of its flights to assign to a time-at-metered-entry-point, based on its business needs that day.
- The IIAT is envisioned to be able to calculate the times-at-metered-entry-point, the new arrival time at the airport, and the departure time of each affected flight.
- The IIAT evaluates the impact of one strategy at a time, considering all existing or planned strategies as constraints to the subject strategy. The order in which strategies are evaluated is important.

Section 4

Next Steps

A need has been shown to explore the concept of an automation capability to help traffic managers evaluate the impact of proposed TFM strategies on traffic in the NAS. For example, the capability would help answer questions such as the following:

- Would an increase in MIT restriction on this route cause an unacceptable demand-capacity imbalance elsewhere in the NAS?
- How much of a restriction would be sufficient?
- Is this strategy going to work?

As the next steps, it is recommended that additional research be conducted on the following topics.

4.1 Metrics

One product of the IIAT is a set of values calculated for the metrics, defined by traffic managers, indicating the impact of a TFM strategy on the NAS. A sample of possible metrics is shown in Table 3-1. Additional research in these metrics is of the highest priority, including the following activities:

- Identify useful metrics
- Identify the factors that comprise each metric
- Determine how the metric is calculated
- Validate the usefulness of the metric

4.2 Impact Evaluation Order

The order in which strategies are evaluated by IIAT affects the outcome. In the scenario, it is suggested that the evaluation of a strategy is constrained by the outcomes of planned or existing strategies. Research should be conducted to answer the following questions:

- How do traffic managers determine which is the more important problem to solve? For example, diminished arrival rate at a pacing airport versus diminished capacity in en route airspace through which traffic flows are heavy?
- How do traffic managers compromise on a solution? What does that compromise mean in how IIAT should work?

- What factors contribute to the order in which the IIAT should evaluate strategies? For example, strategy for the most certain problem first versus strategy for the most important problem?

4.3 National vs. Local TFM Responsibilities

One assumption made for the scenario is that the IIAT is available at the local TFM facilities as well as at the national TFM facility, the Command Center. What should be the division of responsibility between local and national TFM facilities when the IIAT is available? For example, the scenario suggests that the Command Center uses the tool to evaluate strategies whose implementation affects more than one en route center. Furthermore, TMUs can offer suggestions to the Command Center, including using the IIAT to evaluate local impact. Is this division of responsibility acceptable?

4.4 Feasibility of TFM-Designated Routes in Managing Traffic Flows Around Constrained Airspace

Although organized route structures are used routinely in some oceanic airspaces today, many issues need to be addressed to determine feasibility of an organized route structure for CONUS traffic in a time frame where the principles of Free Flight are operating. These issues include the following:

- Is it acceptable to airspace users and to traffic managers that flights to certain destinations or in certain airspaces be *required* to fly on the organized route structure, called in this paper "TFM-designated routes"? If not, how much Free Flight would be allowable in and around those airspaces?
- Under what conditions is using original route structures acceptable?
- Once a strategy involving TFM-designated routes is in place, how and when should the routes cease being used?
- How many TFM-designated routes are necessary and sufficient to accomplish the TFM objectives of the day?
- How is the location of a TFM-designated route determined?
- How feasible is the idea of metered entry points?
- How many metered entry points are necessary and sufficient to maintain an orderly flow of traffic at close to capacity?
- How is the location of a metered entry point determined?
- What is the right algorithm to match a flight's route with the a TFM-designated route?

- What should be the procedures for changing altitudes once on a TFM-designated route?
- Once TFM-designated routes are established, under what conditions would a secondary route structure be needed to safely carry traffic to a metered entry point?
- How should such secondary route structures be established?

4.5 Preliminary Estimate of Operational and Economic Benefits

Completion of a strawman operational concept will allow for more focused discussions on how both the FAA and airspace users could benefit from the capability defined in this report. Inputs from traffic management specialists on both the local and national level, as well as from the airspace user community, will be needed to obtain the qualitative estimate of benefits expected from the CE phase.

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Appendix

Capability Development Priority

The scenario presented in Section 3 identifies several tasks performed by an integrated impact assessment tool. Assuming that this tool would be developed in different stages, Table A-1 suggests priorities in capability development, based on the traffic management specialists' ability to perform these tasks today, or on the relative degree of difficulty in implementing a capability.

Table A-1. Capability Development Priority

Capability	Input	Output	Priority in Development	
			Initial version	Advanced version
Generate FCAs	Weather forecasts	Time-series of FCAs		x
Estimate sector capacity	Weather forecasts Other airspace constraint information, such as SUA schedules	Sector capacity		x
Develop route restriction • Identify TFM-designated routes • Identify metered entry points • Identify altitude restrictions, if any	TFM objectives, translated into rules Flight intent information for all flights in NAS	TFM-designated routes Metered entry points		x

Evaluate impact of a single TFM strategy when other TFM strategies are in place or will be implemented	Parameters of other existing or planned TFM initiatives, stated as constraints to this strategy Parameters of this restriction	Impact metric values		
• Ground stop			x	
• TFM-designated route				x
• MIT restriction			x	
Evaluate impact of multiple TFM strategies	Parameters of each restriction	Impact metric values		x
Evaluate impact of other TFM strategies than ground stop, TFM-designated route, and MIT restrictions	TBD	Impact metric values		x
Calculate time-at-metered-entry-point	Flight intent information MIT restriction or route rate information	Time at metered entry point		x
Calculate revised departure time	Flight intent information Time at metered entry point or time of arrival at airport	Time of departure		x
Calculate revised time of arrival	Flight intent information	Time of arrival at airport		x
Evaluate impact of a replanned flight or a rerouted flight[8]	Parameters of other existing or planned TFM initiatives Flight intent	Impact metric values	x	

[8] Development of a new route, time of departure, or time of arrival are done by the airspace user's in-house software which optimizes according to the user's objectives.

Glossary

AOC	Aeronautical Operational Control
ATC	Air Traffic Control
ATL	William B. Hartsfield Atlanta International Airport
ATM	Air Traffic Management
CAASD	Center for Advanced Aviation System Development
CBA	Cost/Benefit Analysis
CCFP	Collaborative Convective Forecast Product
CD	Concept Development
CE	Concept Exploration
CONUS	Contiguous United States
CRCT	Collaborative Routing Coordination Tool
CTA	Controlled Time of Arrival
CVG	Greater Cincinnati International Airport
EWR	Newark International Airport
FAA	Federal Aviation Administration
FCA	Flow Constrained Area
FSM	Flight Schedule Monitor
FY	fiscal year
GDP	Ground Delay Program
IAD	Washington Dulles International Airport
IIAT	Integrated Impact Assessment Tool
LAX	Los Angeles International Airport
MCI	Kansas City International Airport
MIT	Miles in Trail
NAS	National Airspace System
OKC	Oklahoma City Will Rogers World Airport
ORD	Chicago O'Hare International Airport
SAN	San Diego International Lindberg Field Airport
STL	Lambert St. Louis International Airport
SUA	Special Use Airspace
SWAP	Severe Weather Avoidance Program
TBD	to be determined
TFM	Traffic Flow Management
TMU	Traffic Management Unit
TUL	Tulsa International Airport

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