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MITRE TECHNICAL REPORT

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Abstract

Collaborative decision making between air traffic service providers and National Airspace System users has been identified as a primary feature of the future air traffic system. This document presents a concept for traffic flow management (TFM) operations in a collaborative environment in the year 2005. This concept is intended to help identify supporting procedures and automation capabilities that must be in place to support a collaborative environment. The approach taken in this document is to identify major situations that call for TFM intervention in today's system and to describe how these situations will be managed in 2005.

KEYWORDS: traffic flow management, traffic management, collaboration, collaborative decision making, information exchange, Free Flight

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Section 1

Introduction

This document presents a concept for traffic flow management (TFM) operations in a collaborative environment for the year 2005. RTCA Task Force 3 on Free Flight Implementation has identified collaborative decision making between air traffic service providers and National Airspace System (NAS) users as a primary feature of the future air traffic system. A collaborative environment gives NAS users greater operational flexibility and better access to NAS resources. The RTCA report identifies the need for development of and community-wide agreement on detailed Air Traffic Management (ATM) concepts of operations. (RTCA, Inc., 1995)

The concept of operations for TFM presented in this document is intended to identify supporting procedures and automation capabilities that must be in place to create a collaborative environment. Therefore, it has not been constrained by systems now available or under development. However, for the concept to be viable, it must be constrained by what can feasibly be developed in the available time. In some cases, this includes completion of capabilities for which development is already in progress.

The TFM concept of operations is one part of a larger effort to develop a system-level concept of operations for the NAS. The Air Traffic Operations (ATO) branch of the Federal Aviation Administration (FAA) has published a draft, high-level document that outlines its vision for all NAS operations in 2005 (FAA, 1997). That document, written from a service-provider perspective, is part of an effort to develop consensus between NAS users and the FAA on the shape of the evolving system. The RTCA Select Committee on Free Flight Implementation has developed a similar document emphasizing the NAS user perspective. The RTCA document has been published as a joint government and industry concept (RTCA, Inc., 1997a).

These high-level documents can guide system development effectively only after the concept developers describe many details and resolve many issues that short descriptions must necessarily omit. One step in adding more detail is to prepare scenarios and to describe how concepts outlined in the high-level documents would be implemented in the specific situations envisioned in the scenarios.

It is the purpose of this document to provide more details about TFM operations in 2005, using scenarios to illustrate the system-level view. It discusses how traffic management personnel at local facilities[1] and at the Air Traffic Control System Command Center (ATCSCC), or Command Center, work together and collaborate with users to resolve problems, such as extended reduced airspace capacity caused by weather, or to develop strategies to alleviate the excess demand during extended instrument arrival operations at a major airport.

The Center for Advanced Aviation System Development (CAASD) began work in 1997 on a TFM concept for 2005, as tasked by the FAA, and produced previous versions of this document (Toma *et al.*, 1997a; Toma *et al.*, 1997b; Toma *et al.*, 1998), which were used primarily for coordination purposes. This version reflects extensive feedback from both FAA operational personnel and NAS users on ideas presented in earlier versions. It remains a working document in that the TFM concept of operations is expected to continue evolving.

1.1 Purpose

This working document is intended to communicate information valuable to those defining requirements and developing the architecture of the communications, information, and automation support for the TFM elements of the NAS concept of operations for 2005. System developers should view this document as an opportunity to note the kind of issues under examination and to call out any important omissions. Air traffic service providers and NAS users should view it as an opportunity to ensure that details and feasibility constraints added to the TFM concept of operations are consistent with their high-level concept.

1.2 Scope

The focus of the concept described in this document is on collaboration between traffic management personnel and NAS users in 2005. This concept description does not include required coordination and information exchange between traffic management personnel and air traffic control personnel. In support of the Air Traffic Management team (AUA-500) in the FAA's Office of Air Traffic Systems Development and ATO, CAASD is conducting lab and field evaluations to establish a set of capabilities and procedures to improve this information exchange and coordination process.

1.3 Organization

Section 2 of this document provides background information, including a discussion of the benefits of collaboration, the goals that this concept of operations is intended to meet, and general roles and responsibilities. Section 3 describes the overall concept of operations. A

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[1] In this document, a local facility is defined as an individual FAA facility with responsibility for air traffic operations in their airspace. A local facility can be an en route center, a terminal radar control, or an air traffic control tower.

general discussion at the beginning of the section is followed by discussions of situations requiring TFM initiatives, with scenarios to illustrate application of the concept to those situations in more detail. A number of capabilities are assumed in Section 3; these capabilities are summarized in Section 4. Finally, Section 5 identifies issues that need further analysis.

Section 2

Operational Context

2.1 Background

When demand for a NAS resource is expected to exceed its capacity, traffic management personnel at local facilities, known as Traffic Management Coordinators (TMCs), and Traffic Management Specialists (TMSs) at the Command Center consider various strategies to manage the flow problem. Today, traffic flow management personnel are increasingly coordinating with NAS users in selecting and implementing strategies. In 2005, collaboration between traffic management personnel and NAS users is more commonplace. Collaboration can occur among TMCs, TMSs, and staff at Aeronautical Operational Controls (AOCs), or combinations of participants.

Information exchange and collaboration ensure that participants' separate sets of objectives are considered, and provide more information and greater range of experience to the decision process. Therefore, information exchange and collaboration have benefits for both NAS users and traffic management personnel. Sharing information about airspace constraints with NAS users, and giving them the opportunity to plan their operations accordingly, could potentially reduce the intervention of traffic management personnel in resolving flow problems. When traffic management intervention is necessary, active participation by NAS users (through AOCs) could help shape flow strategies that are fair, more efficient, and more cost effective to the users' overall operation. It must be noted, however, that while collaboration is the norm for TFM strategy development, it is not appropriate or even possible in all cases. The degree and type of collaboration vary according to the problem to be resolved, the lead time, the relevance of the potential strategy to users, and other factors.

In 2005, several changes in procedures, system infrastructure, and decision support capabilities change the way flow problems are resolved. The following are the expected changes.

- An improved infrastructure allows NAS users and air traffic service providers responsible for air traffic control (ATC) and TFM to share timely and operationally significant information. This information, particularly user preferences (e.g., flight priority), is used by traffic management personnel when developing flow strategies.
- Traffic management personnel have improved capabilities to predict the time and location of congestion and the impact of flow strategies on the NAS. Traffic management personnel use this capability together with the more accurate information to determine the most effective flow strategy.

- Traffic management personnel have access to tools that help them to better visualize areas of current and predicted hazardous weather. They use this information to better determine capacity implications for the affected NAS resources and to provide options to NAS users for avoiding the affected resources.
- Capabilities and procedures are defined and implemented to improve collaboration among FAA facilities.
- Where practical, traffic management personnel and NAS users jointly develop strategies to resolve flow problems.

2.2 Operational Goals

This concept of operations is based on the following goals: Improve traffic flow, support NAS users' operational objectives by allowing more Free Scheduling and Free Routing (two Free Flight principles), and promote NAS safety objectives. These goals were established by consensus between government and industry and are cited, for example, by RTCA in its development of a concept of operations from the NAS users' perspective (RTCA, Inc., 1997b).

Improve Traffic Flow

Collaboration improves the efficiency of traffic flows by making timely and accurate information available to decision makers. This information improves the predictability of the NAS and the reliability of these predictions. During the times of reduced capacity, information exchange together with shared decision making results in fair and reasonable solutions from the perspectives of both NAS users and traffic management personnel.

In 2005, data on NAS operations is collected and archived for post-operation analyses. These analyses enable traffic management personnel to redefine their future flow strategies if necessary, hence resulting in more efficient operations.

Support NAS Users' Objectives

Better information and active participation in decision making ensure that NAS users' objectives are taken into consideration when resolving flow problems. Decisions maintain, to the extent possible, the users' preferences in routing and schedules. Because NAS users' preferences have been taken into consideration, the resulting solutions are more cost-effective for the users than today's TFM solutions.

Promote NAS Safety Objectives

Although individual TFM actions and capabilities are not safety-critical, TFM has an important safety role in preventing situations in which controllers become overloaded, which would compromise their ability to maintain separation. Collaboration gives both traffic management personnel and NAS users better information to aid them in avoiding situations where there is potential for unsafe operations. For example, when NAS users share their most up-to-date schedules with ATM, the results of the improved traffic prediction tool are more accurate. Where congestion is predicted, the information can then be distributed to NAS users. They, in turn, may modify their schedules or routes of flight to avoid the congested resources to the extent possible. This could reduce the burden on TFM, allowing it to perform its safety role more effectively without sacrificing its other goals.

2.3 Roles and Responsibilities

To achieve the above goals, the roles and responsibilities of the operational staff must evolve. This section briefly discusses roles and responsibilities from a high-level perspective.

In general, traffic management personnel have the responsibility to manage NAS resources, while the NAS users have the responsibility to manage their own operations. Traffic management personnel must monitor the NAS, must make any constraints known to the users, and in cooperation with users must develop solutions to those constraints. In a complimentary manner, the NAS users must inform TFM of their operational demand and intent and must operate within the solutions when the system is constrained. NAS users also have the option (when time permits) of participating in the development of solutions. Through this information exchange and collaboration, TFM can improve their management of NAS resources, thereby improving access for all NAS users.

In this operational concept, the Command Center retains its current role as the overall manager of TFM.

- For large-scale TFM situations with national impact, the Command Center is the lead facility, managing all aspects of resolving the situation.
- For smaller situations, the Command Center facilitates coordination among local facilities, reviews analyses of flow situations performed at the local level and the recommended strategies, and serves as the final arbiter if discussion among local facilities fails to reach a mutually acceptable means of handling the situation.
- For situations that affect only one local facility, the Command Center remains cognizant of the situations, reviews TMC decisions for managing them, and monitors national effects of the local actions.
- In all situations, the Command Center is the primary point of contact for AOCs.

TMCs apply their expertise and knowledge of local conditions in managing traffic flow situations within their own airspace. They are responsible for the following activities:

- Monitoring demand and capacity within their own facility
- Planning small-scale initiatives as necessary with Command Center cognizance

- Initiating collaboration among facilities and with the Command Center when a problem or its resolution extends beyond the borders of their own facility
- Contributing knowledge of local conditions and analysis of local effects to the management of large-scale situations with national impact
- Communicating all TFM initiatives, regardless of scale, to the controllers responsible for implementing those initiatives

AOC staff[2] manage their own operations while choosing their own level of participation in developing solutions when a TFM situation constrains NAS operations.

- They may support planning for flights affected by flow problems. For instance, an AOC collaborating on resolving a situation has the opportunity to provide input on the flow strategies to be evaluated and, eventually, implemented.
- They may share weather information with TMCs or Command Center staff, especially if their information sources differ.
- They may discuss their conclusions regarding the consequences of a flow problem on actual operations.
- They implement solutions that meet their operational objectives while operating within the constraints of the NAS.

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2 AOC operations described in this document are typical for a large AOC. At smaller AOCs, functions may be combined and some tasks may be performed manually or by an affiliated partner or service provider. References to air carrier concerns obviously do not apply to AOCs providing flight planning service to general aviation (GA) pilots.

Section 3

Description of the Concept of Operations

3.1 High-Level Description of Collaborative TFM

Collaborative TFM is characterized by information sharing and shared system management between FAA and NAS users. Information exchange, on its own, improves decisions made by both traffic management personnel and NAS users since more, better, and up-to-date information is available. Information exchange moves the current operational paradigm toward the Free Scheduling and Free Routing principles of Free Flight (RTCA, Inc., 1997b). NAS users also participate in system management either by collaborating in development of flow strategies, by taking action to meet the flow initiatives proposed by traffic management personnel, or by modifying their operations to reduce their demand on NAS resources without initiatives proposed by TFM. The latter only occurs when NAS users perceive this action as beneficial to their overall operational objectives.

If a NAS resource is predicted to become congested and NAS users' individual initiatives do not resolve the capacity problem, traffic management personnel are responsible for resolving the problem. When restrictions are necessary, they have capabilities in hand to identify and implement those strategies that constrain demand only enough to resolve the problem.

In general, this TFM concept of operations assumes that information exchange is the norm. Infrastructure support exists to accommodate timely and accurate sharing of operationally significant information. Traffic management personnel have access to and provide information on the status of NAS resources, and notify NAS users of conditions requiring TFM involvement. NAS users provide information regarding their intent and preferences by providing their daily operating schedule and other pertinent information to ATM. Based on the information provided by the NAS users, the Command Center automation determines the expected aggregate demand for NAS resources, and makes this information available to all NAS users. If demand at any NAS resource is expected to exceed its capacity, automation makes this information available to NAS users and ATM facilities.

If demand for a resource, for example an airport, is predicted to exceed its capacity, and there is sufficient lead time, the traffic management personnel responsible for managing the situation can elect to invite AOCs to participate in flow strategy development (collaborative decision making). Alternatively, the traffic management personnel can select appropriate strategies and notify NAS users of the impending flow strategies so that the NAS users can adjust their operations to meet the flow restrictions (information sharing).

3.2 Flow Problem Resolution Process

Any problem resolution requires the following three-step process:

- Problem identification
- Strategy evaluation and selection
- Strategy implementation

Flow problems are no exception from this process. The next sections describe how this process can be applied to resolving flow problems.

3.2.1 Problem Identification

Traffic management personnel monitor airspace for conditions that can result in constraints to NAS operations, such as developing severe weather, runway closures, and changes in winds aloft (which can affect traffic patterns). Improved weather prediction capabilities, such as predicting movement and tops of storms, and availability of the NAS Information System[3] provide for more reliable and accurate weather forecast and distribution of information among FAA facilities. More importantly, because NAS users, particularly AOCs, are providing accurate and up-to-date information on their schedules and preferences, results of the TFM decision support capabilities have the basis for accurate problem prediction and situation assessment. This application of user-supplied information in TFM decision support tools enables better decision making. (These capabilities are discussed in Section 4.) Furthermore, problems are identified earlier, giving more time for traffic management personnel and AOCs to develop and implement efficient flow initiatives that alleviate the problem.

Traffic management personnel consider available information (for example, demand as represented by the initial daily operating schedule, resource capacities, current and forecast weather conditions throughout the NAS) to identify situations that can have significant impacts on traffic flow in the NAS. The updated weather forecast, together with reflectivity data and lightning strike data, helps them anticipate the effects on traffic flow over time. Furthermore, better information on NAS users' schedules and more detailed flight plans allow TFM's traffic congestion prediction capabilities to provide both quantitative and qualitative (for example, a graphical display of traffic density over time) information useful for characterizing flow problems.

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[3] In this document, "NAS Information System" is used as a generic name for a capability (described in Section 4) that is referred to by a variety of names, including "NAS-Wide Information System" (FAA, 1997).

NAS users can use their own capabilities concurrently to identify a developing situation before it becomes severe enough to have significant operational impact. An example of a developing situation that NAS users can identify is loss of capacity due to severe weather. With other capacity and aggregate demand information, they may also be able to identify potential congestion problems. Depending on the lead time (i.e., how long before the situation is to develop), accuracy, and expected benefit to their operations, NAS users may decide to develop contingency plans for their own use. Examples of these plans include adjustments to schedules or reroutes of airborne flights. No actual changes to operations are required until TFM notifies all NAS users of the need to implement flow initiatives to resolve an expected problem.

Traffic management personnel are primarily concerned with maintaining the manageability of the traffic in the locations affected by a developing situation and with the effects of flow management strategies on the NAS. It is important to understand the magnitude of the situation, which requires identifying the number of flights that can be affected by the problem. If the problem is located at an airport, NAS users' schedules identify affected flights. If, however, the problem is located in en route airspace, it is necessary to define the volume of airspace with reduced capacity, and to identify the flights that plan to go through this airspace.

3.2.2 Strategy Evaluation and Selection

When demand is expected to exceed capacity, traffic management personnel propose possible strategies for resolving the problem. Depending on the problem being resolved, different strategies or combinations of strategies can be considered. Examples of strategies available to traffic management personnel are aircraft reroutes and altitude changes, airborne holding, ground holds, capacity control programs, miles-in-trail (MIT) restrictions, imposition or modification of route structure near a terminal, and airspace resectorization.

When airspace resectorization can resolve a problem, it has the advantage of being transparent to NAS users. In 2005, the most common airspace resectorization continues to be the combining and de-combining of predefined sectors as it is done today. Whether dynamic resectorization, which goes beyond combining and de-combining sectors, is available in 2005 remains an issue, discussed in Section 5.5.

When resectorization cannot resolve a problem, it is necessary to constrain traffic. If the situation is confined to one center, the normal sequence is for the local TMC to define the airspace where traffic must be constrained and to contact and coordinate with the Command Center. With Command Center cognizance and approval, the local TMC can then contact affected AOCs (time permitting) and other facilities affected by the proposed flow strategy. Problems affecting more than one center must be defined jointly by the affected facilities and the Command Center. Depending on the scale of the problem, discussion may be initiated by one of the affected TMCs or by a TMS at the Command Center. Time permitting, AOCs are notified of the scheduled visual collaboration. NAS users represented by AOCs submit their preferences through the AOCs. Otherwise, NAS users receive information about the expected situation, such as location or cause, via the NAS Information System.

When NAS users identify potential flow problems, they may find it operationally beneficial to modify their operations, taking actions that reduce their individual demand on NAS resources to mitigate the congestion. NAS users provide their schedule modifications to ATM via secure communications. Furthermore, NAS users can propose flight plan changes for airborne flights. TFM automation uses this information to update aggregate demand for the affected resources. This information is available to traffic management personnel, to evaluate various flow strategies if demand is still expected to exceed capacity.

Traffic management personnel consider the effectiveness of each strategy or combination of strategies in resolving the flow problem. Additionally, traffic management personnel assess the proposed strategies according to the following criteria:

- The potential traffic volume and density resulting from the strategy, both internal to the center as well as in adjacent centers' airspace (i.e., an assessment of the effects of the strategy on adjacent centers' airspace)
- The burden the strategy levies on the NAS users (for example, in terms of extra distance flown, or total delays in the system)
- The resulting complexity of operations

Strategies affecting neighboring facilities are coordinated with the TMCs of those facilities. The Command Center continues to facilitate inter-facility discussions, but arbitration of differences should rarely be needed because strategy evaluation results and post-analysis of historical data should indicate whether a particular restriction is the minimum necessary to meet operational goals. The results of strategy evaluations are made available to the participants in the collaboration as well as to other NAS users. Making evaluation results available provides a common view of the effects of each strategy evaluated. When the lead time is sufficient, AOCs may submit their preferred strategies to the facility in charge of resolving the problem. If evaluation shows a user-generated strategy to be acceptable and equitable (that is, does not provide unfair advantage to one AOC), this strategy is implemented. Using the evaluation results, a strategy or combination of strategies is selected that resolves the problem with minimum system impact.

The selected strategy or strategies, referred to collectively as the flow initiative proposal, is published on the NAS Information System with additional information, such as a list of flights affected by each flow strategy, the time at which each flow strategy is expected to be implemented, and the duration of each flow strategy. NAS users with sufficient notice may decide to alter their operations to minimize the consequences of any TFM action. For flights with operational constraints that require special handling, such as low fuel or crew legality, NAS users may also verbally coordinate alternatives to a strategy with TFM. As new information is received from NAS users on their intent, traffic management personnel modify the strategies if necessary.

While traffic management personnel are evaluating strategies and selecting a flow initiative, they continue to monitor the current and expected demand for the affected NAS resource.

3.2.3 Implementation

In some cases, NAS users may use the information conveyed by TFM to modify their schedules or routes of flights based on their unique objectives and priorities. Where TMCs must generate flight plan amendments (for example, for non-participating flights[4]) as part of the solution, they are submitted automatically to NAS automation for communication to the controllers in charge of the affected sectors. The controllers deliver new clearances to the affected flights. New routes, altitudes, or speeds specified in an amendment received from the TMC or from a NAS user may create conflicts. The controller remains responsible for identifying and resolving any conflicts and placing the flight in compliance with the approved flow strategy as soon as practical.

3.3 Daily Operations and Situations Requiring TFM Involvement

During daily operations, both traffic management personnel and NAS users are continuously engaged in planning, monitoring, and analysis. In the course of these activities, they identify any situations requiring TFM involvement.

The first section illustrates the interaction between traffic management personnel and NAS users, particularly AOCs, during daily operations of planning, monitoring, and analyzing TFM performance. The remaining sections describe their interactions when the following situations requiring intervention by traffic management personnel arise:

- Large-scale severe weather
- Reduced capacity at airports
- Localized line of severe thunderstorms
- Dynamic weather
- Predicted congestion without weather constraints
- Routine excess demand

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4 Non-participating flights are either flights whose AOCs have chosen not to participate in the collaboration or flights that are not equipped to participate (e.g., most GA).

- TFM in oceanic operations

Each subsection describes how information exchange and NAS users' responses to flow strategies help in alleviating capacity constraints.

3.3.1 Planning, Monitoring, and Analysis

Operations planning for the day involves an iterative set of activities by traffic management personnel and AOC staff. TFM uses initial daily operating schedules from AOCs (as well as historical data) to determine resource demand. Initial resource status (for example, of a Navigational Aid [NAVAID] or a Special Use Airspace [SUA]) and other factors, such as weather, are used to determine resource capacity. The NAS Information System is updated and is used by NAS users to refine their planning. As NAS users provide updated schedule information, and later flight plans, TFM automation calculates and provides more accurate demand information. Similarly, more accurate capacity information is calculated when updated information on status and other factors is received. In turn, this may lead to adjustments to NAS user plans. Eventually, a TFM comparison of resource demand and capacity indicates areas that may require traffic management strategies if users do not adjust their demand (FAA, 1993). The following describes in more detail the actions summarized above.

3.3.1.1 Daily Planning

Early in the day, AOC personnel typically review the maintenance and operational status of their fleets, adjusting their schedules based on aircraft availability and anticipated delays in completing planned maintenance. Dispatchers coordinate changes to routings where originally scheduled aircraft are not able to complete their series of flights. Crew scheduling and tracking specialists provide status reports on the availability of reserve or standby crews, possibly leading to further adjustments to the schedule. Dispatchers consult the NAS Information System to determine possible constraints and restrictions that may affect their schedules, including projected delays and congestion based on preliminary schedule information. Meteorologists brief expected weather conditions en route and at the air carrier's key airports. An initial operating schedule for the day is sent to the NAS Information System, replacing the air carrier's previous data, and the flight planning process begins (ADF, 1995).

At the same time, traffic management personnel review the initial estimates of resource demand as a function of time, based on advance schedule data and historic unscheduled flight data, as updated with air carriers' initial daily operating schedules and with flight plans that have already been filed. Upper-air wind forecasts and historical data are used to predict requested flight paths between city pairs, leading to more accurate fix and sector demand estimates. Traffic management personnel update the NAS Information System with the current and forecast status of NAS resources and other factors known to them. For example, local facilities provide equipment status, runway availability, and noise abatement procedures for the current flight day. TFM also coordinates the availability of SUAs for public access, including their schedules or time in use and affected altitudes. Initial capacity information is derived using the updated information on NAS resource status and conditions. Capacities are determined as a function of time for airport arrivals and departures; and for routes, fixes, and airspace volumes. The updated demand and capacity information is placed in the NAS Information System.

NAS users normally calculate flight plans one to six hours prior to flight departure using either their own system or that of a service provider. Tasks involved include:

- Determining payload and coordinating with load planners for weight and balance calculations
- Selecting alternate airports (if necessary)
- Selecting route, speed, altitude profile, and estimating flight time
- Selecting en route alternates (as required)
- Calculating fuel requirements and coordinating with fuel loaders

Databases used may contain aircraft performance characteristics, weather, and regulations governing fuel requirements, as well as proprietary company policies and information such as fuel costs at various airports. Before a final flight plan is selected, the flight planning software may be used to analyze a variety of routes, altitudes, and scenarios, including determining whether the flight would encounter any NAS restrictions known at the time. Restrictions include active SUAs, agreements between facilities about crossing altitudes and speed, MIT restrictions, and system outages. A notification that some restriction is encountered does not prevent the NAS user from filing the flight plan. Likewise, a notification that the flight will encounter no restrictions does not guarantee that conditions will not change before departure time. The AOC supplies the pilot with a full flight plan including departure times, weather data, waypoint data (including waypoint names, locations, time at waypoint, fuel at waypoint, etc.) and altitude-speed profiles. An enhanced flight plan filed with the appropriate en route center includes information about user preferences (for example, climb profile, preferred departure runway and departure speed).

TFM’s initial comparison of predicted resource demand and capacity over time identifies potential situations requiring flow initiatives; for example, airport or sector demand significantly greater than capacity for an extended period. These situations, along with anticipated consequences (for example, projected delays and congestion) are input to the NAS Information System. Demand-capacity monitoring is an ongoing process to improve predictions with time as better data is received. For example, demand estimates improve as the initial daily operating schedule is updated, and improve more as the schedule is replaced by flight plans. Capacity estimates are improved as winds aloft and hazardous weather forecast data improve during the day . As users modify their plans to avoid resources at times of predicted excess congestion or delay, the number of situations that may require action decrease.

Once a situation requiring TFM involvement is identified, traffic management personnel and AOCs work together to develop, evaluate, and implement flow strategies that resolve the situation. For selected situations, these activities are described in Sections 3.3.2 through 3.3.8.

3.3.1.2 Strategy Monitoring

Once a traffic management strategy has been implemented, its progress is monitored. This involves several processes: determining whether the conditions requiring the strategy are continuing to develop as predicted, determining whether the effects of the strategy are developing as predicted, and maintaining a common situational awareness among participants.

Strategy monitoring continuously assesses the underlying conditions leading to the situation that required the TFM strategy. If these conditions change (for example, weather moves in more quickly than predicted) everything may be reexamined, including the need for the strategy. In some cases, only a modification to various parameters of the strategy may be necessary; for example the amount of delay or the metering rate required. In other cases, the strategy may be terminated and another one implemented. Of course, the phasing of such changes must take into account the effects on flights already committed to the previous strategy. The required monitoring process involves the same activities that determine the need for a strategy in the first place.

To determine whether the effects of a strategy are developing as predicted, traffic management personnel use the same strategy evaluation tool that they used in selecting that strategy. Comparing their estimate of the strategy's impact (for example, delays or other measures) to the current values of those measures lets them monitor the effect of the strategy. If the measures are significantly worse than predicted, a change in strategy may be necessary. Eventually, if no change is necessary, the actual impacts are measured and the results are used to refine future decision making.

3.3.1.3 Post-Operations Analysis

After the day's activities have ended, they are reviewed to determine how well the NAS performed. Because performance measures must be evaluated relative to the conditions that existed, data are kept for previous bad-weather days, as well as for clear days. A baseline is established for clear-weather days, and subsequent clear-weather days are evaluated against it. Comparison with data from similar previous days allows aspects of the NAS that performed particularly poorly to be detected. Such comparison may also reveal some aspects that performed better than expected, and analyzing these is also important to better understand system operations.

Baselines are maintained for each facility, as well as for the NAS as a whole. This allows each facility's TMCs to evaluate whether the strategy performed as expected. For example, a strategy may have been planned with a certain sector's capacity at 25. In the post-analysis, it may be discovered that demand did not exceed 20. The TMC may conclude that the strategy was more restrictive than necessary, and will consider this in dealing with a similar situation in the future.

Areas to investigate may come to light in several ways. For example, strategy monitoring during the day may have shown some strategies performing unsatisfactorily, but there was not enough lead time to make significant changes at the time. Also, statistics and performance measures computed using data recorded in the NAS Information System may indicate problems not noted at the time. A wide variety of performance measures are available for analysis, including delays, sector and fix usage, flight progress, airport operations, arrivals, and departures, as well as measures of access, predictability, and flexibility. NAS users provide to TFM their own assessment of items of significance to them.

Review of data recorded in the NAS Information System allows identifying activities that give insight into the sequence of events leading up to the observed results. When significant events have been identified, traffic management personnel use the strategy evaluation capability to test the effect of alternative strategies, such as different reroutes, metering rates, or airspace configuration. They also conduct long-term planning and analysis to develop, refine, and validate performance indicators.

3.3.2 Large-Scale Severe Weather

Large-scale severe weather, such as thunderstorms and snowstorms across a large portion of the NAS, can have significant impact on air traffic operations and may require TFM intervention. On the East Coast, for instance, afternoon thunderstorms are a common occurrence during the summer, and they can extend across several states. When this type of situation is predicted, the Command Center has the primary responsibility in contacting affected en route centers and AOCs to negotiate the most efficient flow initiative.

The Command Center conducts "planning" conference calls with other FAA facilities and AOCs during thunderstorm season. These conference calls are held as early in the day as possible to provide information on potential capacity constraints and flow strategies to AOCs. During the conference call, the participants discuss the expected situation and any differences between weather forecasts available to AOCs and FAA facilities. AOC representatives for these conference calls inform the Command Center of their preferred flow strategies at this time although the expected situation is several hours away. The purpose of providing this information is to ensure that traffic management personnel are aware of the user preferences if it becomes necessary to implement strategies to alleviate the capacity problem. AOCs have the option to contact the Command Center to suggest other strategies as they receive better information on weather and its impact on capacity.

The development of flow strategies is led by the Command Center. The TMS informs AOCs of the time of the inter-FAA facility conference. At the specified time, the TMS initiates the conference among the affected facilities. This conference uses a visual collaboration capability to share common views of the situation and of strategy evaluation results. Since AOCs were able to voice their preferences during the morning conference call and throughout the day, they are not active participants in this conference but might listen in.

Depending on the current and predicted location, the time, and the duration of the storm, different strategies are considered and evaluated. For example, if the severe weather is expected to affect a major airport, traffic management personnel consider implementing airborne holding, metering, ground holds at first tier airports, and alternate arrival and departure routes. If, on the other hand, the severe weather is predicted to affect high altitude sectors in en route centers, then potential strategies include reroutes and altitude changes. Traffic management personnel evaluate AOC- and TFM-proposed flow strategies. TMCs consult Area Supervisors in the en route centers prior to agreeing on a flow strategy. This is particularly important when reroutes are to be implemented. The strategy, or combination of strategies, with the best results with respect to the appropriate metrics (such as delays and traffic density) is selected.

The TMS makes available the selected strategy as the one that will go into effect if expected demand continues to exceed the expected capacity. The expected time and duration of the flow strategy are also distributed. At this time, NAS users might modify their schedules and flight plans to meet the flow strategy, drawing upon any earlier contingency planning. As new information is received from NAS users, the flow strategy can be modified. For example, the start time may be delayed, or its duration may be shortened.

When the severe weather materializes, the TMS activates the flow strategy if demand is still above capacity. Since Area Supervisors have been consulted during strategy development and have been informed of the selected strategy, they are able to accommodate the flow strategies. AOCs have the option to contact the Command Center to discuss any new information they might have received that could help in modifying the flow strategy to help them maintain their operations. For example, a dispatcher may receive information from one pilot about a gap in the line of thunderstorms. The AOC staff then contacts the Command Center and the TMC at the facility with a plan to fly as many of their flights as possible through this gap.

In the following scenario, severe weather is forecast for a large portion of the East Coast, affecting several major airports. The scenario describes the process of developing and implementing flow initiatives to avoid the predicted large-scale severe weather. This process is based on information exchange regarding constraints and user preferences. The second scenario describes TFM and AOC actions when severe weather impacts a large airspace in the Midwest, where there are more options for resolving the situation.

3.3.2.1 Large-Scale Severe Weather on the East Coast

It is a hot summer day on the East Coast. The weather forecast is for a low pressure system located over central Maine at 2000Z. A line of severe thunderstorms is expected to develop along a cold front from central Maine to Charlotte, North Carolina, reducing capacity at major airports along this line by approximately 1900Z. The line is expected to move off the coast by 2100Z.

Early in the morning, the Command Center conducts its planning conference call with all the TMCs and various AOCs. One of the topics discussed is the expected line of thunderstorms in mid-afternoon and possible strategies to accommodate the reduced capacity. Any disagreements regarding the forecast (for example start time, duration, speed) are discussed. AOC staff participating in this conference call take this opportunity to indicate their preferred flow strategies if implementing a flow strategy becomes necessary. Since the situation will not develop for several hours, no actions in terms of developing a flow initiative proposal are taken. Traffic management personnel plan to hold a second conference later in the afternoon to select flow strategies for implementation. In the meantime, TFM automation at the Command Center calculates initial aggregate demand information and makes it available to NAS users and other FAA facilities. This information is based on the initial daily operating schedule provided by AOCs and historical data. Aggregate demand information is updated as necessary when changes from NAS users are received throughout the day.

TMCs at en route centers (Boston, Cleveland, New York, and Washington) and at the terminal areas within these centers provide information on current and expected capacity of resources in their airspace. This information is based on the current and forecast weather, the status of resources such as runways, and SUA schedules.

At 1600Z, the TMS for the afternoon shift is briefed on the content of the morning conference call. This briefing includes the AOC-proposed flow strategies to be evaluated if conditions do not improve. The TMS reviews current and forecast weather. The weather forecast has been updated; the severe weather is now predicted to develop at 2000Z and move off the coast by the previously predicted time, 2100Z (a shorter duration for the thunderstorm activity). The geographical area affected is better defined at this time as well. This line of thunderstorms is expected to extend from Charlotte, North Carolina, to Presque Isle, Maine, and move east at 20 knots. The tops are expected to be between 35,000 and 45,000 feet.

AOC staff, as well as other NAS users, analyze the current and future weather forecast, monitor its progress over time, and consider demand and capacity information provided by TFM to determine the impact on their operations. Given the accuracy of the information and the expected impact on flight operations, AOCs may decide to contact the Command Center and discuss alternate or additional strategies to be considered during the anticipated strategy development conference. This is in addition to suggestions made during the morning planning conference call.

Two hours before the weather is expected to impact the East Coast, the TMS sends an electronic message to AOCs notifying them of an upcoming FAA inter-facility strategy development conference. The TMS contacts the appropriate TMCs to discuss strategies to resolve the expected congestion problems on the East Coast. Since most FAA facilities are equipped with a visual collaboration tool, it can be used to distribute the current and forecast weather, identify areas with reduced capacity and their expected demand, and show the available airspace for air traffic operations. TMCs are able to present any new information about the status of their resources, not yet distributed on the NAS Information System. Furthermore, they already have consulted with the Area Supervisors responsible for the affected airspace, discussing any constraints from the ATC perspective, such as staffing constraints. These constraints are also brought forward to make sure that TFM proposals are acceptable to air traffic control personnel. AOCs with appropriate automation capability have permission to "listen in" on the inter-facility discussion; they are able to see and hear the strategies being discussed but do not comment at this time.

TFM participants arrive at a consensus as to how much the storm will affect the capacity of various NAS resources, and therefore, air traffic operations (en route, terminal area, and airport capacity). They discuss various strategies (AOC-proposed, as well as those from TMCs and the TMS), and identify the volume of airspace the severe weather will affect. Capacity is expected to be between zero and fifty percent for the duration of the thunderstorms.

The TMCs use the traffic prediction tool to identify flights in their airspace that contribute to the excess demand. This information is pooled and used to determine the percentage contributed by each NAS user (different AOCs, general aviation, and military). This assists in determining how much of a reduction in demand is required of each NAS user to meet the capacity.

The TMS uses strategy evaluation tools to determine the effects of the suggested strategies. The evaluations consider combinations of strategies, as well as individual ones. The results of the strategy evaluations are shared with all participants (TMCs and AOCs). The combination of strategies that best meets NAS capacity constraints and AOC concerns is selected as the flow initiative proposal.

The flow initiative proposal consists of a combination of strategies: general reroutes (including altitude changes) for en route flights, pre-planned arrival and departure routes (i.e., today's Severe Weather Avoidance Program [SWAP] routes), and ground holds for departures from airports in the affected centers. The TMS makes these strategies available to all NAS users and FAA facilities through the NAS Information System, including the time each flow strategy will be implemented, its duration, and the airspace available for reroutes.

The TMS gives AOCs 30 minutes to propose new flight plans for their flights to alleviate the excess demand and accommodate the flow initiative proposal. AOCs have the option of calling the Command Center to discuss other strategies that may be more beneficial to their operations.

NAS users who have access to the NAS Information System are able to review the flow initiative proposal, identify their active and inactive flights that are affected by the initiative, and send proposed amendments to their flight plans or schedule to meet the capacity constraints. Proposed flight plan amendments are submitted to the ATM automation system.

If the Command Center does not receive a response from an AOC, then the TMC at the center is notified to create proposed flight plan amendments designed to comply with the flow initiative proposal. This is accomplished easily, via a graphic automation capability that draws the routes and creates proposed flight plan amendments for the flights. TMCs also create flight plan amendments for any other non-participating flights located in their facility airspace.

The TMS evaluates the proposed flight plans to determine their overall impact on traffic count and complexity of operations. Because of the planned reroutes, it is predicted that three Atlanta Center sectors will have excess demand. These problems are resolved by the Atlanta Center TMC with appropriate consultation (see the scenario described in Section 3.3.4). Since other aspects of the strategy are acceptable to all participants, the amendments can be implemented as soon as the TMS activates the flow initiative. When the weather conditions become severe enough, the TMS upgrades the flow initiative proposal to active status and updates the NAS Information System.

The TMS, TMCs, and AOCs monitor the weather conditions. Additionally, they monitor the NAS performance with regard to traffic flow and airport acceptance rates as affected by the storm. They assess how the system is acting as compared with expectations. If necessary, the active flow initiative is adjusted to maintain the highest throughput in the NAS while maintaining safety.

When the weather dissipates, the TMS cancels the active flow initiative. This cancellation is communicated to the NAS users and other ATM facilities through the NAS Information System.

3.3.2.2 Large-Scale Severe Weather in the Midwest

A low pressure area is located over north-central Iowa. A trailing cold front extends southward from the low through Kansas City, Missouri, to Tulsa, Oklahoma, and then westward to near Amarillo, Texas. A solid line of slow-moving Level 4, 5, and 6 thunderstorms, some with tops above flight level (FL) 450, extends from the low to Kansas City, Missouri. Along the cold front from Kansas City to Tulsa, Oklahoma, Level 4 and 5 thunderstorms have formed broken lines. West of Tulsa, the thunderstorms are scattered along the cold front.

The low is expected to move to a location between Green Bay and Milwaukee, Wisconsin, by 0015Z. The cold front will extend from the low to just west of Chicago, to St. Louis, Missouri, to Fort Smith, Arkansas, to near Lubbock, Texas. A solid line of Level 4, 5, and 6 thunderstorms are expected along the cold front from the low to a location between St. Louis and Fort Smith. West of this point, the line of thunderstorms will become broken to scattered, and decrease in severity to Level 4 and 5.

Since 0600Z, aircraft have avoided the line of thunderstorms by proceeding north of the low, navigating over southern Minnesota, or penetrating the broken line of thunderstorms over central Missouri. The National Weather Service (NWS) forecasts, weather radar data, pilot reports, and information supplied by controllers and AOCs indicate that as the day's traffic increases, there will be a need for TFM actions.

Early in the morning, the Command Center holds a conference call with all participants (TMCs, and various AOCs) to talk about the existing front and related storms. They discuss reroute options and generate lists of affected flights. Lists are generated for all filed flight plans, and are available over the NAS Information System, as well as via the visual collaboration tool. Although reroutes are discussed, none are assigned at this time. This allows AOCs to select and submit their preferred routes and make schedule changes as best fit their operations.

After the conference call, TFM and AOCs begin internal planning in response to it. AOCs have the option to submit flight plans based on their preferred routes, automatically updating the NAS Information System. TMCs, in coordination with Area Supervisors, use the updated flight plans to decide what reroutes may be needed due to expected reduced sector capacity. AOCs can also indicate to TFM which of their flights have higher operational priority (i.e., which flights need to adhere to their arrival times).

The AOC participants submit reroute plans and preferences to the Command Center via the NAS Information System. Also via the NAS Information System, TMCs have submitted expected capacities. The Command Center, in a visual collaboration session, outlines where congested sectors and reroutes are predicted for the next four hours. Arrivals will be rerouted either north or south of the line of severe thunderstorms and then via standard arrival routes to Chicago and St. Louis. Westbound departures from Chicago and St. Louis will depart via standard departure routes and their reroutes around the north or south of the severe thunderstorms will begin after they have exited the terminal areas. All participants concur with this flow initiative proposal. The Command Center asks for some flights to be moved from Kansas City Center's airspace into Minneapolis Center. The flow initiative proposal is made available to NAS users and FAA facilities via the NAS Information System.

One and half hours after the early morning conference call, the flow initiative proposal is recorded in the NAS Information System as the active flow initiative. En route flights are cleared in accordance with the plan, and flights that have not yet departed are replanned and refiled by their respective AOC.

An assessment is conducted by the TMS, TMCs, and AOC staff of success so far. The discussion focuses on the forecast weather (no change) for the next several hours. The severe line of thunderstorms is expected to impact Chicago and St. Louis sometime between 2200Z and 0100Z. It is expected that when the line passes the Chicago and St. Louis airports, arrival and departure operations will be severely curtailed for approximately 30 minutes.

It is decided to continue to utilize normal departure and arrival routes at Chicago and St. Louis until approximately 2100Z. After that time, westbound departures will be rerouted through either north or south departures gates, as appropriate for their destination.

At 1630Z, the AOCs submit plans via the NAS Information System for the next phase from 1700Z to 2100Z. En route flights continue to be recleared in accordance with the active flow initiative, and flights that have not yet departed are being replanned (from their normal or expected routes) and filed by their respective AOC.

Plans include reroutes, a small arrival bank at Chicago delayed by 20 minutes to preserve bank integrity due to some delays as a result of reroutes, some speed changes, and a few cancellations.

In early afternoon another assessment is conducted by the TMS, TMCs, and AOC staff. The discussion focuses on managing the arrivals and departures at Chicago and St. Louis during the time the line is expected to pass over the airports. The severe line of thunderstorms is expected to pass Chicago between 2200Z and 2230Z and St. Louis between 2300Z and 2330Z. It is agreed that flights en route to Chicago with estimated arrival times between 2200Z and 2230Z will continue, and will be placed in airborne holding if necessary. Flights en route to St. Louis with estimated arrival times between 2300Z and 2330Z also will continue, and be placed in airborne holding if necessary. Internal departures with estimated arrival times during the time when the line of thunderstorms is passing the airports are placed on “hold for release” by the local TMCs. These flights will be released on schedule, if airborne holding slots are available. Otherwise, the flights bound to Chicago and St. Louis will be delayed on the ground sufficiently to move their arrival time out of the period during which the line of thunderstorms is passing the airports.

The delay of the arrival bank mentioned above puts it even closer to the time when the storm is predicted to be over Chicago. The affected airline states that it expects some of the flights in that bank to hold in the air and is planning fuel load accordingly. They have also delayed a larger arrival bank that would have started arriving at Chicago at 2215Z. Instead, those flights will begin arriving at 2245Z, freeing arrival slots that probably won’t exist because of the approaching storm.

In mid-afternoon, a final assessment is conducted by the TMS, TMCs, and AOC staff to refine the plan for the 2200Z to 0100Z time period. Also, a plan for the remainder of the day is developed, focusing on the time period after the line passes the two airports and begins to affect traffic arriving from the east, or departing for airports to the east.

3.3.3 Reduced Capacity at Airports

The traffic management personnel and NAS users monitor airport weather information for situations that may adversely affect NAS system capacity and safety. One such situation is when weather reduces arrival capacity at a major hub airport for an extended period of time. For TFM, the focus is on identifying possible demand/capacity imbalance conditions. Weather data provides them with information to help determine capacity. If arrival demand at an airport is expected to exceed predicted capacity significantly, then TFM personnel ensure demand is managed accordingly. They also determine whether other NAS resources (for instance, proximate airports) are affected as a consequence, and manage that situation as appropriate.

Rather than focusing on capacity, NAS users are concerned about managing their individual operations. Weather information helps them strategically plan their operations. When weather conditions are expected to adversely affect arrival and departure capacity at an airport, NAS users must assess their overall operations and plan accordingly. NAS users with scheduled operations are especially concerned with maintaining their flight schedule (for passengers and/or packages), while considering other factors such as crew requirements and qualifications, equipment requirements, crew schedule, equipment schedule, maintenance needs, and catering schedules.

In the collaborative environment, when there is a discrepancy between an AOC and TFM understanding of expected weather conditions, capabilities are available to support an exchange of weather information. Any remaining disagreement is likely to be an issue of interpretation rather than a lack of common information.

Updated operating schedules from NAS users are available to ATM in real time, providing them with demand information that is more accurate and reliable; when the NAS users know what demand they will place on the NAS, TFM is thus informed. In a complementary and synergistic manner, capacity information (actual and predicted) is available to NAS users in real time, allowing them to adjust their schedules according to the situation.

During normal operations, TFM and the NAS users exchange real-time information on capacity and demand. When weather is predicted to reduce capacity at an airport, NAS users may modify their schedules to meet their objectives, and TFM is given updated demand information through the NAS Information System. If TFM subsequently determines there is a demand/capacity imbalance, they inform NAS users so that NAS users may respond. TFM allocates airport arrival slots to NAS users in proportion to their demand as estimated from the Official Airline Guide (OAG). NAS users can substitute flights among their allocated slots, and adjust flight times to earlier slots when cancellation of a flight frees a slot in the schedule.

The scenario that follows illustrates a weather situation where ceiling and visibility significantly reduce capacity at Chicago O'Hare International Airport. At the beginning of the scenario, an imbalance situation is predicted to occur. Demand is expected to exceed the airport's ability to accept aircraft. Two air carriers with hubs at O'Hare address the situation based on their unique business requirements. A third air carrier uses O'Hare as a significant part of their operation, though it is not one of their hubs.

Scenario

The weather forecast shows rain and fog expected for the Chicago area, from late afternoon into early evening (see Figure 3-1). Ceiling and visibility at O'Hare are expected to be low.

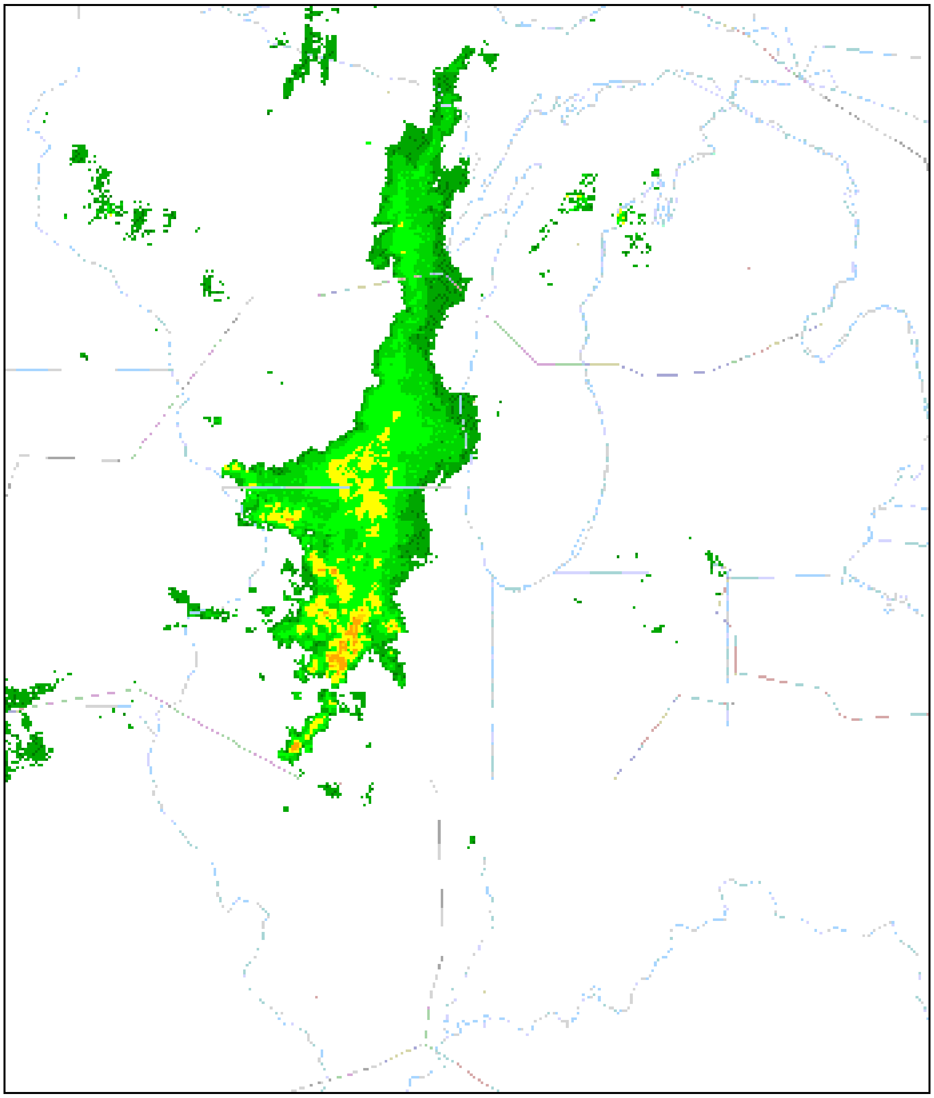

Figure 3-1. Rain and Fog Expected in the Chicago Area

The Command Center identifies that the weather situation is likely to significantly reduce capacity at O'Hare running late in the afternoon and well into the evening. Accordingly, they issue an advisory message to NAS users.

The TMS examines demand data and weather data for the time period of the expected weather situation, quantifying the characteristics of the situation. The specialist considers ceiling and visibility estimates, and the times at which the values are expected to change. The specialist also considers storm location (vertical and horizontal), movement rate, and strength. From this the specialist estimates the impact on arrival capacity at O'Hare, quantified by arrival rate for an expected time period.

At the same time, the TMC in the Chicago Center examines the weather situation expected to reduce capacity at O'Hare in the late afternoon and evening. The TMC likewise quantifies the characteristics of the situation and estimates the impact on arrival capacity at O'Hare.

The air carriers that either use O'Hare or might otherwise be impacted by conditions at O'Hare examine the weather situation, and evaluate its impact on their operations. Schedules (flight, crew, and airframe) are considered. Crew and aircraft qualifications are verified for operating in the reduced ceiling and visibility conditions expected at O'Hare. Most of the air carriers make independent adjustments in their overall schedules to accommodate their individual needs in the reduced capacity situation.

ABC Airline operates a hub at O'Hare. Its AOC staff evaluates the situation at O'Hare and examines their company schedule. Their goal is to reduce their demand as needed for the day and return to a normal schedule on the next day. They consider arrival and departure rates for O'Hare. They modify their schedule for the current day by canceling those flights they consider lowest priority and consolidating other flights. They reschedule remaining flights, adjust times for their operations at other airports, balance equipment requirements, and reassign crews. They create a couple of ferry flights to ensure equipment and crews will be available for normal operations on the following day.

EFG Airline also has a hub at O'Hare. Like the staff at ABC Airline, the AOC staff at EFG Airline evaluate the situation at O'Hare and examine their company schedule. Their goal is to operate as many of their scheduled flights as possible despite the reduced arrival capacity. They consider how long it will take to run the current day's schedule, with the expectation that some flights might need to be flown the next day. They determine what flights, if any, must be canceled to accommodate their overall schedule. They modify their schedule to accommodate the situation at O'Hare. They reschedule flights based on their expectation of the acceptance rate at O'Hare, adjust times for their operations at other airports, balance equipment requirements for current and subsequent flights, and reassign crews for current and subsequent flights. As applicable, they cancel those flights they consider lowest priority for the day, consolidating a couple of flights. They also create a couple of ferry flights to ensure equipment and crews will be available for normal operations on the following day.

XYZ Airline flies aircraft into and out of O'Hare, though it does not have a hub there. Their goal is to minimize perturbations to their overall schedule resulting from the weather situation in Chicago. They evaluate the situation at O'Hare and examine their company schedule. Only two flights are directly affected by the situation, and they change their departure times based on the expected arrival capacity at O'Hare.

The TMS and the TMC at Chicago Center discuss their assessments of the weather situation. They exchange their views on the weather effects on airport capacity, while considering updated user demand information. They reach agreement on how they expect the storm to affect capacity at O'Hare. They conclude O'Hare will have a demand/capacity imbalance. Additionally, they conclude the solution may affect other centers, so the Command Center brings those affected facilities into the discussion to develop plans for an airport-related flow initiative.

The Command Center communicates the O'Hare flow initiative proposal to NAS users through the NAS Information System. The proposal includes information on start and end times, as well as the projected departure and arrival rates. NAS users are provided the opportunity to contact the TMS, and some AOCs do. The specialist and AOCs agree on the weather situation in general, but disagree on the time at which the weather should improve. Since the current projected airport demand is in excess of the expected capacity, the Command Center also provides arrival slot allocations per air carrier that are proportionally based on the air carrier flight schedule information from the OAG.

The flow initiative proposal is expected to regulate traffic for six hours. The first four hours of regulated flow cover the expected period of reduced arrival capacity. The last two hours are a recovery period run at the normal airport acceptance rate to address the imbalance caused by extra demand delayed from the first four hours.

To account for arrival rate prediction uncertainty, the traffic management personnel and AOCs discuss a planned arrival rate uncertainty allowance. They mutually agree that for flights arriving during the fourth hour of the period of expected reduced capacity (and later), they can plan to arrive for landing 10 minutes early, subject to a planned announcement by the Command Center one hour into the period of reduced capacity. This uncertainty allowance provides a reservoir of flights for arrival at O'Hare should conditions improve sooner than expected.

In accordance with the flow initiative proposal, ABC Airline is not required to further alter their operations. Earlier in the day, ABC Airline lowered its demand for the reduced arrival rate conditions to a level that was below the proportion eventually allocated to them by the TMS. They also reduced their demand below the capacity limit for the recovery period.

Conversely, EFG Airline must further reduce its demand. Their planning to this time has not been sufficient to reduce demand to the proportion allocated by the TMS. They must reduce their demand for both the period of reduced capacity and the recovery period.

Since XYZ Airline's flight arrival times had already been adjusted to be commensurate with the expected airport acceptance rate, their updated schedule is not required to be changed.

NAS users are expected to modify their schedules before the flow initiative is anticipated to go into effect. They change slot assignments within the Command Center allocations.

The Command Center plans departure delays for those flights not being replanned by NAS users such as GA flights. They also reserve additional GA slots, based on historical information for operations under similar weather conditions. When updated proposals are submitted by users, the Command Center integrates all of the proposed flight plans, evaluates the overall proposed updates, and makes final adjustments accordingly. Formal notification of the flow initiative is transmitted to the NAS users and affected NAS facilities at this time through the NAS Information System, and the flow initiative is deemed "active".

For the active flow initiative, ABC Airline did not further alter its operations as it was not required to do so. EFG Airline decreased its flights as required, but received a benefit from slots unused by ABC Airline; the schedule was "compressed" and everyone moved up. XYZ Airline chose not to take a "compression" benefit, preferring to maintain the schedule they have already planned.

NAS users launch flights for arrival at their planned times. Arriving flights land on a 'first-come, first-served' basis to allow maximum slot usage while allowing for variation between planned and actual arrival times. The Command Center continuously assesses the situation.

After one hour of reduced capacity, the Command Center determines that arrivals into O'Hare are being accepted as expected. The weather information as coordinated between the Command Center, the Chicago Center TMCs, and some of the AOCs indicates the weather will progress as predicted; it will improve neither later nor earlier. The 10-minute allowance for arrival rate prediction uncertainty is still planned by the Command Center; the TMS announces this to the NAS users, as agreed upon while developing the flow initiative.

Toward the end of the period of reduced capacity, arrival delays are incurred by flights arriving the agreed-upon 10 minutes before their slot. As weather improves and the arrival rate returns to normal, these delays are gradually eliminated. For the next few hours, operations recover from the situation as planned by both the NAS users and the FAA. ABC Airline concludes its operations for the day as planned. EFG Airline continues flying until as many of its flights as possible are completed. XYZ Airline continues their overall operations with minimal impact from the weather situation in Chicago. The initiative terminates at the end of the planned recovery period.

3.3.4 Localized Line of Severe Thunderstorms

Severe weather of modest extent creates some of the same problems as the large severe weather situation described in Section 3.3.2. When the weather can be predicted in advance, many of the same TFM approaches apply. However, because the problems affect a smaller airspace, they can be resolved with less severe effects on users and with the involvement of

TFM personnel at fewer facilities. When the weather is primarily within one center, that center's TMC identifies the problem and initiates consultation with other facilities as needed. The Command Center remains the primary point of contact for the AOCs, but visual collaboration capabilities allow direct input of AOC preferences to the TMCs during strategy development, when the lead time is sufficient to permit AOC involvement.

A primary concern of the TMC in this situation is potential sector loading problems in sectors adjacent to the weather. The objective is to address these problems proactively by reducing the traffic through the sectors where the congestion is expected to occur.

The scenario that follows illustrates the situation through resolution of a serious congestion problem caused by aircraft deviations around an extensive line of thunderstorms.

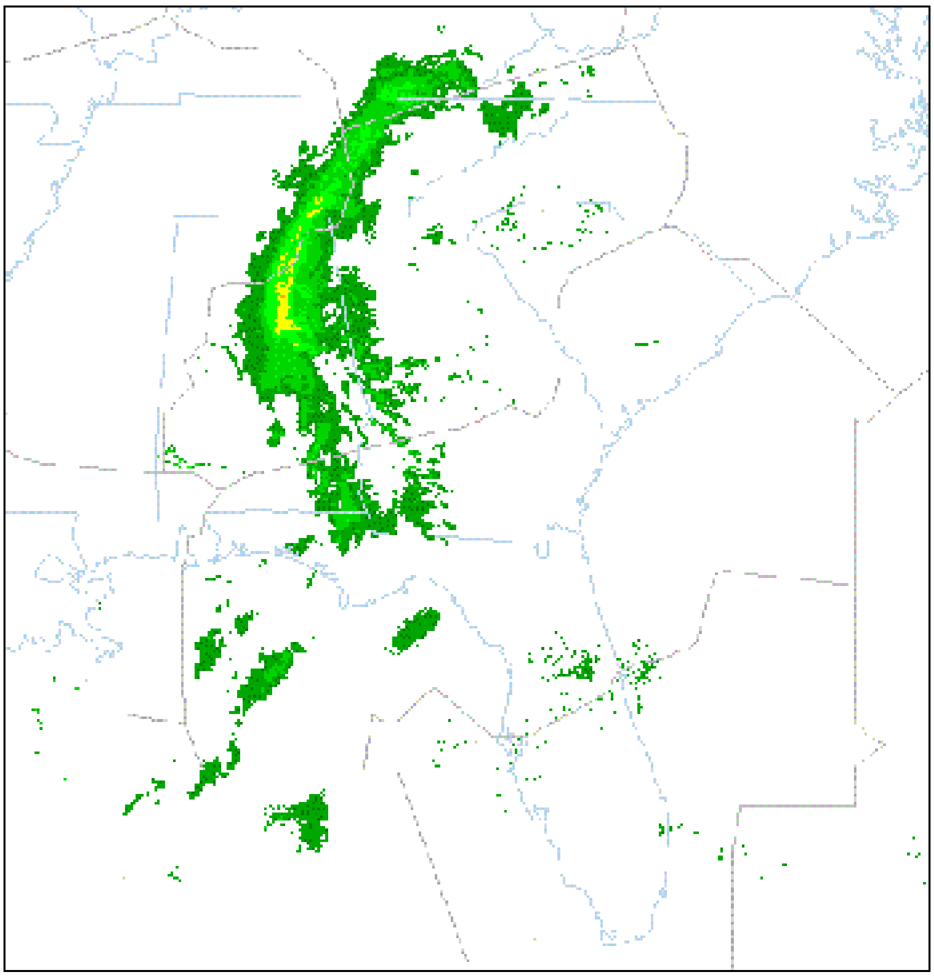

Figure 3-2. Line of Severe Thunderstorms in Atlanta Center

Scenario

Weather radar reflectivity data, lightning strike data, and an automated forecasting weather product indicate a solid line of Level 5 thunderstorms developing in the western sectors of Atlanta Center within the next 15 minutes (see Figure 3-2). The available weather data, along with the experience of the TMC and meteorologists supporting Atlanta Center, suggest that the weather will impact traffic for the next two hours. At the same time, AOCs, using their own weather forecast capabilities, also recognize the developing situation.

The TMC contacts the TMS at the Command Center about the developing situation, advising that the line of storms is large enough that it, or the resulting flow strategy, will affect other centers. Visual collaboration is established between TMCs at the appropriate centers and the TMS. The Atlanta Center TMC specifies a moving volume of airspace where weather is expected to constrain air traffic flow, taking into account the forecast track of the weather, its rate of movement, and its expected start and end times. The Command Center concurs with the need to define the volume as a flow constrained area (FCA).

Once the FCA is defined, automated capabilities identify the flights that will pass through it during the time it is active. The TMCs and the TMS examine a graphical display of the routes of the flights penetrating the FCA to get a sense of how many flights are likely to be deviating. The TMS makes available the FCA definition and descriptive information about the developing situation, including that reroutes will be needed, to NAS users via the NAS Information System.

Using their own capabilities, the information about the situation sent by the Command Center, and their own company data, several carriers identify and examine their own flights affected by the flow constrained area. Two carriers have a small number of flights that are affected. AOC staff for these carriers decide it would be beneficial to their operation to avoid the area where the weather is located, so they contact the pilots involved and ask them to amend their routes of flight via ATC. For flights still on the ground, they file revised flight plans that avoid the line of storms.

Because there is insufficient lead time for AOC collaboration, the TMCs define reroutes for all the flights that are still identified as entering the FCA. These are submitted for analysis of their effects on traffic and sector loading.

The TMS makes the analysis results available via the NAS Information System. The analysis shows that one sector is expected to experience congestion problems as a result of the reroutes, and the TMC at the affected center makes two small adjustments to avoid the problem. After adjustment, the sector loading is acceptable. Subsequently, the routes are conveyed to the appropriate sectors for clearance delivery and communicated to the NAS users via the NAS Information System.

Two other carriers with multiple flights affected by the FCA use their own capabilities to analyze the impact of the reroutes on their flights, based on considerations and information unique to their company. One carrier determines that a flight landing just beyond the line of storms does not have adequate fuel on board to follow its specified reroute, so the AOC coordinates an exception with the Atlanta Center TMC through the Command Center to allow the flight to pick its way through gaps in the line. The other carrier finds that two of its flights can climb over the storms, so its AOC coordinates this alternative to rerouting those flights.

3.3.5 Dynamic Weather

In 2005, meteorological forecasts of mesoscale convective complex conditions continue to be highly accurate. However, predicting the exact time, location, and extent of specific thunderstorm cell development within the convective complex remains difficult. Therefore, a collaborative approach to managing traffic is constrained by inability to predict when and where airspace will be blocked to air traffic. Monitoring and problem identification take place in much the same way as for the more predictable weather described in Section 3.3.4. Strategy development procedures differ in that the lead times are smaller and the need for specific traffic management initiatives may be less obvious. The traffic management personnel are concerned about the reduced airspace capacity, a direct result of these convective activities, as well as with congestion in neighboring sectors caused by NAS users who choose to reroute flights around the affected airspace volume.

The scenario that follows describes possible collaboration during a period of airmass (non-frontal) thunderstorm activity that affects a major airport.

Scenario

Conditions are favorable for air mass thunderstorm development after 1900Z in central Texas northward into Oklahoma. These storms are expected to be scattered, with occasional clusters of cells forming short lines (see Figure 3-3). The individual storm cells are expected to develop in random locations, rapidly reach maturity, and slowly dissipate.

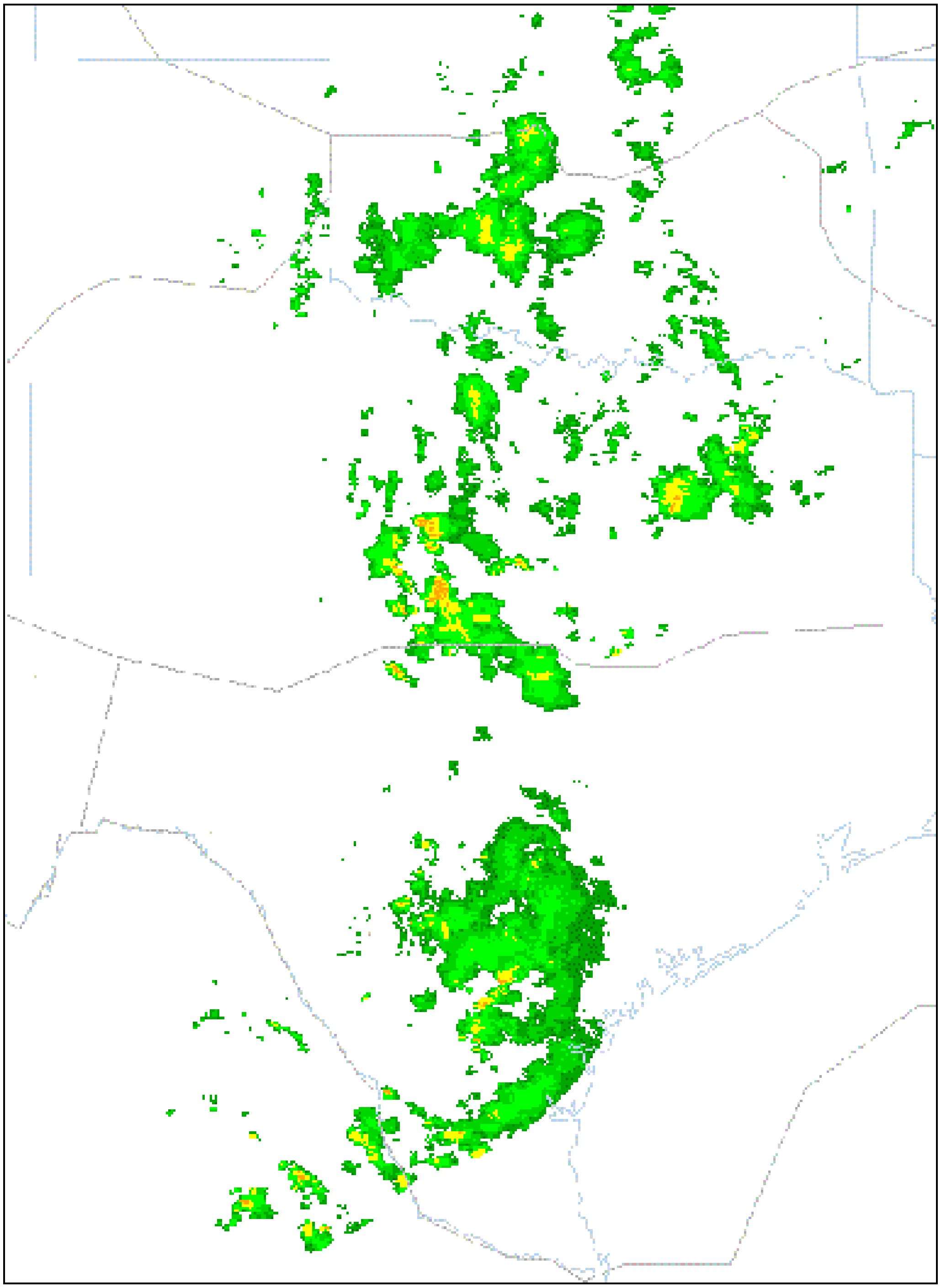

Figure 3-3. Scattered Thunderstorms Across Texas and Oklahoma

Due to weak winds aloft, little movement of individual storm cells or clusters is expected. Some cells are expected to reach severe levels, with tops in excess of FL 450, associated surface winds of 70 knots, hail, severe turbulence, and heavy rainfall. Disruptions to surface operations at Dallas/Fort Worth International Airport (DFW) can be expected if a storm cell or short line moves over the airport. Also, disruptions of the arrival and departure flows are possible if these routes are affected by thunderstorm activity. The storms are expected to dissipate rapidly after nightfall and few will remain after 0300Z.

Early in the morning, the TMS and the TMCs at Fort Worth Center and Houston Center use visual collaboration capabilities to brief AOCs about the possibility of service disruptions at DFW. Since the weather forecasters cannot predict the specific locations and times that a thunderstorm will develop, plans for strategically managing the situation are ruled out. TFM informs NAS users that standard instrument departures (SIDs) and standard terminal arrival routes (STARs) will be dynamically assigned as necessary to avoid storms that affect DFW arrival and departure flows. Therefore, routing changes can be expected for both arriving and departing flights. Airborne holding and ground delays will be used when thunderstorm activity at or near the airport forces temporary suspension of takeoff and landing operations. TFM does not expect departures to DFW from other airports to be subject to ground delays, unless the actual weather is more severe than forecast or unless DFW takeoff and landing operations are affected for long periods of time. TFM informs NAS users that, due to possible sector congestion resulting from airborne holding and rerouting, overflights through the affected Fort Worth Center and Houston Center airspace may have to be rerouted to avoid the saturated sectors. The potential definition of the airspace where future capacity is to be constrained by the storm is discussed by TFM and the users. The consensus is that due to the difficulty of predicting the exact location, extent, severity, and timing of the hazardous activity, a TFM initiative is not warranted at this time. The parties agree that it may be needed later, as the storm evolves.

The forecast conditions and TFM's plan for managing the resulting traffic conditions are disseminated through the NAS Information System.

Several AOCs participate in the visual briefing conducted by TFM. Other NAS users, not equipped for visual collaboration, receive the forecast and plan through the NAS Information System. NAS users review all available data, including the forecast weather information.

Based on this information and the data and discussion provided by TFM, some AOCs elect to replan some of their flights away from the area expected to be affected by the thunderstorm activity. Primarily, they select those flights not yet departed and not required to operate through the forecast thunderstorm area to reach their destination. Few airborne flights are replanned. Other AOCs, considering the long time before the hazardous conditions are expected to develop and the uncertainty of the location and time of development, do not replan any flights. They expect the conditions to be sufficiently localized that replanning is not practical.

AOC staff with flights scheduled to or from DFW make fuel adjustments to allow for possible delays and consider possible schedule contingencies.

As the day progresses, scattered thunderstorms develop in the area north and northwest of DFW. These storms are affecting DFW arrivals from the northwest and departures to the north, as well as overflight traffic through the area. Aircraft deviations to avoid the storms are occurring, and these deviations are increasing sector workload.

The TMCs at Fort Worth Center review traffic prediction information. Estimated sector capacities resulting from the current and expected weather conditions are entered into the traffic prediction capability. As a result of the new sector thresholds, the traffic prediction capability indicates significant congestion in the arrival and departures sectors affected by the thunderstorm activity. Unacceptable congestion levels are expected to occur in 30 minutes and last for more than an hour. Analysis of the predicted traffic indicates that several aircraft transiting the area during the congested period are overflights.

The TMCs at Fort Worth Center decide to create a flow constrained area encompassing the airspace where aircraft deviations are occurring. When identifying flights that are planned through the area, the TMC exempts traffic operating to and from DFW and its satellite airports. Therefore, only overflights operating through the constrained area are affected. Automated capabilities identify the specific flights, and the TMC examines their expected impact on sector traffic activity and density. The TMC concludes that even with those flights removed, traffic levels would still be too high in the arrival sectors northwest of DFW.

The TMC decides to test the effects of rerouting non air carrier flights arriving at DFW satellite airports around the constrained airspace. Automated capabilities identify these flights, and the TMC uses a group aircraft planning capability to plan potential reroutes to other arrival fixes. With these changes, predicted activity in the northwest arrival sectors is reduced to acceptable levels, and the activity levels in the sectors receiving the satellite arrival traffic are also acceptable since these sectors are unaffected by the weather conditions.

Because of the short lead time, it is not practical to consult NAS users about the proposed reroutes. The TMC advises the Command Center of the actions taken and transmits the reroutes to the sector controllers for implementation. The planned reroutes are made available to NAS users via the NAS Information System, as is the definition of the flow constrained area.

3.3.6 Predicted Congestion Without Weather Constraints

One of the consequences of increased freedom in routing flights is that the location and pattern of traffic congestion vary from day to day with changes in winds and other conditions that influence NAS users' choice of operationally desirable routes. The first choice for handling such problems is to maximize the capacity of the airspace. In addition to increasing sector capacity by increasing sector staffing, facilities are able to combine and de-combine predefined sectors to balance the traffic load. Dynamic resectorization, redefining the boundaries of sectors other than by the combining and de-combining of predefined sectors available today, is technically complex and still raises enough issues (see Section 5.5) that it is unlikely to be a practical option in 2005. In 2005, today's methods of adjusting sector staffing and configuration will be applied on a more frequent, dynamic basis in order to accommodate greater daily fluctuations in route preferences.

When capacity cannot be adjusted to meet the demand, other TFM initiatives are required. Depending on the scope of the problem, resolution may involve collaboration among multiple TMCs, the Command Center, and AOCs.

The scenario that follows describes a situation involving predicted congestion without weather constraints. The situation is resolved through collaboration similar to that used in resolving problems associated with weather, using flow strategies developed by multiple en route centers, the Command Center, and air carriers.

Scenario

The traffic prediction capability at Kansas City Center forecasts significant traffic congestion in the high altitude sectors in the southern portion of Kansas City Center in 2 hours. The congestion involves Kansas City Center's traffic flows to and from Chicago.

The TMC at Kansas City Center initiates voice contact with a TMS at the Command Center and a TMC at Chicago Center. Visual collaboration is activated between each site so that all three parties are able to observe and interact with the situational and decision support data. From discussion, the consensus is that a FCA should be defined around the area that is expected to become congested.

The TMC at Kansas City Center defines the FCA's lateral and vertical boundaries and time limits, and its definition is observed via visual collaboration by the TMS and the Chicago Center TMC.

An hour before the congestion problem is to occur, the TMC at Kansas City Center uses automated capabilities to identify the carriers and the flights affected by the FCA. The two TMCs and the TMS see the results of the problem prediction capability via visual collaboration and discuss the situation. A projection of currently active and inactive flights as they converge on the congested sectors is made by the Kansas City Center's TMC using a graphical traffic density capability, and congestion metrics show the loading is expected to exceed thresholds established for that day. The TMS and the Chicago Center TMC are also able to observe the patterns of predicted traffic in the Chicago Center sectors as well.

The TMS issues an electronic message on the NAS Information System that identifies the situation, the defined FCA, and the AOCs having affected flights. All but one affected AOC indicate to the Command Center that they want to participate in the problem's solution, rather than replan their flights without coordination, and each joins the visual collaboration. The abstaining AOC has no staff free at this time to participate due to other more pressing situations that they are working.

When the AOCs join the he visual collaboration, they are briefed by the TMS on the situation. The participating AOCs, the Command Center, and the TMCs at Chicago Center and Kansas City Center are now tied together through the visual collaboration session.

Lateral and altitude reroutes are discussed. In this situation, descent into the low altitude sectors is ruled out due to weather and airborne holding of arrivals into Kansas City Center. The collaborators decide that lateral reroutes will be used to avoid the congestion, and it is determined that the resulting reroutes most likely will impact Chicago Center and Minneapolis Center to the north, and Denver Center to the northwest.

The TMC at Kansas City Center uses the strategy evaluation capability of the traffic prediction function to determine the percentage of flights that need to be rerouted to resolve the problem. The results indicate that fifty percent of the flights that are predicted to penetrate the FCA must be rerouted to alleviate the expected congestion problem. All collaborators observe the results of the strategy evaluation through the visual collaboration.

Since it is determined that Denver Center and Minneapolis Center will also be affected, the TMS contacts their TMCs to join the visual collaboration and reviews the situation with them. The TMCs review the predicted traffic count, the density data, and the FCA boundaries, and indicate an understanding of the need for reroutes into their centers' airspace.

The TMS requests that participating AOC staff select half of their flights for rerouting clear of the FCA. The AOC staff select the flights to be rerouted according to their internal data and objectives, and convey their candidate reroutes or other ideas to the Kansas City Center TMC. At the same time, the Kansas City Center TMC develops candidate reroutes for the non-participating flights affected by the congestion.

The overall sector loading resulting from all proposed plans in the aggregate is assessed using the traffic prediction what-if analysis function. All participants view the results via the visual collaboration. The Chicago Center TMC requests minor revisions to the reroutes for one flight per carrier, to reduce the predicted loading for a Chicago Center sector to acceptable levels.

At this point, the reroute strategy is agreed to, and is recorded in the NAS Information System as the active flow initiative. The system records the amount of penalty assumed by each carrier. The Kansas City Center TMC transmits the reroutes to the sector controllers for implementation. The planned reroutes are made available to NAS users and other FAA facilities via the NAS Information System.

The predicted sector congestion situation is resolved. In the process, the participating AOCs have selected the flights and the new routes that are most compatible with their company objectives.

3.3.7 Routine Excess Demand

Periods of high demand occur at predictable times and involve reasonably predictable levels of activity, especially near airports. The characteristics of the routine situations requiring local TFM action in 2005 remain essentially unchanged from the present. Day-to-day arrival management at major terminals and airports and high demand on en route sectors continue to be primary concerns of local TMCs.

Although there continue to be routine periods of high demand, increased user freedom to select routes makes the exact details more variable. For example, arrival rushes at a major airport may involve the same number of flights and time periods, but users may vary their arrival fixes from day to day to take advantage of favorable winds. Additionally, overflights may exacerbate the sector congestion that routinely results from arrival or departure rushes, because they are no longer restricted to today's structured routes that segregate them from arrival and departure sectors.

The Command Center uses its capabilities to predict the probable effects of high-altitude winds and other large-scale weather and operational conditions on traffic flows. This information is disseminated to TMCs and made available to NAS users through the NAS Information System. TMCs use this information and other local data to develop proposed flow strategies that are appropriate to accommodate traffic during the expected high demand periods. For each airport in the center, the TMC makes available the expected situation and the contingency flow strategies to NAS users and other FAA facilities through the NAS Information System. Since the busy periods occur routinely at predictable times, the flow strategies selected are probably very similar, with minor changes to a previously implemented strategy.

The electronic dissemination of the information minimizes the need to repeat the same information over the telephone to several AOCs, which often occurs today. Further, the intent is to minimize manual data entry, such as typing in airport acceptance rates. If the situation changes during the course of the day, the TMC updates the briefing, which is time-stamped. If a radical change is involved, a special flag alerts users.

The TMC has a repertoire of standard strategies for dealing with routine rushes. Examples of these strategies include automated time-based metering systems, used at some airports to deliver arrivals to the airport runways at a predetermined rate. Other airports continue to use MIT constraints at the arrival fixes. Offering aircraft reroutes to different arrival fixes is used to achieve arrival fix load balancing. However, because even routine rushes are likely to be more variable than they are today, the TMC has increased responsibility and automated capability to assess the impact of any given combination of strategies on expected traffic, and to make adjustments to fit the day's situation. Subsequent to the busy period, the TMC automatically receives an analysis of the effects of the constraint and is able to use the strategy evaluation capability to investigate how alternative strategies would have worked with the traffic that actually materialized.

Except where problems are exacerbated by special conditions, such as winds that encourage overflights through arrival sectors, TMCs usually resolve routine rush problems without actively consulting the affected AOCs. The predictable nature of the problems and their associated solutions would make the benefits of active consultation too small to justify the demand on TFM and AOC resources. However, improved information about the expected situation is available to help NAS users adjust their operations to take best advantage of limited capacity. For example, NAS users informed that a certain number of flights will be rerouted for fix load balancing may elect to replan a few flights away from the overloaded fix, resulting in a more efficient route to the fix they will eventually use. Similarly, NAS users informed of the projected arrival sequence of flights during an arrival rush may choose to take action, independent of ATM, to accelerate a high priority flight, or to slow a low priority flight, so that the high priority flight arrives earlier in the "first-come, first-served" sequence at the airport.

In exceptional situations, a NAS user may ask the TMC to make adjustments from a first-come, first-served order. Time and workload permitting, problem prediction capabilities at the sector and strategy evaluation capabilities available to the TMC are used to evaluate such a request. If the request is operationally acceptable, it is accommodated. However, when constraining operational conditions exist and constraints are being applied to all, such requests are likely to raise equity issues with other NAS users, create unacceptable traffic situations, or negatively affect safety and controller workload. It is expected that accommodation of such requests for non-emergency flights is an exception.

The scenario that follows illustrates the activities associated with an arrival rush at Lambert-St. Louis International Airport (STL). To give a sense of how this "routine" activity might be shaped by other events, the rush is placed in the context of a day's activities, including congestion elsewhere in the center associated with the same traffic.

Scenario

Early in the morning shift, the TMCs at Kansas City Center confer with the meteorologist supporting them. The purpose of the weather conference is to receive detailed information and forecasts on conditions that are expected to affect Kansas City Center traffic. The TMCs use the weather information and other pertinent information, as necessary, to tailor the day's plans to manage the high demand periods at St. Louis, Kansas City, and other center resources, as needed.

After reviewing the weather forecast, initial aggregate demand information, and historical data, the TMCs confer with internal terminal TMCs, the TMS at the Command Center, and AOC staff at the two primary users of STL, which are identified here as ABC Airline and XYZ Airline. The TMS and the TMCs note that flights are taking advantage of prevailing high altitude winds and circumnavigating an area of thunderstorms over Texas. The TMS postulates that these actions will result in a significant increase in traffic through Kansas City Center. Although the terminal TMCs have already made available the airport conditions and runway use configurations through the NAS Information System, they reiterate this information. No significant operational problems are present at this time at Kansas City Center's major airports, and the current and predicted weather does not present any operational problem.

During the conference, the TMCs assess whether the operational conditions may require TFM action. The TMCs conclude there is a high probability of both significant en route sector congestion and arrival fix load imbalances at STL. The conclusions are based on the information provided by the Command Center, as well as the TMCs' experience. These conditions may require TFM actions to reduce sector traffic demand and to balance arrival fix loading at STL.

Following the conference, the information collected from conference participants, including the assessment of the operational conditions that may require TFM action, is made available to NAS users via the NAS Information System.

The TMC monitors projected traffic demand on the center's sectors and on major airport arrival and departure fixes. As forecast by the Command Center, the traffic prediction capability is displaying an increase over the usual daily traffic activity in sectors in the western portion of the center. Sector saturation conditions are predicted to occur in 60 minutes and continue for another 30 minutes.

The TMC at Kansas City Center observes that ABC Airline's STL arrivals taking advantage of the high altitude winds are the primary cause of the congestion problem. The TMC uses the analysis capabilities to test whether the remaining saturation problem is resolvable if some of the ABC Airline flights are rerouted to avoid the congested sectors. The analysis verifies that rerouting seven of ABC Airline's 15 arrival flights will reduce the predicted traffic to acceptable levels.

Since it is expected that most reroutes will be initiated in the airspace owned by Denver Center, the Kansas City Center TMC initiates visual collaboration with the TMC at Denver Center, the AOC staff of ABC Airline, and the TMS. The situation is displayed to all parties. After an explanation of the situation, ABC Airline selects new routes that avoid the saturated sectors for five of their arrivals. For two other arrivals, they prefer altitude changes that take those flights out of the congested sectors. This results in acceptable predicted traffic activity for the subject sectors, without creating unacceptable traffic conditions in other sectors. The selected flights and their planned amendments are communicated to the appropriate Denver Center sectors for new clearances.

The system processes active and proposed flight plan data to project demand on airports and on arrival and departure fixes. The Kansas City Center TMC observes that as a result of the STL arrivals from the west using the high altitude winds, plus proposed departures from Kansas City and other internal airports, the TRAKE arrival fix is predicted to be overloaded in 60 minutes. This overload is expected to last for 30 minutes. Under similar operational conditions in the past, ground holds for the proposed flights from the internal airports have been a successful strategy. First, the TMC tests various ground delay parameters and determines that a 30-minute delay on internal departures will be required to resolve the fix overload condition. Because of the severity of the constraint, the TMC decides to test rerouting to a different arrival fix as an alternative strategy.

The analysis determines that when all internal departures to STL scheduled to depart within the next 90 minutes are rerouted to another arrival fix, the overload at the TRAKE fix is resolved. The TMC disseminates information via the NAS Information System that proposed internal departures to STL, arriving via the TRAKE arrival fix during the 30 minutes TRAKE is expected to be overloaded, will be sent over other arrival fixes. Active flights are not affected. The TMC develops default reroutes that will apply to the internal departures that are not replanned by the users. These default reroutes are made available to NAS users and other FAA facilities via the NAS Information System.

NAS users amend existing flight plans or file new flight plans, sending some flights via other arrival fixes. For some other flights, NAS users revise departure times so the flights arrive at TRAKE after the 30-minute period. The remaining flights are rerouted via the default reroutes developed by the TMC and depart on time. With this combination of actions, the TRAKE overload condition is resolved.

3.3.8 TFM in Oceanic Operations

3.3.8.1 Background

Oceanic TFM operations evolve to achieve the following goals in 2005:

- Work more collaboratively with users[5] in the area of problem detection and strategy development
- Reduce the number and magnitude of TFM constraints to the extent feasible (such as in establishing flexible tracks only when needed) while still maintaining a safe operating environment

5 In the discussion of oceanic operations, the term "users" includes all aircraft operators with flights that fly through oceanic airspace.

- Increase the users' level of flexibility in operations by providing them alternatives, whenever possible
- Increase the users' level of predictability in achieving their planned routes in an environment of reduced TFM constraints

Oceanic TFM vs. Domestic TFM

As in today's environment, Oceanic TFM operations in 2005 are conducted somewhat differently from domestic TFM. This difference is due primarily to limitations in surveillance and communications over the ocean and limitations in aircraft equipage to take advantage of such technologies. Though technology in 2005 is improved over today, oceanic airspace is still more structured than domestic airspace, particularly when demand is high or traffic flows are complex.

In 2005, oceanic operations continue to vary among the Flight Information Regions (FIRs) for which the U.S. has control responsibility. These variations are due to several factors, such as the following:

- Differences in the operations between the FAA and each of the Civil Aviation Authorities (CAAs) responsible for controlling a neighboring FIR
- Size of the airspace under U.S. control
  - For example, the airspace under control by New York Oceanic is considerably smaller than the airspace under control by Oakland Oceanic.
- Type of traffic flows
  - Traffic flows in the Atlantic experience more complex crossing situations than traffic flows in the Pacific. This is because in the Atlantic, traffic is more dense, there are North-South as well as East-West flows, and aircraft frequently fly random routes. Also, aircraft fly longer routes in the Pacific than in the Atlantic.
- Equipage of aircraft
  - Because flight distances are longer, aircraft traversing the Pacific Ocean are often larger, newer, and better equipped with sophisticated technology than those aircraft traversing the Atlantic Ocean. Furthermore, the airframe mix flying the Atlantic and Caribbean basin is more complex than that flying the Pacific. The traffic flying the New York Oceanic FIR consists of high capability aircraft to and from Europe mixed with shorter range aircraft to and from the Caribbean islands.

Oceanic Airspace

In 2005, the oceanic airspaces that the U.S. is responsible for controlling include the following:

- The Oakland Oceanic FIR, comprising the majority of airspace over the South and Central Pacific Ocean

- Oceanic ATC operations are conducted by Oakland Center. Flights increasingly fly flexible tracks, random routes (when possible), and occasionally a fixed route structure.

- The New York Oceanic FIR, comprising a smaller-sized airspace over the western portion of the North Atlantic Ocean
  - Oceanic ATC operations are conducted by New York Center. Flights fly a fixed route structure, flexible tracks, and random routes.
- The Houston Oceanic FIR and the Miami Oceanic FIR, comprising the Gulf of Mexico
  - Oceanic ATC operations are conducted by Houston Center and Miami Center. Flights fly a fixed structure and random routes.
- The Anchorage Oceanic FIR, comprising airspaces over the North Pacific Ocean and Arctic Ocean
  - Oceanic ATC operations are conducted by Anchorage Center. Flights fly a fixed route structure and flexible tracks.

Capacity of Oceanic Airspace

Because surveillance over the ocean is increasingly satellite-based in 2005 and because of the triple inertial navigation system (INS), aircraft that are properly equipped with improved navigation provide more accurate and timely position data. This combination of capabilities allows reduced vertical, longitudinal, and lateral separation standards from today, thereby significantly increasing the capacity of oceanic airspace.

Airspace Structure Management

A major responsibility of Oceanic TFM is the daily management of the airspace structure for U.S. FIRs, as well as the long-term planning and evaluation of the airspace structure. Although users increasingly fly random routes, there could still be the need for route structures, either fixed or flexible.

Long-term planning includes decisions made about airspaces where fixed route structures exist. In this case, changes to the airspace structure, though infrequent, are done. For example, a shift in traffic patterns in the Caribbean basin, over time and with reduced separation standards, might warrant an increase in the number of fixed tracks in that airspace. When changes to fixed route structures are needed, such changes are coordinated with other organizations in the FAA and with affected CAAs.

In a typical day, Oceanic TFM collaborates with several entities to plan for the day's traffic flows and to develop strategies when the traffic situation requires TFM action. These strategies include TFM constraints where needed, such as flexible tracks or other techniques to manage congestion. In airspaces where flexible tracks can be used, Oceanic TFM collaborates with NAS users on the need for tracks to accommodate the day's projected traffic demand, and on the definition of these tracks. In 2005, the tracks are defined based on a best fit of user preferences.

Oceanic TFM collaborates with domestic TFM on locations of entry points, or gateways, to the flexible tracks. Oceanic TFM works with oceanic ATC on an appropriate sectorization of U.S. FIR airspace to distribute workload among controllers; the sectorization varies for different time periods of the day, according to the expected traffic flows. Oceanic TFM also works with oceanic ATC on how flights on random routes merge with flights on a fixed route structure or on flexible tracks, such as for hand-off to a foreign FIR (for example, to meet the entry requirement for aircraft spacing) or for arrival to an airport. Finally, Oceanic TFM collaborates with foreign CAAs to define the tracks and to identify where the flexible tracks cross the FIR boundaries.

When upper-air wind forecasts change during the day, Oceanic TFM adjusts the flexible tracks to take advantage of the winds when possible. Oceanic TFM works with domestic TFM, Oceanic ATC, NAS users, and foreign CAAs in this process. For flights already flying on the previously defined track structure, Oceanic TFM collaborates with the respective NAS users either to ensure an orderly transition to the redefined tracks or to continue flying on the previous course to the flight's destination.

Capacity Management

Oceanic TFM manages the capacity[6] of oceanic airspace for which the U.S. has responsibility. This management is done differently for New York operations than for Oakland (the two largest U.S. oceanic areas). In New York, flights are managed on a first-come, first-served basis; there are no reservations for capacity. On the other hand, in Oakland oceanic airspace, where flights primarily fly flexible tracks, users do make reservations for capacity[7] when necessary.

Oakland Oceanic TFM manages the reservation system for gateway entry. Flights with a gateway reservation time are required to cross that fix within a parameter number of minutes of that time. In 2005, when demand exceeds capacity for these tracks, Oceanic TFM allocates the capacity among all NAS users wishing to fly the tracks, according to an algorithm developed earlier with users. This means that Oceanic TFM determines which share of the capacity each user should get (such as, air carrier JAT is allocated three slots—1800Z, 1820Z, and 1836Z). In turn, NAS users determine which of their flights to assign to

6 In determining capacity, the mix and equipage of aircraft are considered, as well as the separation standards between pairs of aircraft.

7 This capacity can be envisioned as windowed "slots" on the track, with one flight per slot. Each track has an associated fix at its beginning, called the gateway entry, and each slot has an associated gateway entry time (also called a gateway reservation time).

an allocated slot. (For example, air carrier JAT assigns JAT 293 to 1800Z, JAT 800 to 1820Z, and JAT 654 to 1836Z.)

As part of capacity management, when flights cannot achieve their gateway reservation (for example, because of delay incurred en route), Oceanic TFM works to obtain a feasible alternate gateway reservation. Oceanic TFM also collaborates with domestic TFM to enable the gateway reservation to be met, in the case of en route delay.

Flow Progress Monitoring

While Oceanic TFM, like domestic TFM, monitors in-flight traffic flows, Oceanic TFM is limited by availability, frequency, and quality of flight following data from the automation systems of foreign CAAs. In 2005, more foreign CAAs share flight plan and flight following information with the U.S.; this capability evolves over time to include more and more CAAs. In addition, the update of flight following information is supported with Automatic Dependent Surveillance (ADS) position reports from suitably equipped aircraft.

Transition to/from Oceanic Airspace

Oceanic TFM works with domestic TFM toward a manageable flow from domestic to oceanic airspaces and from oceanic to domestic airspaces. This includes metering en route flights and departures from the U.S. to the oceanic airspace at such a rate that they can be managed by ATC.

3.3.8.2 Scenario

The following scenario illustrates Oceanic TFM responsibilities and a concept of operations for the New York Oceanic FIR in 2005. Oceanic TFM activities are described for one particular day, April 10, 2005, and illustrate planning at the beginning of the day, the arrival rush, and the departure rush. In particular, the scenario illustrates a situation where a complex crossing situation is predicted to occur several hours hence, and users are offered options by TFM on how to manage the congestion. The options offer increasing levels of predictability, but also a corresponding decrease in levels of flexibility in operations. Users collaborate in a planning session moderated by Oceanic TFM to mutually select an option.

New York Oceanic manages traffic in two International Civil Aviation Organization (ICAO) regions, the North Atlantic (NAT) and the Caribbean. The major traffic flows that traverse these regions are the following:

- The southernmost tracks of the NAT Organized Track System, between northern Europe and Canada
  - These are flexible tracks, generated by Gander CAA, that sometimes run through New York oceanic airspace and whose position depends on the location of the jet streams.

- The tracks of the West Atlantic Route System (WATRS), between the North American continent and the Caribbean basin
  - These tracks are fixed and crossing, serving a large mix of airframes.
- Between Europe and the Caribbean/South America (through a large airspace, east of the WATRS tracks, referred to as Deep Waters)
  - Traffic primarily fly random routes. TFM constraints, such as flexible tracks or less restrictive measures, would be established only if demand and flow complexity warrant them.
- Between southern Europe and the U.S. (through Deep Waters)
  - Traffic fly random routes which cross the routes flown by the Europe-Caribbean traffic.

10 April 2005, 0900Z. At the beginning of this day, New York Oceanic TFM makes preliminary plans for the day. By the deadline, it receives Preferred Route Messages (PRMs) from air carriers (including foreign air carriers) for departures approximately 12 hours hence for oceanic flights departing from or arriving in the U.S. and flying the NAT, Deep Waters, or WATRS airspaces. The PRM is the initial source of information to help estimate the day's demand for oceanic airspace; it does this by indicating the NAS user's route preference. (In 2005, the PRM route, like the route on the flight plan to be filed, is four-dimensional[8]). Because of updates in wind and weather forecasts and changes in users' schedules, the user's preferred route, as indicated in the PRM, is not necessarily the route that the user eventually files. However, the PRM indicates the user's intentions, given the information available at the time.[9]

TFM also studies wind forecasts and weather forecasts for the day to identify jet streams and the regions that users are likely to avoid. These forecasts are used by an automation

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8 This includes the position in space (where position is specified by altitude and one of the following: a fix name, a waypoint name, or a latitude/longitude designation) and time to the position in space.

9 The flight plan route is the user's best guess at time of filing of what the user intends to fly. When the user files a flight plan, the ATM system accepts the information (including flight route) and uses it for demand prediction and other planning. Acceptance of the flight plan does not mean that the route is "guaranteed." The pilot still must receive clearance from the controller to proceed on a flight path. Additionally, the four-dimensional flight route is useful to the controller because it helps indicate the operational capabilities of that airframe (for example, that it is capable of flying at FL 400 because it is so stated on the flight plan).

system to calculate minimum time tracks (MTTs) in the Deep Waters and North Atlantic airspaces. Although a user could choose a route for the PRM based on criteria other than minimum time, knowledge of the MTTs helps TFM estimate the demand of users who do not submit PRMs (such as some general aviation flights).

TFM is aided with an automation capability to identify time periods and locations of congestion in the North Atlantic and Caribbean basin throughout the day. The capability considers the PRMs filed by the air carriers, historical demand by non-air carriers, the MTTs, and wind and weather forecasts.

The demand profile for the New York Oceanic FIR, generated from the PRMs and other sources, is used in different ways, depending on the particular airspace:

- NAT airspace – to define tracks and develop a sectorization plan
- WATRS airspace – to develop a sectorization plan
- Deep Waters airspace – to determine need for a TFM constraint, define the constraint, and develop a sectorization plan

NAT airspace. Based on the demand information from the PRMs, Gander Area Control Centre (ACC) is responsible for determining whether tracks are needed today in the NAT, and, if so, how many tracks and their location. Gander suggests to New York Oceanic TFM which tracks be located in the New York Oceanic FIR around latitude N37° longitude W62° based on the PRMs, the forecast location of the jet stream, and weather conditions forecast in the Gander, New York, and Shanwick FIRs. New York Oceanic TFM examines the projected demand for the day from flights that wish to fly random routes through the New York Oceanic FIR, and consults with its meteorologists. Together New York Oceanic TFM and Gander ACC agree to establish two tracks through the New York Oceanic FIR, and they collaborate on the position of these tracks. The track information is published on the NAS Information System and distributed to other CAAs and to the users.

WATRS airspace. WATRS traffic demand is projected to be quite high, as suggested by the PRMs. This estimate of demand includes traffic merging from the random routes of Deep Waters. Because a large percentage of the traffic flying the WATRS airspace is not scheduled and does not submit PRMs, TFM uses historical information on such unscheduled traffic to obtain a more accurate estimate of Caribbean basin demand. Based on this estimate, New York Oceanic TFM notes that demand for track XX is over capacity, while demand for tracks YY and ZZ is considerably less. Consequently, New York Oceanic TFM makes a suggestion, published on the NAS Information System and also distributed to other CAAs, that users file flight plans for tracks YY and ZZ if they want to avoid delay on entering oceanic airspace.

Deep Waters airspace. Based on the demand information from the PRMs, demand for Deep Waters airspace is predicted to be moderate throughout the day, except in the late afternoon. During this time, the traffic flows of the Europe-Caribbean basin/South America and Europe-U.S. in Deep Waters are expected to create complex crossing situations and a situation of closely spaced parallel flight trajectories; these situations have been predicted and are illustrated by TFM's automation capability.

Oceanic TFM notifies the users of the predicted traffic situation, identifying the following:

- The volume of congested airspace is bounded by latitude N32° and N39°, by longitude W45° and W53°, and by altitude FL 360 and FL 400.
- The affected time period is 1930Z-2130Z.
- The air carriers whose flights are planned to be in the affected volume at the defined time period are JAT Airways, LYH Airlines, BEW Airlines, and MXY Air Lines.

Oceanic TFM outlines options on how to manage the predicted congestion to the affected air carriers, and requests user input. The users agree to respond back with their preferred option in a collaborative planning session within 15 minutes. The options are the following:

1. Oceanic TFM establishes tracks for Europe-Caribbean basin/South America flows, allowing Oceanic ATC to fit flights on the Europe-U.S. flows into the airspace. The tracks are generated with user input on the track location.
2. Oceanic TFM labels the defined volume as a TFM constrained volume with altitude constraints. This means that aircraft desiring to fly through this volume during the defined time period are restricted to specific altitudes while in the volume, depending on the direction of flight. The altitudes are chosen based on user input.
3. Oceanic TFM does not impose any constraints. Oceanic ATC manages the crossing situations tactically, with the help of *user self-separation*[10]. Oceanic TFM estimates that self-separation would be required for as long as two hours.

Users recognize that, of the three options, the most restrictive offers the most predictability, while the least restrictive offers the least predictability.

TFM mediates the collaborative planning session. Although initially not all the participants propose the same solution, after discussion among all participants, the users finally agree to accept the option of a TFM constrained volume for the time period 1930Z-2130Z. With input from the users, Oceanic TFM establishes the following altitude stratification plan:

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10 Self-separation is aided by automated capabilities in the cockpit that provide the pilot with situational awareness and measurements of separation relative to other aircraft. ATC can provide intent information and separation instructions to the cockpit, and the cockpit can share separation information with ATC.

- Westbound to the U.S.: fly at FL 380
- Westbound to Caribbean basin/South America: fly at FL 360 or FL 400
- Eastbound: fly at FL 370 or FL 390

In addition, with the help of an automation capability, Oceanic TFM examines both the PRMs submitted by the affected users and the altitude stratification plan, assigns an altitude to each flight for its duration in the TFM constrained volume, and specifies amendments to the PRM route to achieve the assigned altitude. These amendments include altitude climbs or descents necessary to achieve the assigned altitude in the constrained volume. The users agree to submit flight plans in accordance with these constraints and specifications, and the ATM system takes note of each such negotiated flight plan. (In this case, TFM does not require that achieving the planned time of entry to the TFM constrained volume be necessary to ensure the assigned altitude and associated altitude climbs or descents. For example, if flight MXY 308 were expected to be late entering the TFM constrained volume by 15 minutes, Oceanic ATC would still give priority to this flight in order for the flight to climb to and remain at FL 380 while transiting the TFM constrained volume, as stated in MXY 308's flight plan.)

After coordinating with the ACCs of Gander, Shanwick, Santa Maria, and Piarco, Oceanic TFM publishes details about the Deep Waters TFM constrained volume on the NAS Information System.

The constraints are developed with modeling automation support. The automation suggests the size of the constrained volume based not only on demand and complexity of traffic flows, as indicated in the PRMs, but also on ATC's ability to grant clearances in accordance with the flight plan negotiated for each affected user.

Based on the demand profile generated by the automation system for the entire New York Oceanic FIR, New York Oceanic TFM works with New York Oceanic ATC to determine sector boundaries for the FIR. These sector boundaries, as well as any hand-off requirements, are coordinated with the ACCs of the neighboring FIRs, as well as with domestic TFM at Boston Center, New York Center, Washington Center, Jacksonville Center, and Miami Center.

1100Z. Users begin submitting flight plans, revising the information on the PRMs submitted earlier, if necessary, to factor in updated wind and weather forecasts as well as revised business objectives.

New York Oceanic ATC evaluates the filed flight plans, looking for significant changes from the PRMs filed at the beginning of the day and considering the additional demand from users who had not submitted a PRM.[11] ATC takes particular note of the TFM constrained volume in the Deep Waters airspace and those flights for which a flight plan was negotiated with Oceanic TFM (such as MXY 308). ATC makes plans to ensure that such flights can be guaranteed the specified altitude in the TFM constrained volume, as well as the step climbs or descents specified in the negotiated flight plan.

1300Z. The NAS automation system continuously exchanges updated flight plan and flight following information with the automation systems of CAAs controlling the Shanwick, Brest, Madrid, Lisboa, Gander, Santa Maria, and Piarco FIRs. Consequently, the New York Oceanic facility is able to view the progression of traffic flows in the entire North Atlantic and Caribbean airspaces.

New York Oceanic TFM and domestic TFM are monitoring the arrival rush from Europe. Thunderstorms over the major airports of western Europe (specifically, London, Paris, and Amsterdam) have delayed departures to the U.S. by as much as two hours, causing a shift in the usual arrival rush. To prepare for these late arrivals, New York Oceanic TFM has been collaborating with TFM in Boston Center, New York Center, and Washington Center. Due to fuel concerns, arrival priority is given to oceanic flights. In turn, each center collaborates with its approach control facility and tower traffic management coordinators on contingency plans. New York TFM, for example, plans a ground hold on internal departures for approximately 15 minutes to accommodate the oceanic arrivals to John F. Kennedy International Airport and Philadelphia airports.

TFM considers possible runway configurations. Boston Center plans for short-term airborne holding for domestic arrivals.

1900Z. Unlike operations in Oakland Oceanic airspace, there are no reservations for gateway entry to specific altitudes in New York Oceanic airspace. Flights are loaded onto tracks or cross the entry fixes on a first-come, first-served basis. New York Oceanic TFM collaborates with domestic TFM to ensure that demand for gateway entry fixes is manageable.

This is the time of the usual departure rush from the East Coast. An unexpected, fast-developing thunderstorm off the coast of New York is causing a large section of oceanic airspace and domestic airspace to be closed to transit for an estimated five hours at minimum. This closing of airspace directly impacts departure flows to an oceanic gateway fix that is

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[11] Before users file their flight plans, they can use in-house or commercially-developed software to evaluate the desired route of flight. This software checks the proposed route against demand information and TFM constraint information (such as about any TFM constrained volumes) in the NAS Information System to identify congested airspaces or any TFM constraints the route would need to follow.

within a mile of the storm. Consequently, New York Oceanic TFM moves the gateway fix further into the ocean, and works with domestic TFM to create departure routes to the relocated gateway fix. This is done with the help of an automation capability that considers traffic already en route, future demand, traffic flow patterns, and departure routes from nearby airports, such as Kennedy, La Guardia, and Logan International.

New York Oceanic TFM, in a conference call with the Command Center and traffic management coordinators at New York Center and Washington Center, develops a plan for the oceanic departures and arrivals. For this departure rush, the plan involves giving priority to flights already en route in domestic airspace (for example, from Dallas/Fort Worth and Los Angeles) that are within one-half hour of entering oceanic airspace. It is also decided that, for the remainder of the day, oceanic departures from Boston Center, New York Center, and Washington Center airports be placed on Approval Request (APREQ) to accommodate flights already en route. For flights that have not yet departed, users replan their departure routes to avoid the congested New York airspace, choosing other gateway entry fixes. No flights are canceled, but delay is incurred, especially for the departures from airports close to the closed airspace.

Section 4

Capabilities Needed to Support this Operational Concept

The concept of operations for TFM described in this document emphasizes collaboration among TFM facilities, and among traffic management personnel and AOCs. Such a collaborative environment requires, for example:

- Reliable and timely information exchange and improved communication between TFM and NAS users
- Improved understanding of system resource capacity and demand for those resources
- Capabilities to aid in problem detection and collaborative problem solving
- Strategy evaluation capabilities to determine the impact of candidate traffic management actions on the NAS
- Improved ways to measure the performance of the NAS (both real-time performance and performance over time)

In particular, the scenarios of this document suggest the capabilities described in Table 4-1. These capabilities require considerable development in infrastructure and automation, some of which is currently in progress. The NAS Information System, for instance, represents a considerable portion of the system development for this concept, and is a key enabling technology for the concept.

Table 4-1. Capabilities to Support TFM in 2005

Capability	Operational Use
NAS Information System	Provides information on the status of the NAS, including demand for NAS resources at a given point in time, the availability of SUAs for civilian use, current and predicted traffic management constraints, airport runway configurations, capacity of NAS resources, and so forth. The NAS Information System is continuously updated and available to TFM facilities, to NAS users, and, where appropriate, to commercial vendors of information. It enhances a common awareness of traffic management situations. (Additional details on the data elements are in [RTCA, Inc., 1997b].)

Capability	Operational Use
Ability to process enhanced flight plans	Allows greater information about NAS user intent and preferences to be included in the flight plan and considered in decision making. This capability provides for updating the flight plan while the aircraft is in flight. (Additional details on the data elements are in [RTCA, Inc., 1997b].)
Improved weather detection and forecasting	Provides more accurate and timely information about aviation-significant weather and winds for display to traffic management personnel, as well as for use algorithmically.
Future situation display	Enables traffic management personnel to view current and future locations of flights. Such displays can be overlaid on a map of sector or en route center boundaries, geographic boundaries, or navigational aids.
Improved capacity and demand estimation	Better identifies demand/capacity imbalances, alerting personnel to situations that could require traffic management action. This capability requires more accurate demand information and estimates of traffic complexity, as well as improved methods of estimating the capacity of system resources.
Strategy evaluation	Analyzes the impact to the NAS of candidate traffic management strategies (for example, airborne holds, ground holds, MIT constraints). Also referred to as a "what-if" capability, strategy evaluation support enables traffic managers to test out different strategies to determine how well they satisfy traffic management objectives. Metrics to evaluate strategies could include sector traffic counts, degree of complexity, and system delay.

Capability	Operational Use
Ability to evaluate proposed flight route against airspace, flow constraints, and airspace density	Enables NAS users to identify predicted problems with closed airspace (for example, severe weather, SUA), flow constraints, and congested sectors before a flight plan is amended. This capability is based on information contained in the NAS Information System. NAS users and commercial vendors can therefore develop such a capability for their specific needs.
Visual collaboration	Allows multiple traffic management facilities and equipped NAS users to observe the same traffic situations. This capability provides a platform for collaborative use of decision support for flow problem definition, analysis, and resolution.
FCA definition	Enables traffic management personnel to define airspace where traffic flows need to be constrained, for use by other support systems. An FCA has vertical, lateral, and temporal dimensions.
FCA problem detection	Evaluates all flight plans against a defined FCA to identify both the magnitude of a flow situation and specific flights that are expected to penetrate the FCA.
Group aircraft trial planning	Supports strategy evaluation by enabling traffic management personnel to develop and visualize candidate routes for more than one flight at a time.

Section 5

Issues for Further Analysis

Five major issue areas have surfaced during development of this concept of operations: (1) infrastructure for information exchange, (2) scope of collaboration in the NAS, (3) equity to users, (4) issues associated with oceanic operations, and (5) dynamic vertical resectorization.

5.1 Information Exchange

This concept of operations is built upon information exchange among traffic management personnel and NAS users and among TMCs at local facilities and TMSs at the Command Center. Without accurate and timely information, the concept presented in this document is not feasible. To support information exchange, the availability of a NAS Information System has been assumed. However, the requirements that would drive the architecture of such a system are insufficiently understood. Many of the needed data elements are known from work done by the RTCA (RTCA, Inc., 1997b), but factors such as update frequency and accuracy requirements have not been specified.

- Which required information elements are available? How easily are they translated into a form usable by automation?
- How can information integrity be ensured? Who is responsible for which information items? What procedures can be used to ensure accuracy, and what protections must there be against accidental or unauthorized changes?
- What mechanisms are available for updating information? What are the workload implications?
- What information must be protected as proprietary to specific users, and what can be made available to all users, either directly or in aggregated form?
- Which information of general interest, such as commercially-produced weather forecasts, can be shared only upon payment to a provider? How is the distribution of such information managed? What is the impact on collaboration of unequal access to such information?
- Which information, despite not being sensitive or proprietary, nonetheless needs to be distributed only to a subset of users of the NAS Information System?
- Which data elements, for example technical data required by computational capabilities within FAA facilities, should be distributed outside the structure of a

system designed to share information with users? What requirements do such data elements impose on communications infrastructure?

The requirement to provide and update information has workload implications that may affect the feasibility of some forms of information exchange called for in this concept of operations. Furthermore, until the details that define the NAS Information System are known, design of the system cannot proceed, and no estimate of cost can be made to trade off against the benefits of the collaborative operations the system will support.

5.2 Scope of Collaboration

The concept presented in this document pursues the benefits of a collaborative system providing for routine sharing of information, expression of user preferences, and in some cases shared, interactive decision making. The degree of collaboration varies in different situations. Sometimes, the actions required to resolve a flow problem may have such a small impact on traffic that the benefits of collaboration do not justify the extra workload it imposes on TFM and AOC personnel. Sometimes the time available between identification of a problem and when it must be resolved may be too short to support collaboration, or may support only a limited form.

Although this document has proposed levels of collaboration that seem appropriate to the different situations discussed, some validation of the concept will require better understanding of the appropriate scope of collaboration:

- How large an impact must an action have before the benefits of collaboration are worth the effort?
- How long does a cycle of interactive decision making take, and how does this depend on the size of the problem and the number of participants?
- In situations where sufficient lead time exists, would it be beneficial for users to propose multiple solutions, ranked by preference, or is it better for them to provide one solution at a time, iterating if the initial solution turns out to be incomplete?
- Can we define classes of situations in which different levels of collaboration are appropriate (e.g., local weather to be avoided versus excessive traffic density in a similar volume of airspace)?
- What metrics are needed to identify congestion problems, and what lead times are realistically possible?

5.3 Equity to Users

Equity to NAS users must be maintained in the collaborative environment. Users cannot be expected to act voluntarily to help solve a problem if other, non-cooperating users can gain a competitive advantage by benefiting from the problem resolution without making comparable operational adjustments. This document has proposed mechanisms for maintaining equity in some cases, but has left others unresolved. It has addressed the question, for example, with regard to airport flow initiatives, by allowing arrival slot allocations to depend on schedules that were in place before the problem was identified. This avoids penalizing NAS users for adjustments they make between identification of the problem and the implementation of a capacity control program. For other situations, the answer is less clear.

- To what extent do the actions of those who take the initiative to avoid a predicted situation constrain the strategies needed once the situation develops? For example, should a flight that was rerouted independently around weather, without waiting for a collaborative session, be exempt from further rerouting to resolve the situation?
- What incentives are needed for NAS users to cooperate in resolving a situation? What are the consequences of their failure to do so? For example, should an early decision to proceed through a weather area lead to a more extensive reroute when the weather materializes and the flight cannot proceed? If so, what are the workload implications for the air traffic management system?
- What is the tradeoff between providing predictability for cooperating NAS users (who get their replanned routes) and providing equitable access to users, such as general aviation pilots, who may not be equipped to participate in collaboration?
- During arrival rushes, is it possible to accommodate an AOC preference for resequencing among its own flights without changing the arrival order of other flights?

In these and similar situations, operations that are most equitable for NAS users may be inefficient or even impractical from the point of view of the ATM system. Resolving equity issues is critical for the operational acceptability of collaborative solutions to traffic flow management problems.

5.4 Oceanic Operations

A number of issues were identified during the development of the oceanic scenario in Section 3.3.8.2. Although this document has provided an initial concept for Oceanic TFM, more work is needed. These issues need to be addressed and a more comprehensive concept developed.

- Does the idea of the TFM constrained volumes give the users enough benefit in predictability to make this a worthwhile concept? In fact, does it really offer the users a less restrictive alternative to flexible tracks? Are sufficient collaboration opportunities with regard to the TFM constrained volume provided?

- What is the right size and shape of the TFM constrained volume so that Oceanic ATC is able to guarantee the altitude within the TFM constrained volume and the altitude climbs/descents, as specified in the negotiated flight plan?
- How can Oceanic TFM work with foreign ACCs to obtain the necessary step climbs to the filed altitude in the TFM constrained volume?
- When a TFM constrained volume is in effect, what would happen in the case that a flight which is planned to fly at a specified altitude in the constrained volume, experiences low fuel? For example, suppose a flight is planned to descend from FL 400 to fly in the constrained volume at FL 380 then climb up to FL 400 after exiting the constrained volume. Suppose further that, due to an unexpected reroute or inaccurate winds information, the flight is low on fuel prior to entering the constrained volume. How is that flight managed for the remainder of its en route time? Should it be required to descend to FL 380 to enter the constrained volume, per its flight plan, or should it be allowed to remain at FL 400 in order to minimize fuel burn?
- Under what conditions should a user be required to submit PRMs for the purposes of better demand prediction? (For example: PRMs must be filed for a flight that requests a "predictable profile.")
- Is the order of activities for collaboration, suggested in the scenario, reasonable—that is, users collaborate with Oceanic TFM first about choice and parameters of a TFM constraint, then Oceanic TFM collaborates with neighboring FIRs?
- To what extent are users willing to relinquish flexibility (for example, in Free Routing) in order to obtain a higher level of predictability?
- The scenario (at 0900Z) suggests that once users and TFM agree on implementing a TFM constrained volume, then the following actions are taken:
  - TFM determines the altitude for each affected flight
  - TFM assigns an altitude to each affected flight
  - TFM determines the step climbs/descents necessary to achieve the assigned altitude on entry to the constrained volume

  How do users feel about TFM taking responsibility for each of these actions? If, for example, users elect to determine the step climbs/descents, how can their individual routing decisions be made so that they collectively do not cause a crossing or congestion problem prior to entering the constrained volume? (In other words, what can be done so that the problem is not merely moved elsewhere?)

- What incentives are necessary (other than priority in step climbs/descents to the constrained volume) for flights agreeing to the conditions of the TFM constrained volume?
- After a flight has been assigned an altitude for the constrained volume, how should the following actions be managed?
  - The pilot requests a different altitude than that agreed to by TFM and the AOC
  - The controller clears the flight for a different altitude than agreed to by TFM and the AOC
- How willing are users to provide continuous updates to flight progress (that is, progress along the route in the filed flight plan) in order for the ATM system to obtain better information about demand and for the users to obtain higher levels of predictability?
- How feasible is it to move an oceanic gateway further toward the ocean?
- How does domestic ATM manage demand-capacity imbalances for National Route Program (NRP) flights today or in 2005? Can that solution be used to solve similar situations in oceanic airspace?
- Should the NRP be extended into oceanic airspace, such that the user can file a flight directly to the oceanic gateway, or directly to its destination?

5.5 Dynamic Vertical Resectorization

Capabilities originally proposed for 2005 included dynamic vertical resectorization, consisting of adjusting the floor and ceiling altitude limits for a sector or group of sectors. This type of resectorization would be useful when a problem is caused by aircraft volume that is concentrated within a limited number of altitudes. An example is when meteorological conditions (turbulence, high altitude winds) are such that most users elect to cruise at altitudes that are in close proximity to each other, such as FL 310 and FL 330.

Changing the definition of a sector, beyond the simple combining and de-combining of predefined sectors available today, raises some broad issues that need further exploration.

- What changes to sector display processing and equipment are necessary to accommodate dynamic vertical resectorization? What additional flight data processing is required to send flight information to the correct position?
- What additional training is needed so controllers can take over airspace they might not normally work? What effect would shifting responsibility for airspace from one controller to another have on situation awareness?
- What is needed to address concerns about operational acceptability, such as the following?

- What are the safety implications of dynamic vertical resectorization?
- How does dynamic vertical resectorization change controller responsibilities? What are the implications for labor-management relations?
- How does dynamic vertical resectorization affect interfacility agreements and other standard practices for handoffs between facilities?
- What impact does dynamic vertical resectorization have on communicating with pilots, such as relaying frequency changes (whether or not this function is automated)?

While the technical barriers to this capability are no greater than those for other capabilities proposed in this concept, adding the concerns about operational acceptability and recognizing the long lead time needed to work out such issues leaves serious doubts that dynamic vertical resectorization is feasible in 2005.

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Glossary

ACRONYMS

ACC	Area Control Centre
ADF	Airline Dispatchers Federation
ADS	Automatic Dependent Surveillance
AOC	Aeronautical Operational Control
APREQ	Approval Request
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATM	Air Traffic Management
ATO	Air Traffic Operations
CAA	Civil Aviation Authority
CAASD	Center for Advanced Aviation System Development
CRS	Computer Reservation System
DFW	Dallas/Fort Worth International Airport
FAA	Federal Aviation Administration
FCA	Flow Constrained Area
FIR	Flight Information Region
GA	General Aviation
ICAO	International Civil Aviation Organization
INS	Inertial Navigation System
MIT	Miles in Trail
MTT	Minimum Time Track
NAS	National Airspace System
NAT	North Atlantic
NAVAID	Navigational Aid
NRP	National Route Program
OAG	Official Airline Guide
PRM	Preferred Route Messages

SID	Standard Instrument Departure
STAR	Standard Terminal Arrival Route
STL	Lambert-St. Louis International Airport
SUA	Special Use Airspace
SWAP	Severe Weather Avoidance Program
TFM	Traffic Flow Management
TMC	Traffic Management Coordinator
TMS	Traffic Management Specialist
WATRS	West Atlantic Route System

DEFINITION OF TERMS

Aeronautical Operational Control (AOC): Any organization that provides flight planning and flight following services to NAS users (ICAO definition). Examples include: Airline operational control facilities, military dispatch facilities, and private dispatch centers. All of these organizations are normally responsible for safe and efficient operation of user resources.

AOC Staff: Individuals at an AOC responsible for flight scheduling, flight planning, and flight following. Examples include dispatchers at air carrier AOCs, Air Traffic Control (ATC) coordinators, military flight dispatch, and general aviation (GA) pilots.

Air Traffic Management (ATM): Term denoting a combination of air traffic control (ATC) separation services and traffic flow management (TFM) services.

Collaboration: Process of joint decision making based on mutual understanding regarding goals (shared and independent) and situation. Collaboration requires timely and accurate information exchange between NAS users and ATM service providers, and sharing responsibility for system management.

Initial Daily Operating Schedule: (as defined in RTCA, Inc., 1997b) Updated scheduled flights on a daily basis, the same as the one available on Computer Reservation System (CRS). It contains new flights (e.g., charter), extra sections, and ferry or balancing flights. For major airports, it includes the current gate plan for all arrivals and departures.

Local Facility: Individual ATM facilities responsible for air traffic operations within their assigned airspace; en route center, terminal radar control, or air traffic control towers.

NAS Users: Aircraft operators, such as air carriers, commuter and air taxi airlines, cargo carriers, military aircraft, and general aviation.

Non-participating flights: Either flights whose AOCs have chosen not to participate in the collaboration or flights that are not equipped to participate (for example, most GA).

Traffic Flow Management: Flow management functions performed by Traffic Management Coordinators (TMCs) at local facilities (en route centers, terminal radar controls, and air traffic control towers), and by Traffic Management Specialists (TMSs) at the Air Traffic Control System Command Center (ATCSCC).

Traffic Management Personnel: Traffic Management Coordinators at local facilities, and Traffic Management Specialists at the Air Traffic Control System Command Center (ATCSCC).

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