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MITRE PRODUCT

A Strawman Concept of Use for Reroute Capabilities in the Traffic Flow Management Infrastructure

August 2001

M. A. Hermes

P. A. Nussman

N. J. Taber

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Center for Advanced Aviation System Development
McLean, Virginia

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and Project Approval:

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Anthony G. Chambliss
Program Manager
TFM Decision Support System Evolution

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Table of Contents

Section	Page
1. Introduction	**1-1**
Background	1-1
Collaboration in the Rerouting Process	1-6
2. Detailed Description for *Resolve Area Constraints*	**2-1**
Monitor Situation and Develop and Adjust Intent Activities	2-1
Define Constraint Activities	2-6
Plan Options and Evaluate Alternatives Activities	2-11
Negotiate Activities	2-16
Distribute Resolutions and Execute Resolutions Activities	2-20
Evaluate Strategy Activities	2-22
3. Issues and Next Steps	**3-1**
Issues	3-1
Next Steps	3-1
List of References	**RE-1**
Glossary	**GL-1**

List of Figures

Figure	Page
1. Collaboration Process	1-3
2. Activities for Resolving Each Category of Flow Problems that Trigger Rerouting	1-6
3. Activities, by Environment, for Resolve Area Constraints	1-7
4. Action Steps for the *Monitor Situation* and *Develop and Adjust Intent* Activities	2-2
5. Action Steps for the *Define Constraint* Activities	2-6
6. Action Steps for the *Plan Options* and *Evaluate Alternatives* Activities	2-11
7. Action Steps for the *Negotiate* Activities	2-16
8. Action Steps for the *Execute Resolutions* and *Distribute Resolutions* Activities	2-20
9. Action Steps for the *Evaluate Strategy* Activities	2-22

Section 1

Introduction

Much research and development has been conducted to explore various aspects of the rerouting process in aviation. However most of that activity has focused on automation components that support individual facilities' activities in rerouting, such as those of the Traffic Management Unit (TMU) in the Air Route Traffic Control Center (ARTCC). This study takes a broader look at rerouting, including collaboration activities, and is intended to provide insights into the complexity of the process.

This paper discusses the process of collaboration for a specific set of Traffic Flow Management (TFM) problems and the approaches to resolving them. The concepts in this paper are also confined to the interaction among three primary types of Federal Aviation Administration (FAA) and National Airspace System (NAS) user facilities: a generic ARTCC, the Air Traffic Control System Command Center (ATCSCC), and a generic Aeronautical Operations Center (AOC). It is understood that significant additional collaboration occurs, within such facilities and with other environments, but is not explicitly addressed in this document.

This paper explores activities, across these three types of facilities, with the focus on rerouting aircraft to relieve demand that is expected to reach or exceed safe limits. These limits reflect both the maximum capacities of the airspace and constraints on that airspace, such as weather, that reduce the available capacity. The reader is assumed to have some familiarity with the terminology and systems used for TFM.

This study offers a near-term concept, intended as a starting point or strawman for discussion among the organizations that conduct collaborative rerouting. The concepts presented are generic and can encompass approaches used for TFM strategic planning and tools currently being used or in development.

The results provide a high level view of the activities needed for collaboration during rerouting and suggest steps in which automation capabilities could be helpful. As reroute capabilities are added to the TFM infrastructure (TFM-I), the automation supporting collaboration to resolve flow problems, the collaborative rerouting process will evolve to make use of those capabilities.

Background

Managing aircraft traffic flows is increasingly important in the United States as both ground and airspace resources are becoming more constrained. As reflected in the recently published FAA aviation forecast, 14.4 million flight hours were flown in 2000 and are projected to increase at a rate of 3.9 percent per year, to reach 22.7 million hours in 2012. Instrument aircraft operations requiring air traffic control will increase at an annual rate of 2.1 percent, from 53 million operations in 2000 to a projected 69 million in 2012 [1].

Three critical factors affecting TFM are:

- Environmental limitations
- National Airspace System (NAS) capacity
- Economics

The greatest environmental constraint that cannot be controlled is weather, such as winds and severe storms. But some effects of severe weather can be mitigated with appropriate planning and cooperation among aviation participants.

Air traffic control (ATC) capacity in the NAS factors in safety considerations, such as aircraft separation standards and radar position resolution, including radar accuracy and display resolution and human reaction time. Available capacity in the NAS is also affected by the mix among commercial, general, and military aviation. Other factors, such as space operations, aviation research, and security operations also affect available capacity. As aviation technology, such as ADS-B with higher position resolution, becomes mature, some incremental gains in increasing capacity may safely be made.

The economic considerations that affect TFM work indirectly via their impact on commercial and general aviation. When more passengers desire to fly between the same city pairs at the same time of day, for example, commercial aviation attempts to accommodate those passengers and establish marketing advantages. The result is rush demands to which TFM must respond.

These three factors, and their critical interdependence, are influencing the evolution of TFM, providing the driving force behind a collaborative approach to problem solving. The collaboration process is very complex but can be reduced to a stepwise process, each component of which can be aided by automation support.

Significant advances are being made in shifting to more collaborative approaches for TFM. Figure 1 illustrates the major steps in the collaboration process. Each step of the collaboration process as currently practiced by FAA and NAS user personnel is shown:

- Common situational awareness
- Projection
- Negotiation
- Consensus
- Execution
- Post-event analysis

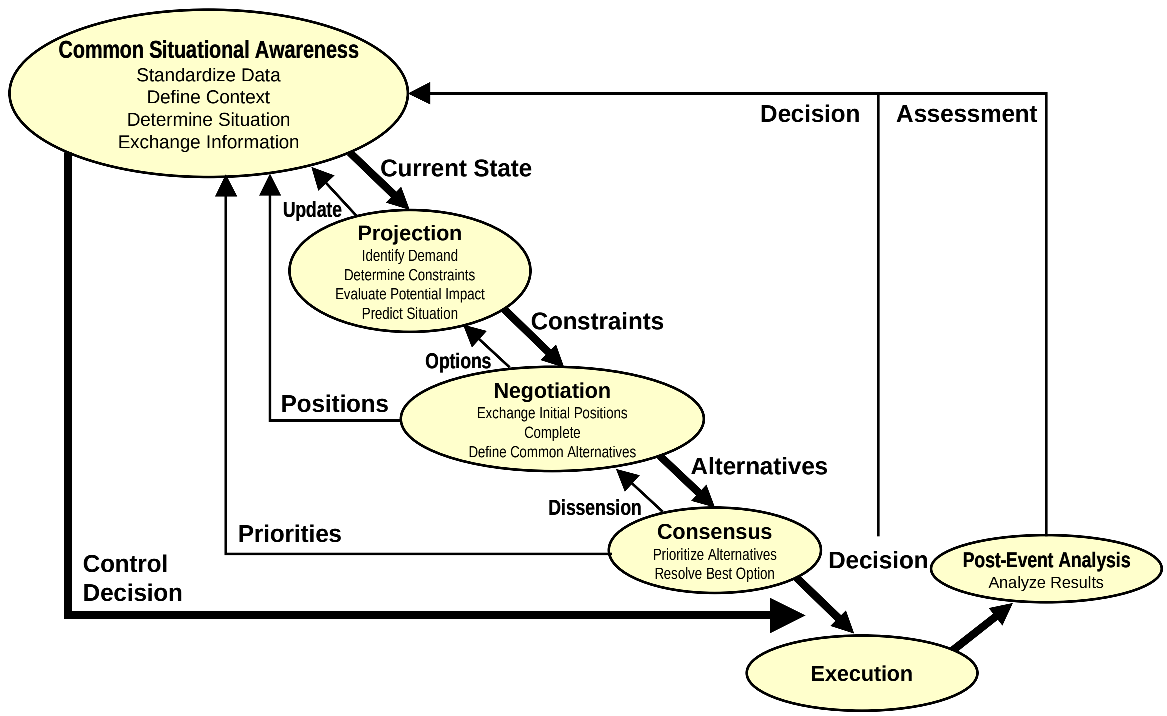

Figure 1. Collaboration Process

Collaboration needs to be accomplished quickly and decisively, and automation can assist in this process. Significant research and development has been devoted to understanding and supporting common situational awareness, projection, and post-event analysis steps, with fewer resources focused on the negotiation and consensus steps. However, identifying each step in the collaboration process helps define the information and decision support automation needed to improve each step and to integrate the flow from step to step. One example of effectively integrating these steps is the procedures developed for using the Flight Schedule Monitor (FSM) automation capabilities during ground delay programs. Following the procedures and using the FSM capabilities, the FAA can equitably allocate available arrival capacity at an airport, each participant can see frequently updated airport loading, participating airlines can select and commit to available arrival slots, and all participants can adjust as the situation changes.

As shown in Figure 1, each step in the collaboration process feeds forward and backward to other steps. Collaboration is a significantly iterative process and each iteration may include a different subset of steps. This iterative and volatile nature of collaboration makes defining automation to assist the process more difficult. For addressing very complex rerouting problems, a systematic approach is defined and applied in this document.

To address flow problems, balancing demand for a NAS resource with that resource's capacity, TFM uses various strategies, such as delaying departures or metering arrivals into an airport. The TFM strategy this paper focuses on is *rerouting*, resolving a flow problem by changing the route of flights from what had been originally filed.

Rerouting is typically applied to three major categories of flow problems, grouped by the type of demand-capacity imbalance that need to be resolved. To avoid confusion in the application of similar terms, this paper uses the following names for these three categories:

- Resolve Area Constraints
- Integrate Flows
- Balance Sectors

The first category, *Resolve Area Constraints*, includes problems typically captured with a Flow Constrained Area (FCA), hence the name. The term *FCA* refers to airspace defined by lateral, vertical, and temporal boundaries; the capability to define such boundaries is available both in the Collaborative Rerouting Coordination Tools (CRCT) Concept Demonstration and Evaluation (CDE) prototype[1] and in the Enhanced Traffic Management System (ETMS) implementation of CRCT capabilities. The flow of air traffic through the defined area of airspace is constrained because of conditions that decrease the capacity of the airspace, such as severe weather or an equipment outage. Currently, this category of problems is the focus of most collaboration efforts.

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1 The CRCT CDE prototype is currently running at two ARTCCs and the ATCSCC.

The second category, *Integrate Flows*, includes problems that arise from the need to provide an orderly and spaced stream of traffic into an airport without exceeding available sector capacity. Such situations are the result of integrating flows to a downstream resource, such as an airport with a reduced arrival rate, rather than of events decreasing the capacity of the sectors merging and spacing the traffic. While FCAs might be used to define the flows involved in these problems, the focus is on rerouting flights to provide the integrated flow downstream. Collaboration may or may not be useful in resolving problems in this category. There are several new tools being researched to address this category of flow problems.

The third category, *Balance Sectors*, includes problems where traffic expected through a sector exceeds that sector's capacity. In some cases, these problems can be addressed by moving some traffic into neighboring sectors that are not as busy, which requires only local collaboration. However, such changes may be part of a larger strategic action.

Problems in each of the triggering categories require similar steps to resolve, as diagrammed in Figure 2. Traffic managers and flight planners work together to take action by providing intent and monitoring situations, defining and compiling constraints, and assessing and selecting predefined plans. Allocating capacity, adjusting flight plans, and executing strategic and tactical traffic management plans are used to implement solutions. As situations evolve, the traffic management strategy is evaluated to determine whether it is working as expected or needs adjusting. The process descriptions in this document were developed to describe the use of rerouting capabilities. However, similar steps may apply for other types of TFM initiatives in current use or being studied.

Resolving problems in the *Resolve Area Constraints* category is under study through significant research and some operational experimentation. Capabilities currently being explored include the CRCT CDE prototype at two ARTCCs and at the ATCSCC. Although significant efforts in FAA and NAS user collaboration, such as the Strategic Planning Team (SPT), have improved response to flow problems in the NAS, systematically using collaboration tools across facilities to resolve problems in the Resolve Area Constraints category has had little concerted analysis up to this point.

Resolving problems in the *Integrate Flows* category is currently handled in a number of ways, such as through airspace design, miles in trail (MIT) restrictions, and metering. The Ground Delay Program (GDP) allocates capacity when an airport is constrained, spacing out arrivals with the upstream sectors integrating and sequencing arrivals from numerous departure airports. Integrating flows is also addressed by research on the interactions between departure and arrival flows.

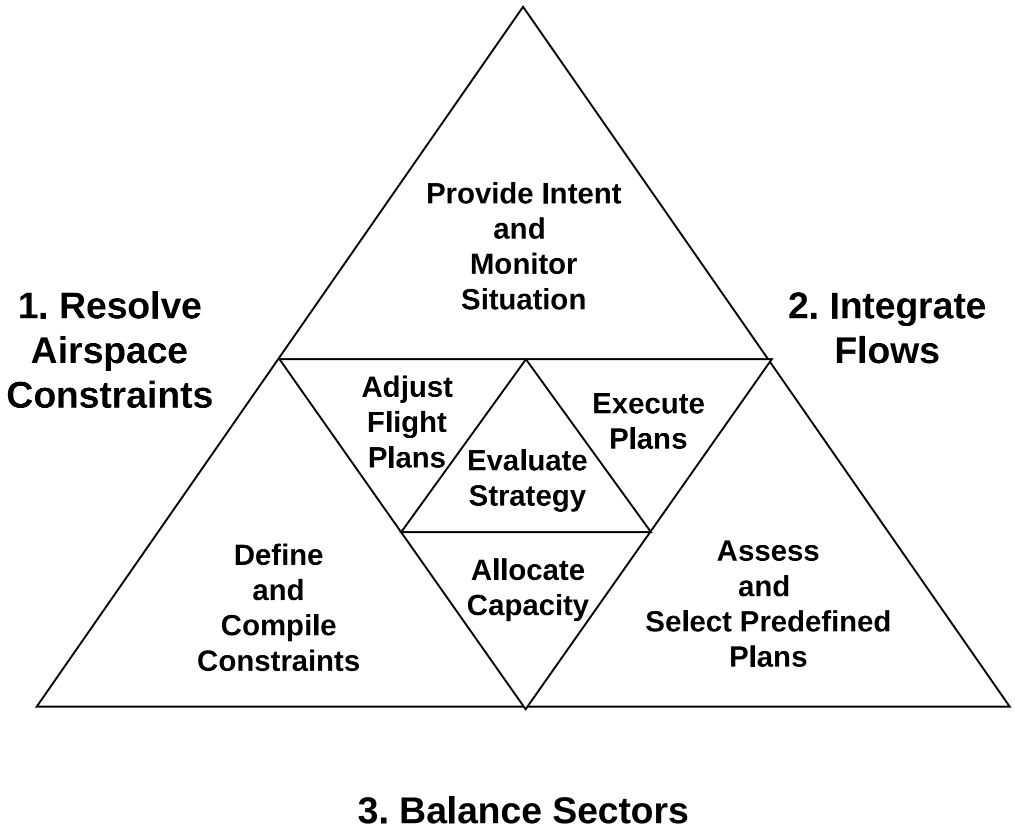

Figure 2. Activities for Resolving Each Category of Flow Problems that Trigger Rerouting

Resolving problems in the *Balance Sectors* category is currently aided by the sector loading (count) display of CRCT and by the Sector Management Tool (SMT).

Collaboration in the Rerouting Process

This paper explores steps that could be taken in three participating environments: an ARTCC, the ATCSCC, and an AOC. The first category of problems that trigger rerouting, Resolve Area Constraints, was selected for in-depth study and is the focus of this paper.

For each environment, descriptions of how rerouting could be conducted collaboratively and with automation assistance are provided in Section 2. A summary of the activities in each environment is shown in Figure 3.

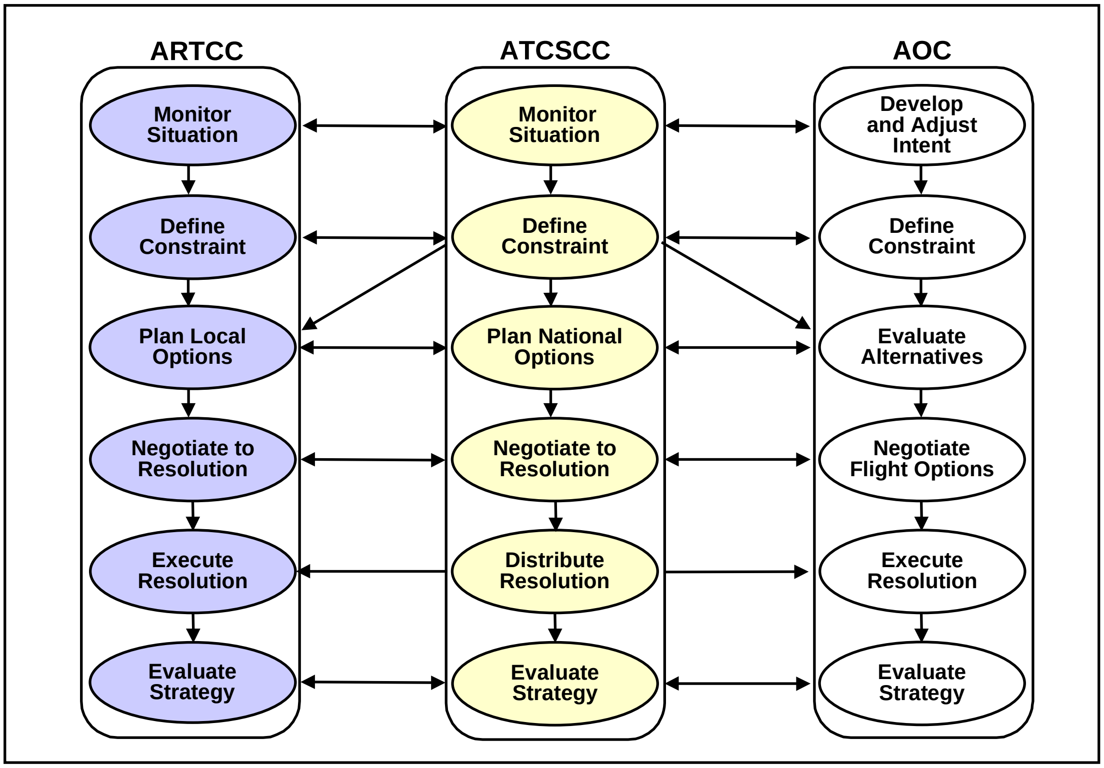

Figure 3. Activities, by Environment, for Resolve Area Constraints

The major participants collaborating to resolve area constraints are the following:

- ARTCC facility participants include traffic management coordinators (TMCs), operational supervisors, and weather specialists at one or more facilities, as well as TMCs at terminal facilities and major towers.
- ATCSCC participants include traffic management specialists (TMSs) at one or more of the operations desks, depending on the situation.
- AOC participants might include dispatchers, operations specialists, and weather specialists. While not explicitly discussed, participants from military operations centers or general aviation planning such as Flight Service Stations typically carry out activities similar to those listed for AOCs.

In most cases, a single spokesperson from each facility or AOC participates in a given collaboration. The other participants from a facility or AOC keep that person informed about situations as they arise or dissipate.

By definition, the process of collaboration is voluntary. Each organization or facility chooses how and when to participate. However, a basic premise for collaboration in the rerouting process is that each participant will benefit from the overall improvement in resolving flow problems.

The *activities* identified in Figure 3 for each participant type are intended to be generic. It is understood that each participating facility or AOC also has unique situations and activities affecting their interactions. However, such special situations are not included in the descriptions in this document.

The flow of activities for each participant is based on the decision process diagrammed in Figure 2 as applied to resolving problems in the Resolve Area Constraint category. That decision process can occur with or without collaboration. Applying the collaboration process, as shown in Figure 2, to the Resolve Area Constraints decision process, results in the activities illustrated in Figure 3.

For each activity in the process, several *action steps* are identified in Section 2, providing additional information on what carrying out that activity entails. The relationships across environments are described in terms of what information is needed to provide awareness of a common situation, what alternatives each environment might consider, how a consensus is negotiated, and how a resolution is executed. Because the collaboration process as applied to rerouting is expected to continue evolving as additional automation capabilities become available, this paper describes only an initial increment to the current process, not an ultimate or “end state” process.

The following are assumed in the descriptions in Section 2:

- The generic aspects of each environment or facility fairly represent high level activities for collaborative rerouting.
- There will be considerably more collaboration or interaction within an environment than is considered here.
- Unfamiliar terminology will be reworded to meet consensus agreements during future discussions to expand and refine collaborative rerouting concepts.

The concept presented in this document is a strawman that is expected to be refined as the understanding of collaboration in rerouting continues to evolve. Future studies may cover topics that are out of the scope of this study:

- Studying and developing equitable allocation schemes
- Developing in-depth operational concepts for collaborative rerouting
- Developing procedures for each action step
- Describing the extensive interactions within each participating environment
- Conducting extensive coordination to refine the activities and their action steps

Section 2

Detailed Description for *Resolve Area Constraints*

The major interactions among the process activities, shown in Figure 3, are identified and developed in more detail in this section. This does not preclude additional interactions not defined here. In addition, each activity and its action steps do not necessarily proceed sequentially down through the illustrated process. There is also significant iteration among steps and within steps that is not illustrated in the figures. However, the action steps capture the general flow of information, projections, negotiation, consensus, and execution.

Note that all of these steps are done repeatedly throughout a day, as new information becomes available. Frequent iteration through the steps and revisiting earlier actions are understood as part of the normal collaboration and decision-making process. However, these cycles are not explicitly noted in the following descriptions.

Currently, most of the action steps are done mentally and verbally, with little entered into an automation system until reaching a decision about how to resolve a flow problem. It is expected that some additional interactions will need to be captured electronically to make full use of planned automation tools.

Each action step in the following discussion is numbered for cross-reference to the diagrams. The steps are numbered as follows:

- The leading number indicates the activity of which the action step is a part.
- The second number (after the first decimal) represents the facility type:
  - 1 for ARTCC participants
  - 2 for the ATCSCC participant
  - 3 for AOC participants
- The final number indicates the sequential step number in that activity for that facility as shown in the corresponding figure.

Monitor Situation and Develop and Adjust Intent Activities

The action steps for the two Monitor Situation activities and for the Develop and Adjust Intent activity are shown in Figure 4.

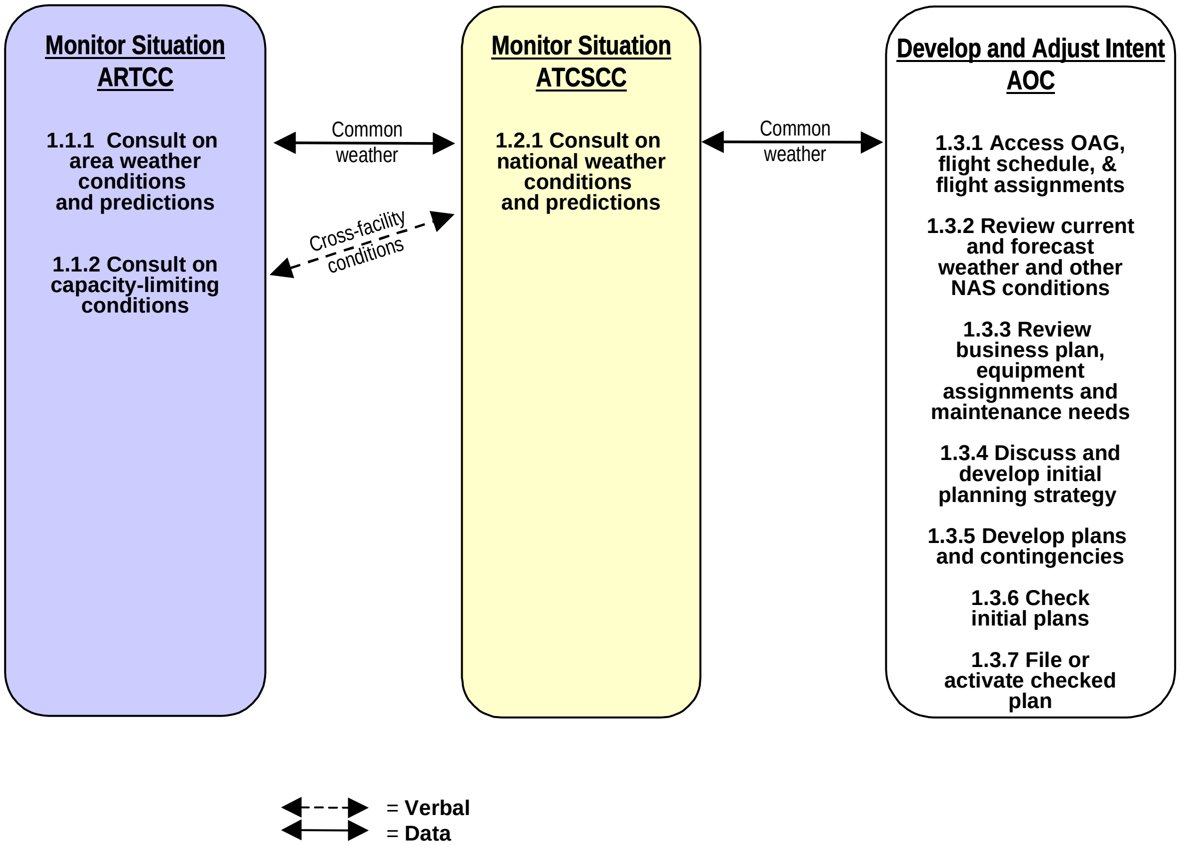

Figure 4. Action Steps for the *Monitor Situation* and *Develop and Adjust Intent* Activities

Monitor Situation (ARTCC)

Step 1.1.1 Consult on area weather conditions and predictions

The ARTCC TMC consults with the facility meteorologist and other sources (such as operational supervisors, tower and terminal personnel) to maintain an up to date understanding of the current and predicted weather conditions in and around the facility's airspace. The TMC also has access to the Common Convective Forecast Product (CCFP). For example, when an operational supervisor reports that pilots are complaining of clear air turbulence at the most heavily traveled altitudes in a sector, the TMC knows that the effective capacity of the sector at those altitudes is reduced.

Step 1.1.2 Consult on capacity-limiting conditions

The ARTCC TMC consults with operational supervisors, terminal facility TMCs, and other sources (such as notices about special events and equipment outages) to maintain an up to date understanding of any events or conditions other than weather that affect the capacity of the facility's airspace. For example, an equipment failure that decreases radar coverage in a sector reduces the number of flights that can be handled by that sector. On the other hand, conditions can also change in ways that increase the previously reduced capacity of the facility's airspace. The TMC may also need to query the ATCSCC about activities external to the center that may influence capacity assessments.

Monitor Situation (ATCSCC)

Step 1.2.1 Consult on national weather conditions and predictions

The ATCSCC TMS consults with meteorologists and other sources to maintain an up-to-date understanding of the current and predicted weather conditions around the country. The TMS also has access to the CCFP.

Develop and Adjust Intent (AOC)

This internal carrier activity won't be significantly changed by most of the planned TFM-I capabilities. The carriers are looking at whatever constraint information they can get, as early as they can get it. Note that there is much variation among carriers in how they carry out this activity. This description is only meant to summarize the activity, with an emphasis on looking at constraints as early as possible and trying to anticipate the effect on their business.

Step 1.3.1 Access flight schedule and flight assignments

Each AOC has access to the carrier's flight schedule for the day and initial assignments of airframes to flights.

Step 1.3.2 Review current and forecast weather and other NAS conditions

Each AOC continually reviews the current and forecast weather, pulling the data from a wide variety of sources, for consideration in how the weather might impact their flights. Those with web browsers have access to the CCFP. Each AOC also stays current on the conditions at airports, which are factored in to how flights are flown and which airframes are assigned to those flights. Information is also available on other conditions affecting their flights, such as FAA equipment outages and special events like the Olympic Games. ATCSCC advisories via the ATCSCC web page and Notices to Airmen (NOTAMs) provide additional information on expected NAS conditions.

Step 1.3.3 Review business plan, equipment assignments and maintenance needs

Each AOC tries to meet the business plan (daily scheduled operations) when assigning airframes to flights. This assignment must consider the scheduled maintenance needs of each airframe, as well as any current problems that might affect when, where, and how the airframe can fly. For example, the AOC might determine that an airframe with certain types of mechanical discrepancies could still fly on some routes, and not on others, making the trade-offs about the resulting reduced performance and increased cost for that flight. For example, if equipment that is only required on over-water flights is not functioning, the airframe could still be assigned to a flight that stays over land.

Step 1.3.4 Discuss and develop initial planning strategy

Each AOC determines whether the scheduled operations can be flown, given the weather and other conditions, revisiting these decisions throughout the day as the situation evolves. If necessary, the schedule is modified by canceling, delaying, and creating new flights. For example, when weather is expected to reduce capacity at an airport for extended periods of time, the AOC must decide which flights to cancel and when to do so, to keep delays down and minimize disruptions to other flights.

Step 1.3.5 Develop plans and contingencies

Each AOC develops flight plans, as well as planning for diversions to alternate airports and for extra fuel to handle anticipated delays. The AOC also continues exploring contingencies for handling possible disruptions to the schedule, preparing plans that may be needed for the more likely alternatives.

Step 1.3.6 Check initial plans

Each AOC checks the flight plans against known filing constraints. When the Flight Plan Preprocessor Prototype (FPPP) becomes available[2], proposed plans can be sent for automatic

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[2] The Flight Plan Preprocessor Prototype is a research activity currently in concept development and is planned to:

- Convert the full route of flight for planning purposes
- Enable air carriers to file their intent earlier than they can today
- Allow trial planning until airspace users are ready to file their intent
- Interface with TFM systems to convey airspace user intent and to receive inputs from the traffic management specialists

checking so that problems that would cause them to be rejected can be fixed before they are filed. In some cases, the AOC may choose to provide early intent information[3] about a flight, before actually filing that flight plan. Early intent information is used to update traffic predictions and projected sector demand.

Step 1.3.7 File or activate checked plan

Each AOC files flight plans throughout the day as appropriate for the planned departures. Plans already checked by the FPPP could be activated without having to file them separately.

3 Plans are in place to evaluate an automation capability (referred to as Early Intent) to permit air carriers to submit flight path data directly to ETMS prior to the time when flight plans are normally filed with the NAS Host Computer System. Currently flight plans are typically filed with the Host only in the hour or two prior to a flight's intended departure. The new capability is hoped to improve the predictive accuracy of ETMS traffic flow models by providing more accurate routing data to ETMS earlier in the planning process. It is being developed as the first step in a multi-phased approach intended to provide air carriers with analytical tools to support flight plan preprocessing.

Define Constraint Activities

Work is under way to define a version of FCA, known as the *Flow Evaluation Area (FEA)*, for initial evaluation and coordination of possible flow problems. That work is also developing procedures for using an FEA and transitioning it to an FCA. The term "FCA" is retained in this document to cover both uses while those definitions and procedures are under discussion.

The action steps for the Define Constraint activities are listed in Figure 5.

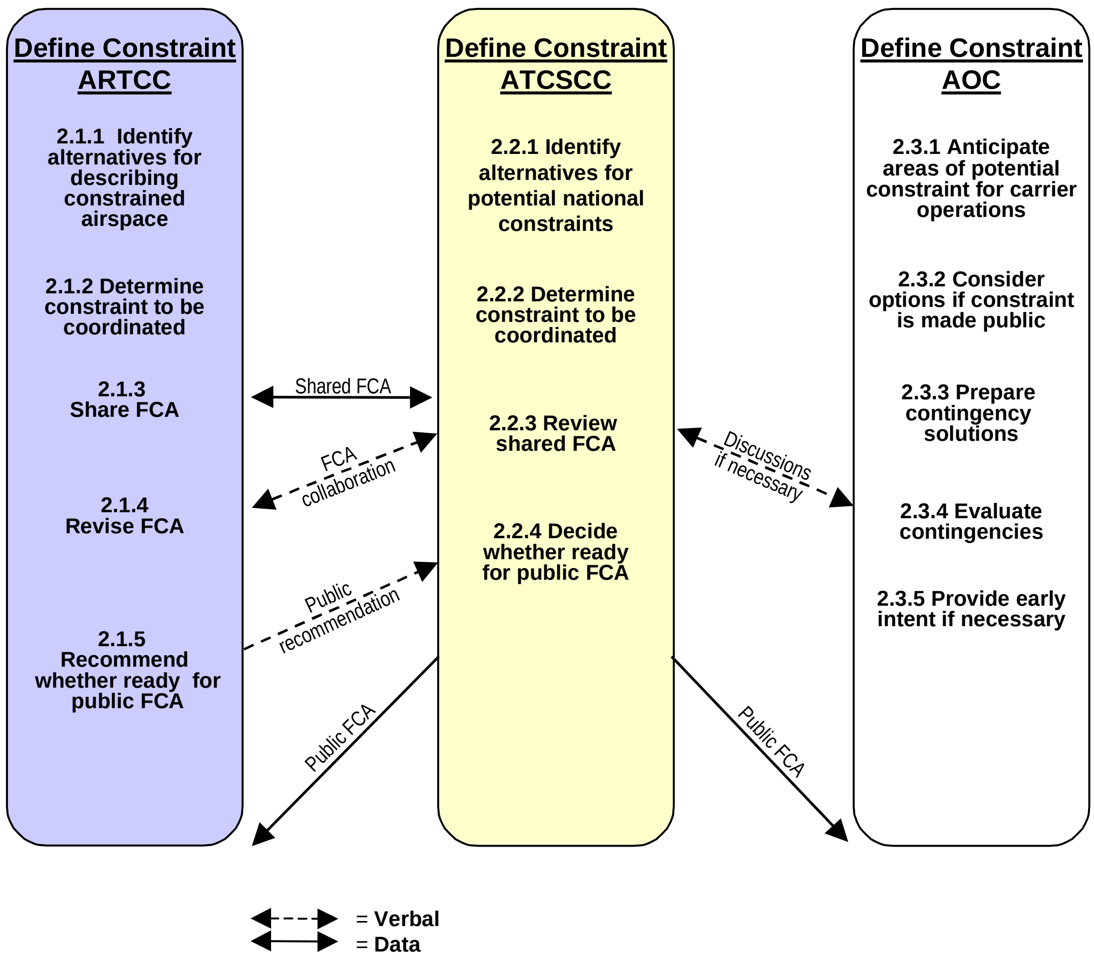

Figure 5. Action Steps for the *Define Constraint* Activities

Define Constraint (ARTCC)

Step 2.1.1 Identify alternatives for describing constrained airspace

The ARTCC TMC determines the volume of constrained airspace in the ARTCC, the time period during which its capacity is affected and the capacity available during that time period, including possible alternatives. The alternatives for defining a potential constraint might, for example, be either defining a single long thin FCA around a predicted line of thunderstorms or defining a series of scattered FCAs around the most active sections of severe weather. The basic FCA parameters for each alternative are the outline, floor altitude, and ceiling altitude. Additional FCA parameters that can be specified for each alternative are the start time and end time, as well as the direction and speed at which the FCA is to move (representing the movement of a storm front, for example). In addition, particular flows or types of traffic can be specified as part of the FCA definition. For example, when airspace around an arrival fix is constrained by severe weather, it may be sufficient to apply the constraint only to arriving flights that are filed across that fix. At this point, the FCA is private and can be viewed only by the originator [see the *CRCT Capabilities* functional description[2] and ETMS Version 7.3 requirements document[3] for additional details], but the TMC might coordinate verbally with the ATCSCC and neighboring ARTCC TMCs to provide a "heads up" on what alternatives are being considered.

Step 2.1.2 Determine constraint to be coordinated

The ARTCC TMC evaluates the alternatives and determines how best to describe the reduced capacity. For example, a TMC may define the constrained area differently for altitudes at which flights are able to pick their way between storm tops than for the altitudes at which the storms are severe enough that flights are unlikely to fly through. Even if few flights will be affected and traffic is light enough that workload concerns are not a consideration, it is important to define an FCA for each airspace volume with reduced capacity and share it with other facilities, so all constraints are known when resolving flow problems. If there is already a constraint in place, the ARTCC TMC determines what, if any, adjustments to that constraint need coordination.

Step 2.1.3 Share FCA

The ARTCC TMC selects the facilities with which to share the FCA and initiates the sharing. Sharing an FCA lets others see and edit the FCA. The TMC selects the facilities with which to share the FCA, typically including those ARTCCs that need to be involved in coordinating its definition and strategies for resolving the problem, as well as the ATCSCC. For example, the selected facilities might be those through which traffic would be rerouted around severe weather or the ones that would have to implement reroutes for flights already in the air. Currently, shared FCAs are expected to be available only to other FAA facilities that have Traffic Situation Displays (TSDs), which includes some terminal facilities. Terminal facilities might be involved for problems that affect arrivals or departures at their airports. Those that can see the FCA determine which flights are affected and analyze the impact on their own traffic.

Step 2.1.4 Revise FCA

Sharing an FCA is expected to be the basis for verbal coordination among the affected facilities. For example, a neighboring facility might point out that an FCA unnecessarily picks up an arrival stream into one of its airports, which could be avoided by reshaping the FCA slightly to exclude that flow. Based on the feedback as needed and as changing conditions or predictions warrant, the TMC revises the FCA and re-evaluates whether it adequately reflects the capacity constraint. The revised FCA is available to those with whom it is being shared.

Step 2.1.5 Recommend whether ready for public FCA

At some point, the ARTCC TMC must decide whether to recommend that a shared FCA (from this facility or another) should be made public and made available to AOCs and other FAA facilities by an ATCSCC action, and if so, whether conditions warrant making it active at this point. For a planned public FCA, the TMC may have responsibility for deciding when conditions warrant making it an active public FCA. Or the TMC may recommend that the shared FCA be deleted because the constraining conditions did not unfold as expected.

Define Constraint (ATCSCC)

For some flow problems, such as those caused by large-scale severe weather, the ATCSCC TMS will be responsible for defining flow constraints that extend across multiple ARTCCs. In this case, the TMS takes actions very similar to those of an ARTCC TMC defining a local constraint. In other cases, constraints defined by two or more ARTCC TMCs may actually be parts of a larger constraint, which the ATCSCC TMS would be responsible for defining. In either case, the TMS may develop private FCAs that would need to be shared and made public in much the same way as those developed by ARTCC TMCs.

Step 2.2.1 Identify alternatives for potential national constraints

The ATCSCC TMS determines whether local constraints are actually pieces of a larger national constraint. If so, the TMS determines the volume of constrained airspace, the time period during which its capacity is affected and the capacity available during that time period, including possible alternatives. The alternatives for defining a potential constraint are the same as for the ARTCCs. These alternatives might include, for example, either defining a single long thin FCA around a predicted line of thunderstorms or defining a series of scattered FCAs around the most active sections of severe weather. The basic FCA parameters for each alternative are the outline, floor altitude, and ceiling altitude. Additional FCA parameters that can be specified for each alternative are the start time and end time, as well as the direction and speed at which the FCA is to move (representing the movement of a storm front, for example). In addition, particular flows or types of traffic can be specified as part of the FCA definition. In some cases, additional adjustments to intent will be available from some AOCs. These data may influence consideration of FCAs. At this point, the FCA is private.

Step 2.2.2 Determine constraint to be coordinated

The ATCSCC TMS evaluates the alternatives and determines how best to describe the reduced capacity. Even if few flights will be affected and traffic is light enough that workload concerns are not a consideration, it is important to define an FCA for each airspace volume with reduced capacity and share it with other facilities, so all constraints are known when resolving flow problems. If there is already a constraint in place, the ATCSCC TMS determines what, if any, adjustments to that constraint need coordination.

Step 2.2.3 Review shared FCA

The ATCSCC TMS reviews shared FCAs received from ARTCC TMCs, considering the impact of early intent information provided by the air carriers and interactions with other situations in the national airspace. If needed, the TMS provides verbal feedback on a shared FCA to the initiating ARTCC TMC on the nation-wide implications of the FCA and facilitates verbal coordination among the TMCs of affected ARTCCs. When the TMS develops an FCA, it is shared with others and revised as needed.

Step 2.2.4 Decide whether ready for public FCA

Once the initiating TMC finishes refining the FCA definition, the ATCSCC TMS solicits input from each of the involved TMCs as to whether the FCA should be made public, and if so, under what conditions it should be made active. The TMS collects the decision options offered by the ARTCC TMCs in response. In some cases, the TMS may choose to discuss options with AOC representatives prior to declaring an FCA public, such as during the Strategic Planning Team (SPT) teleconferences that are conducted every two hours. Additional discussions may take place between the scheduled teleconferences.

At some point, the ATCSCC has to decide whether the shared FCA is ready to be made public, and if so, whether it should be planned or active. When the FCA is made a planned public FCA, there should be a triggering condition defined or triggering responsibility assigned for when the FCA will be made active. Or, when conditions do not continue to unfold as expected, the FCA may be deleted without ever being made public or transitioning from planned to active.

Define Constraint (AOC)

This section describes an internal carrier activity to evaluate potential constraints and to plan for contingencies. The carriers will focus on the impact of proposed FCAs as soon as the information is available, as well as addressing expected problems they themselves identify. Future automation capabilities that may be available to air carriers in the 2002–2005 time frame include viewing planned public FCAs and their flights that intersect those FCAs, getting feedback on flight plans from FPPP before filing, and providing early intent information before filing flight plans.

Step 2.3.1 Anticipate areas of potential constraint for carrier operations

Based on the situation information constantly being gathered by the carrier, each AOC identifies where potential constraints to their operations may occur. For example, predicted severe weather indicates that a constraint may develop.

Step 2.3.2 Consider options if constraint is made public

Each AOC considers what options are open to it if an anticipated constraint materializes. For example, if weather constrains traffic over their preferred arrival fix into a major hub airport, they may consider planning to a different arrival fix and delaying the next arrival bank as options to explore further.

Step 2.3.3 Prepare contingency solutions

Each AOC develops contingency solutions for the options it identified, developing alternative plans for the flights that would be affected.

Step 2.3.4 Evaluate contingencies

Each AOC evaluates its contingency solutions, using the FPPP (if available) to determine whether the plans would be acceptable to the system.

Step 2.3.5 Provide early intent if necessary

Each AOC decides what additional early intent information to share, based on its evaluation of contingencies. Because ARTCCs and the ATCSCC may be considering actions as a result of the same conditions that are influencing the AOC's decision, providing additional intent information may influence ATCSCC decisions regarding potential constraints. In addition, verbal discussion with the ATCSCC about potential FCAs may benefit all parties.

Plan Options and Evaluate Alternatives Activities

When an FCA becomes a public FCA, all participants can see it and determine how it affects their own traffic. This impact assessment becomes part of the on-going monitoring each TMC, TMS, and AOC continues to do. Currently, public FCAs are expected to be available to all FAA facilities with TSDs and to all air carriers that are receiving the CDMnet data feed. A publicly accessible web-based display may also be provided at some point.

The action steps for the two Plan Options activities and the Evaluate Alternatives activity are shown in Figure 6.

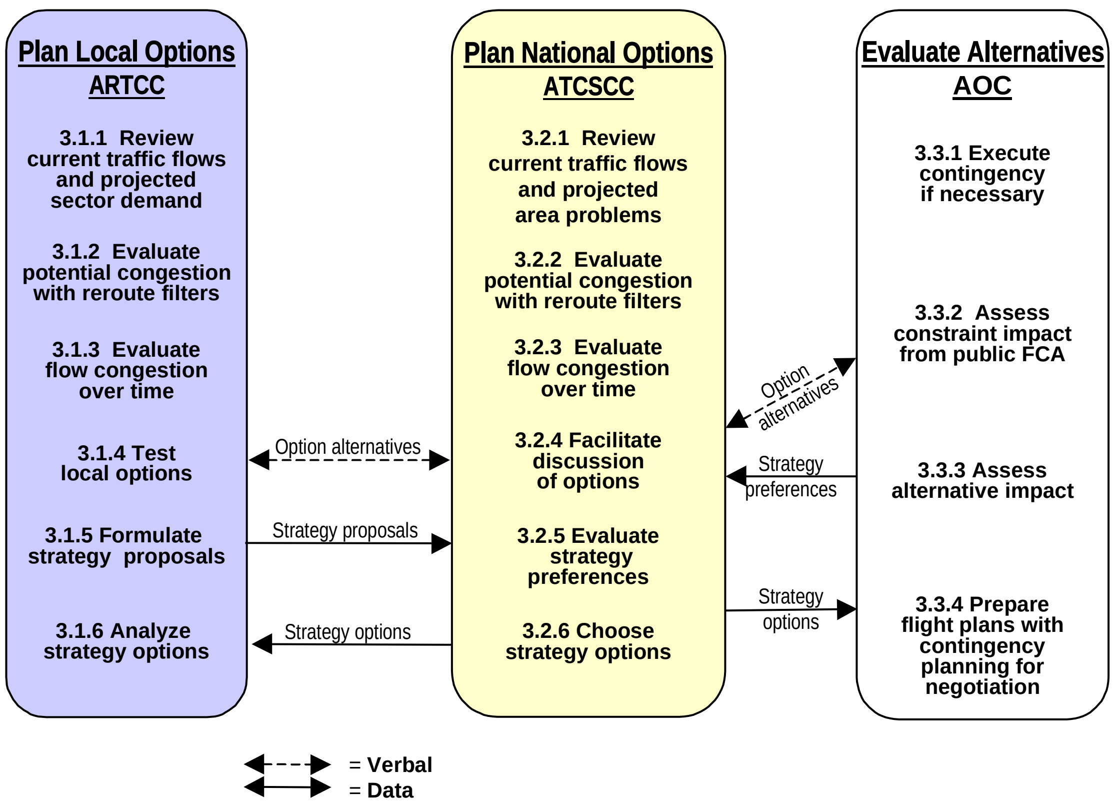

Figure 6. Action Steps for the *Plan Options* and *Evaluate Alternatives* Activities

Plan Local Options (ARTCC)

Step 3.1.1 Review current traffic flows and projected sector demand

The ARTCC TMC reviews current and projected traffic demand for the facility, using the TSD and Display System Replacement (DSR) displays, as well as applying relevant experience about how traffic might develop under the expected conditions. The TMC has access to projected demand provided on the TSD, which will include carriers' early intent information, as well as to flight plans and updates available through the facility's Host Computer System.

Step 3.1.2 Evaluate potential congestion with reroute filters

The ARTCC TMC evaluates segments of the facility's airspace for congestion problems, where the expected traffic demand exceeds capacity, given known constraints both public and shared. Specific flows of traffic can be selected and examined using various traffic filters such as origin and destination airport, direction of flight, and fix or route segment. For example, if traffic predictions indicate that an arrival sector will have more traffic than capacity during a given time period, the TMC may use a combination of arrival and departure filters for the airport to determine whether overflights are contributing significantly to that load.

Step 3.1.3 Evaluate flow congestion over time

The ARTCC TMC evaluates the expected pattern of traffic congestion over time, especially whether the duration of the congestion suggests that sectors will be unacceptably overloaded. For example, a sector predicted to be just over its sector count limit for a 15-minute period may not need action while a sector over its limit for two hours probably will.

Step 3.1.4 Test local options

The ARTCC TMC tests some initial local options (internal to the ARTCC) for resolving each potential flow problem. These options might include rerouting flights, holding internal departures on the ground, spacing traffic through congested sectors, and resectorizing the airspace. Predefined resolutions, such as Coded Departure Routes and options in the National Playbook, are also available for the TMC's consideration, as well as combinations of these options. For example, the TMC may look at holding internal departures below a sector with clear air turbulence in combination with internal MIT restrictions for major streams into the sector. The TMC also may compare various alternatives, looking at the impact on both airspace users and sector controllers. For example, the TMC may evaluate two alternatives: one that reroutes flights around the sector with turbulence and the second, spacing major streams through the sector. The TMC determines that the second alternative delays twice as many flights as the first, although both represent the same impact on the traffic counts in that sector.

Step 3.1.5 Formulate strategy proposals

Based on the evaluation of local options, the ARTCC TMC may formulate one or more strategy proposals to share with the ATCSCC and other facilities. For example, the TMC may propose that an en route spacing strategy be combined with ground delay for departures from selected airports.

Step 3.1.6 Analyze strategy options

Once strategy options are selected, the ARTCC TMC continues analyzing ways to apply those options so the resulting actions will adequately address the flow problem without causing additional problems in the facility. For example, the TMC analyzes whether ground delay for departures at selected airports will result in delays for flights arriving at those airports, due to limited space on the airport surface. The ARTCC TMC develops local resolution options for resolving the flow problem with the selected strategy, taking known constraints into account. Resolution options available for a given strategy include how to divide up the traffic into flows, which restriction values to choose for each flow, and when to begin and end applying restrictions to each flow.

Plan National Options (ATCSCC)

Step 3.2.1 Review current traffic flows and projected area problems

The ATCSCC TMS reviews projected traffic demand, using the TSD, as well as applying relevant experience about how traffic might develop under the expected conditions. The projected demand provided includes carriers' early intent information. The TMS also considers the interactions of existing and planned TFM initiatives with the consolidated constraints and the public FCA.

Step 3.2.2 Evaluate potential congestion with reroute filters

The ATCSCC TMS evaluates segments of the NAS for potential congestion problems, where the expected traffic demand exceeds capacity, given known constraints, both public and shared. Specific flows of traffic can be selected and examined using various traffic filters such as origin and destination airport, direction of flight, and fix or route segment. For example, if traffic predictions indicate that arrival traffic will exceed an airport's arrival rate during a given time period, the TMS can determine whether the flights are predominantly from one direction.

Step 3.2.3 Evaluate flow congestion over time

The ATCSCC TMS evaluates the expected pattern of traffic congestion over time, especially whether the duration of the congestion suggests that it will have nation-wide repercussions. For example, an airport where the projected arrivals exceed the airport arrival rate for a 15-minute period may not need action while arrivals exceeding capacity for two hours probably will.

Step 3.2.4 Facilitate discussion of options

The ATCSCC TMS facilitates the verbal discussion with ARTCC TMCs and interested AOCs about the alternatives available for resolving the flow problem. The discussion focuses on which alternatives to explore further. Currently, most of this discussion is held during the SPT teleconferences that are conducted every two hours. Additional discussions may take place between the scheduled teleconferences.

Step 3.2.5 Evaluate strategy preferences

The ATCSCC TMS solicits proposals for the strategies to consider in resolving the flow problem from all interested parties, collecting the proposals and preferences expressed. The TMS then evaluates the collected strategy preferences, looking for combinations that will resolve the problem and narrowing the range of options for further analysis.

Step 3.2.6 Choose strategy options

The ATCSCC TMS chooses strategy options to pursue further, based on the evaluation results, and shares them with all interested parties.

Evaluate Alternatives (AOC)

Step 3.3.1 Execute contingency if necessary

When an FCA is made public, and when a planned public FCA is made active, each AOC decides which (if any) of its contingencies need to be implemented without further collaboration and files flight plans and amendments as needed to carry out that decision. The new and revised flight plans update the traffic demand predictions available to traffic managers.

Step 3.3.2 Assess constraint impact from public FCA

Each AOC assesses the impact of the public FCA, and determines which business rules will guide their response to the public FCA. For example, one carrier may have a policy of canceling flights that are expected to be delayed at both their origin and destination airports in order to keep later flights on schedule, while another prefers to fly all of its flights no matter how much delay will accumulate by the end of the day. Each AOC then identifies strategies that address the constraints within the guidance of the applicable business rules, and participates in discussing which alternatives to explore further.

Step 3.3.3 Assess alternative impact

Each AOC develops alternative flight plans for the options under study and assesses the impact of the alternatives being considered, deciding which strategy options have the least impact on their overall operations and sharing those preferences with the ATCSCC.

Step 3.3.4 Prepare flight plans with contingency planning for negotiation

For the strategy options selected by the ATCSCC, each AOC does additional contingency planning for the affected flights, preparing for further negotiations on how to resolve the flow problem.

Negotiate Activities

Note that participants iterate through some or all of these action steps as necessary to reach a final resolution. In some cases, this may mean taking some actions, then waiting to see whether those actions were sufficient before implementing additional actions.

The action steps for the Negotiate activities are shown in Figure 7.

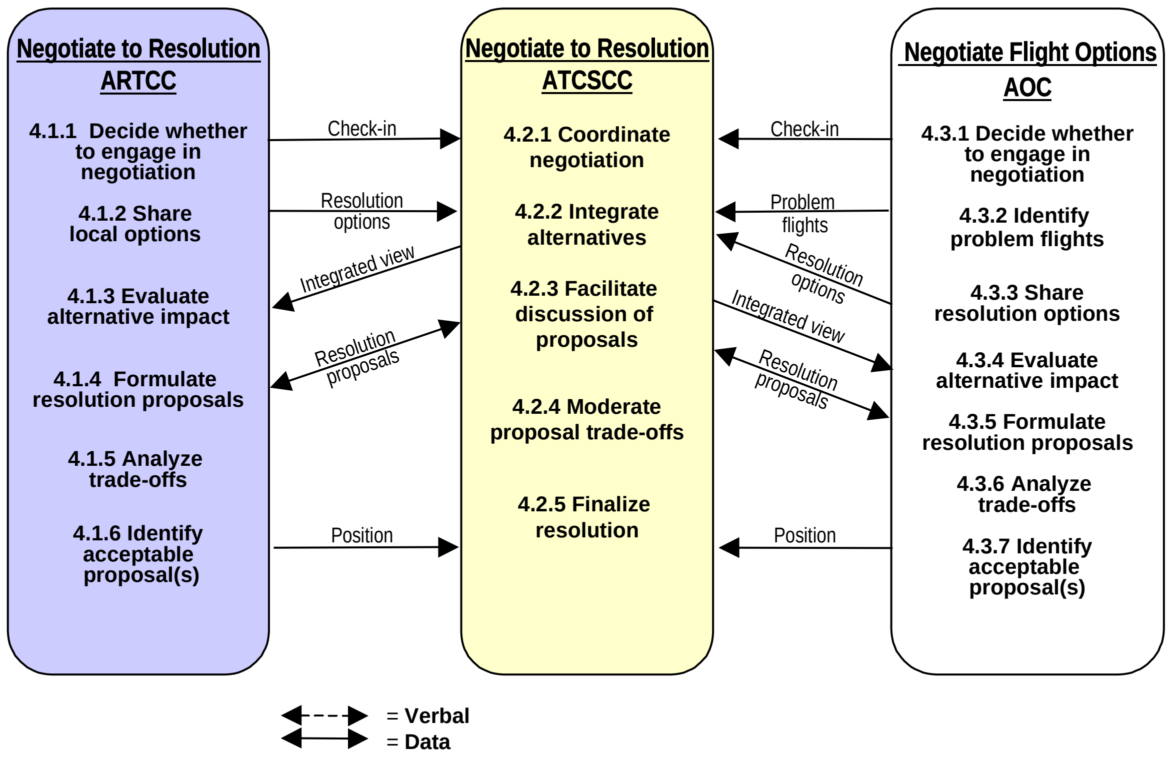

Figure 7. Action Steps for the *Negotiate* Activities

<u>Negotiate to Resolution (ARTCC)</u>

Step 4.1.1 Decide whether to engage in negotiation

When it's time to collaborate on the details of the resolution, each ARTCC TMC decides whether to participate and, if so, checks in with the ATCSCC position facilitating the discussion. An ARTCC might choose not to participate if, for example, the resolution is not expected to have much impact on their traffic or more immediate unrelated problems are claiming their full attention.

Step 4.1.2 Share local options

The ARTCC TMC shares the preferred local resolution options (see Step 3.1.6) with other participants. The TMC continues refining these proposals as needed during the collaboration process.

Step 4.1.3 Evaluate alternative impact

The ARTCC TMC assimilates the ATCSCC's integrated view of resolution options and evaluates the impact of alternative resolution options on the facility's traffic.

Step 4.1.4 Formulate resolution proposals

The ARTCC TMC formulates resolution proposals that both consider the integrated view and address the impacts on the facility's traffic, and then discusses these with the other participants, including other ARTCCS, the ATCSCC, and AOCs.

Step 4.1.5 Analyze trade-offs

The ARTCC TMC continues analyzing the trade-offs among resolution proposals being discussed.

Step 4.1.6 Identify acceptable proposal(s)

The ARTCC TMC determines which proposals are acceptable to the facility, based on the trade-off results, and states that position in the discussion.

<u>Negotiate to Resolution (ATCSCC)</u>

Step 4.2.1 Coordinate negotiation

The ATCSCC TMS determines whether the next scheduled teleconference is soon enough to discuss resolution details or whether the discussion is needed sooner, then notifies all users and facilities of the time and topic(s). When it's time to discuss the details of the resolution, the ATCSCC TMS checks in those choosing to participate in the discussion.

Step 4.2.2 Integrate alternatives

The ATCSCC TMS integrates local resolution options from ARTCCs and information on problem flights from AOCs and evaluates them to identify those that interact on the national scale. For example, reroutes around a large weather system that were proposed by neighboring facilities may assign different reroutes to the same flight, which need to be reconciled and the integrated impact of the actions determined. The TMS also determines whether the options resolve the flow problem adequately without unnecessary restrictions.

For mutually exclusive alternatives, the TMS compares the impact of each alternative both on flights and on sector workload. The TMS then provides an integrated view of the options to the participants.

Step 4.2.3 Facilitate discussion of proposals

The ATCSCC TMS facilitates discussion among the participants of the alternative resolution proposals, pointing out interactions and national implications as needed. This might be done as part of the SPT teleconferences that are held every two hours.

Step 4.2.4 Moderate proposal trade-offs

The ATCSCC TMS keeps track of which proposals are acceptable and proposes ways to reach common ground on what needs to be done. When no proposal is acceptable to all participants, additional iterations of examining the alternatives and modifying the proposals may be necessary.

Step 4.2.5 Finalize resolution

The ATCSCC TMS determines when to end the resolution discussion, checking that the resolution adequately addresses all aspects of the flow problem and finalizing the appropriate parameters (such as start and end time) to use for the resolution. When the resolution is designated as a planned public resolution, the TMS also specifies who is responsible for deciding when it should become an active public resolution.

Negotiate Flight Options (AOC)

Step 4.3.1 Decide whether to engage in negotiation

When it's time to collaborate on the details of the resolution, each AOC decides whether to participate and, if so, checks in with the ATCSCC position facilitating the discussion. An AOC might choose not to participate if, for example, the resolution is not expected to have much impact on their flights or more immediate unrelated problems are claiming their full attention.

Step 4.3.2 Identify problem flights

Each participating AOC identifies the flights of particular concern in resolving the flow problem, both those that may need special treatment and those with more flexibility, and notifies the ATCSCC of those flights.

Step 4.3.3 Share resolution options

Each participating AOC develops and proposes resolution options for their flights, such as which to reroute north of congestion and which to reroute south. As decisions are made about canceling or delaying flights, these are also shared.

Step 4.3.4 Evaluate alternative impact

Each AOC assimilates the integrated view of resolution options and evaluates the impact of alternative resolution options on the carrier's traffic.

Step 4.3.5 Formulate resolution proposals

Each AOC formulates resolution proposals that both consider the integrated view and address the impacts on the carrier's traffic, and then discusses these with the other participants.

Step 4.3.6 Analyze trade-offs

Each AOC continues analyzing the trade-offs among resolution proposals being discussed.

Step 4.3.7 Identify acceptable proposal(s)

Each AOC determines which proposals are acceptable to the carrier, based on the trade-off results, and states that position in the discussion.

Distribute Resolutions and Execute Resolutions Activities

In some cases, a resolution might be made public as a plan that will go into effect if the situation continues to develop as predicted. At some point, that planned public resolution would be made active, to indicate that the planned actions are indeed needed.

The action steps for the two Execute Resolutions activities and the Distribute Resolutions activity are shown in Figure 8.

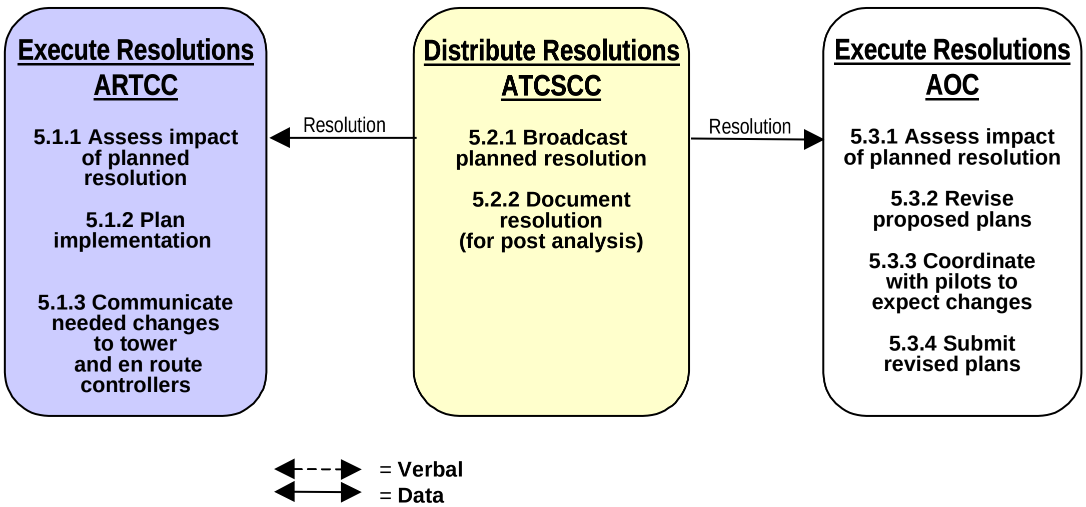

Figure 8. Action Steps for the *Distribute Resolutions* and *Execute Resolutions* Activities

<u>**Execute Resolutions (ARTCC)**</u>

Step 5.1.1 Assess impact of planned resolution

The ARTCC TMC assesses the impact of the planned resolution both on the facility's traffic and on sector workload, as well as coordinating with the appropriate operational supervisors and terminal facility TMCs to understand the impact on local operations.

Step 5.1.2 Plan implementation

The ARTCC TMC determines what actions need to be taken at the facility to implement the planned resolution, coordinating with the appropriate operational supervisors and terminal facility TMCs.

Step 5.1.3 Communicate needed changes to tower and en route controllers

The ARTCC TMC communicates the needed changes to those who will implement them, whether by entering flight plan amendments, sending General Information (GI) messages via the Host Computer System, or calling the appropriate people.

Distribute Resolutions (ATCSCC)

Step 5.2.1 Broadcast planned resolution

The ATCSCC TMS makes the planned resolution available to all interested parties (this may include a voice message for dial-in access, as well as via a web page, such as the ATCSCC Advisories currently provided).

Step 5.2.2 Document resolution (for post analysis)

The ATCSCC TMS documents the flow problem, the collaboration process, and the resulting resolution, adding information on the results and any revisions as the situation unfolds.

Execute Resolutions (AOC)

Step 5.3.1 Assess impact of planned resolution

Each AOC assesses the impact of the planned resolution on the carrier's flights, including coordination with appropriate dispatchers and other carrier personnel.

Step 5.3.2 Revise proposed plans

For flights that have not yet departed, each AOC revises flight plans as need to implement the planned resolution and determines what actions are needed for flight plans that have yet to be filed.

Step 5.3.3 Coordinate with pilots to expect changes

For flights that are already in the air or about to depart, each AOC coordinates appropriately so that the pilots know to expect changes to their flight plans.

Step 5.3.4 Submit revised plans

For flights that have not yet departed, each AOC submits each revised plan, as early intent information, as a filed flight plan, or potentially, in the future, as an amendment to a filed plan, whichever is appropriate. As the situation evolves, it may be necessary to iterate through the definition and resolution steps again.

Evaluate Strategy Activities

The action steps for the Evaluate Strategy activities are listed in Figure 9.

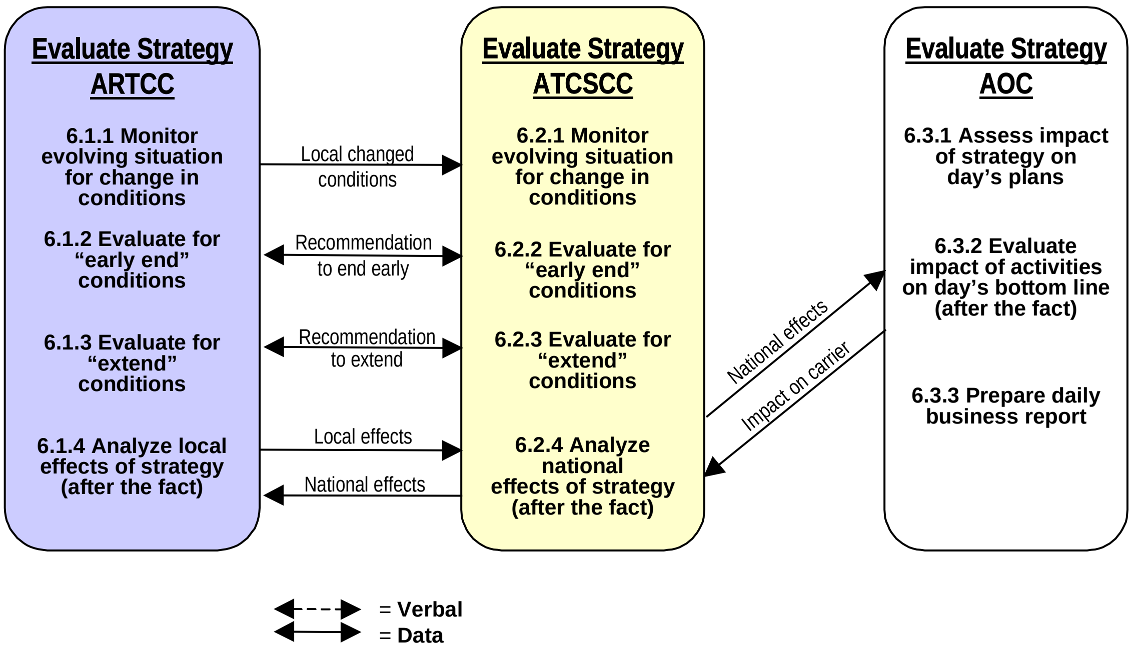

Figure 9. Action Steps for the *Evaluate Strategy* Activities

<u>Evaluate Strategy (ARTCC)</u>

Step 6.1.1 Monitor evolving situation for change in conditions

The ARTCC TMC assesses the impact of implemented strategies, on an on-going basis, to determine whether the facility's response needs to be adjusted. In many cases, this will mean iterating through information gathering and evaluation processes.

Step 6.1.2 Evaluate for "early end" conditions

The ARTCC TMC evaluates the evolving situation to determine whether the restrictions implemented to handle the flow problem can be lifted early. If so, the TMC notifies the ATCSCC and recommends a new end time for some or all of the restrictions. For example, the TMC notices that a traffic flow restricted to 20 MIT is no longer predicted to stay heavy as long as originally thought and the restriction can be lifted without overloading any sectors.

Step 6.1.3 Evaluate for "extend" conditions

The ARTCC TMC evaluates the evolving situation to determine whether the restrictions implemented to handle the flow problem need to be extended later than originally planned. If so, the TMC notifies the ATCSCC and recommends a new end time for some or all of the restrictions. For example, the TMC notices that demand on an overloaded sector is now predicted to stay heavy longer than originally thought and extending the MIT restriction for a major traffic flow would keep the sector counts within the threshold.

Step 6.1.4 Analyze local effects of strategy (after the fact)

The ARTCC TMC analyzes the local effects of the strategy chosen to resolve a flow problem, once the problem has ended, for use in briefing management and deriving "lessons learned." The local effects might be measured by the number of operations handled by the facility, the peak and average counts of traffic in each sector, the delay taken in the facility's airspace, and the added distance flown in the facility's airspace. The TMC also considers how well the impact of the situation and strategy were predicted and whether some actions had unexpected consequences.

Evaluate Strategy (ATCSCC)

Step 6.2.1 Monitor evolving situation for change in conditions

The ATCSCC TMS assesses the impact of implemented strategies, on an on-going basis, to determine whether adjustments are needed. In many cases, this will mean iterating through information gathering and evaluation processes. The ATCSCC TMS also continues monitoring conditions to determine whether the situation is evolving differently than predicted. If so, the process of identifying and resolving the problem may need to iterate.

Step 6.2.2 Evaluate for "early end" conditions

The ATCSCC TMS evaluates the evolving situation to determine whether the restrictions implemented to handle the flow problem can be lifted early. The TMS also receives recommendations from the ARTCC TMCs about restrictions that can be lifted early. If lifting a restriction can be done without adversely affecting other traffic, the TMS notifies all interested parties of the new end time. When it's not clear whether lifting the restriction early will cause other problems, iteration through the collaborative processes may be necessary. In any case, the TMS keeps the ARTCC TMCs informed.

Step 6.2.3 Evaluate for "extend" conditions

The ATCSCC TMS evaluates the evolving situation to determine whether the restrictions implemented to handle the flow problem need to be extended later than originally planned.

The TMS also receives recommendations from the ARTCC TMCs about restrictions that need to be extended. If extending a restriction is clearly needed, the TMS evaluates the impact and notifies all interested parties of the new end time. When it's not clear whether extending the restriction is needed, iteration through the collaborative processes may be necessary. In any case, the TMS keeps the ARTCC TMCs informed.

Step 6.2.4 Analyze national effects of strategy (after the fact)

The ATCSCC TMS analyzes the national effects of the strategy chosen to resolve a flow problem, once the problem has ended, for use in briefing management and deriving "lessons learned". The national effects might be measured by the peak and average delay flights took, the number of flights cancelled and diverted, and the throughput for major airports. The TMS also considers how well the impact of the situation and strategy were predicted and whether some actions had unexpected consequences. The non-proprietary aspects of this analysis are shared and may be accessible by anyone, whether or not they are participants in the collaboration.

Evaluate Strategy (AOC)

Step 6.3.1 Assess impact of strategy on day's plans

Each AOC assesses the impact of implemented strategies, on an on-going basis, adjusting their response as the situation develops. In many cases, this will mean iterating through information gathering and evaluation processes.

Step 6.3.2 Evaluate impact of activities on day's bottom line (after the fact)

Each AOC evaluates the impact of a day's activities on the carrier's bottom line, for reporting to their management. Most carriers have their own set of metrics for measuring how well operations were performed. They may also note any "lessons learned" about what responses worked particularly well or poorly. An AOC may choose to share significant results of this evaluation with other participants when it would aid in improving the collaboration process.

Step 6.3.3 Prepare daily business report

Each AOC reports on the outcome of the day's activities using the metrics chosen by that carrier. Each AOC also considers how well the impact of the situation and strategy were predicted and whether some actions had unexpected consequences.

Section 3

Issues and Next Steps

Issues

Some issues were identified in the course of this study:

- The capability to specify the capacity of an FCA and of the sectors it affects is needed, but not currently planned for implementation. Note that the use of flow filters to select a portion of the traffic may not lead to the desired percent reduction, when the filters depend on picking out flights that are flying given routes or fixes.
- How to share responsibility for resolving flow problems needs to be defined. Possibly, each TMC will have responsibility for resolving some problems, while the ATCSCC TMS will have responsibility for others. Also, if only the ATCSCC can make FCAs and resolutions public, and AOCs can only see the information once it's made public, then the ATCSCC has to be involved every time collaboration with the AOCs is needed.
- Fine-tuning of Monitor Alert parameters is needed, as is better information on actual pushback and on early intent.
- Automation to support the negotiation process would be useful, analogous to how the real-time slot selection process in the FSM function of ETMS provides support for interactive negotiation during ground delay programs.
- Current exploration of additional capabilities, such as automatically defining weather volumes and using pre-defined rationing schemes for assigning flights to reroutes, will have a major impact on the collaboration process that will need further study.

Next Steps

Additional work is needed on the following:

- Identify the information needs for each action step
- Map proposed automation to the concept and identify where additional automation tools would be helpful
- Prepare detailed process descriptions for the other two categories of triggering events
- Produce a solution set for collaborative rerouting
- Develop procedures for the action steps
- Describe the extensive interactions within each participating environment
- Conduct extensive coordination of the activities and their action steps

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Glossary

AOC	Aeronautical Operations Center
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
CCFP	Common Convective Forecast Product
CDE	Concept Demonstration and Evaluation
CRCT	Collaborative Rerouting Coordination Tools
DSR	Display System Replacement
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FCA	Flow Constrained Area
FEA	Flow Evaluation Area
FPPP	Flight Plan Preprocessor Prototype
FSM	Flight Schedule Monitor
GDP	Ground Delay Program
GI	General Information
HCS	Host Computer System
MIT	Miles In Trail
NAS	National Airspace System
NOTAM	Notice to Airmen
SMT	Sector Management Tool
SPT	Strategic Planning Team
TFM	Traffic Flow Management
TFM-I	TFM Infrastructure
TMC	Traffic Management Coordinator
TMS	Traffic Management Specialist
TMU	Traffic Management Unit
TSD	Traffic Situation Display