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MITRE TECHNICAL REPORT

Layered Strategic Planning in the En Route National Airspace System (NAS): Air Route Traffic Control Center (ARTCC) Perspective

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Abstract

In an effort to accommodate predicted growth in air traffic, the Federal Aviation Administration (FAA) and the aviation community have developed a future concept of operations for the National Airspace System (NAS) called Free Flight. The Center for Advanced Aviation System Development (CAASD) at The MITRE Corporation, which supported the development of the Free Flight concept, has also identified a number of issues associated with both its implementation and its evolution. One of the major issues to be resolved involves layered strategic planning, a concept for strategic planning that associates overlapping planning layers with the different types of problems and situations that occur hierarchically in the NAS. Overlapping planning layers provide flexibility in handling the daily variations in traffic patterns and loads, as well as the different types of traffic planning events (such as Special Use Airspace [SUAs] and severe weather) that occur in the NAS. Before a more extensive layered strategic planning concept can be achieved as an enhancement to today's implementation of layered planning, a detailed description of that concept is needed for the NAS. This document takes a first step in that direction by providing an overview of layered strategic planning in the NAS. This document then focuses on strategic planning in the Air Route Traffic Control Center (ARTCC) by describing the roles, responsibilities, and capabilities for strategic flight planning in the ARTCC environment, and the issues that need to be examined for exploring the resulting layered strategic planning concept.

KEYWORDS: air traffic control, multi-layered planning, layered strategic planning, multi-sector planning, strategic time frame, user preferences, collaborative decision making, complex airspace situations, problem prediction, problem resolution, air traffic management, free flight

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Executive Summary

Introduction

The Federal Aviation Administration (FAA) and the aviation community have developed a concept of operations called Free Flight to accommodate the predicted growth in air traffic while maintaining safety and efficiency in the National Airspace System (NAS). This future FAA operational concept has been developed for the midterm time frame (nominally a period of time that centers around 2005) and builds on Free Flight Phase 1 (FFP1) capabilities that are scheduled for implementation by 2002.

One of the major issues to be resolved in this concept involves an underlying concept called "layered strategic planning." This concept associates overlapping planning layers with the different types of problems and situations that occur hierarchically in the NAS. Overlapping planning provides flexibility in handling the daily variations in traffic patterns and loads, as well as the different types of traffic planning events (such as accounting for changes in Special Use Airspace [SUA] activity and severe weather) that routinely occur. Before a more extensive layered strategic planning concept can be achieved as an enhancement to today's implementation of layered planning, a detailed description of that concept is needed for the NAS, with a focus on the Air Route Traffic Control Center (ARTCC, or Center). This document incorporates extensive feedback from FAA personnel to describe the use of layered strategic planning in the en route environment. It defines the issues associated with layered strategic planning that must be resolved in laboratory and en route site operational exercises. The concept is expected to evolve to reflect changing procedures and capabilities.

The purpose of this document is to identify the various types of planning problems and situations associated with the en route environment in the NAS, and then describe a layered strategic planning approach to efficiently handle these problems and situations. This document describes the use of overlapping layers of strategic planning for the Air Traffic Control System Command Center (ATCSCC, or Command Center) and Center domains that are designed to provide for the strategic resolution of various problems and situations. This concept describes the roles and responsibilities associated with the layers within the Center domain, and the capabilities needed to support various planning tasks. Although specific scenarios are not included, the concept provides examples of how the tasks associated with the planning layers within the Center domain can be assigned to en route service providers. The roles, responsibilities, and capabilities necessary for specific planning layers will be explored in future laboratory validation efforts.

Overview of the Future NAS Environment and Operational Concepts

The future **en route** concepts have been developed with the goals of accommodating user preferences, handling increased traffic, and maintaining or improving aviation safety. The concepts incorporate emerging technological advances and identify capabilities that will be used by Air Traffic Management (ATM) service providers to better manage their workload and to collaborate with the NAS users.

Using new technologies to assist in workload management requires an understanding of the tasks performed by the ATM service providers, particularly the en route sector controllers. It is envisioned that most of the tasks performed today will also be performed in the future; however, the allocation of the tasks will differ. In some cases, different service providers or decision support capabilities may perform one or many tasks. Consequently, a portion of this document presents the roles of the different planning layers to meet changing traffic workloads.

As service providers become accustomed to using automated decision support capabilities, their job will likely evolve from one with tactical emphasis to a more strategic one. This longer range outlook should also be supported by improved trajectory estimation—and therefore improved strategic problem prediction—resulting from information downlinked from equipped aircraft. It is anticipated that an improvement in problem prediction, a reduction of tactical problems, and an evolution toward a more strategic NAS will enable service providers to manage increases in traffic and possibly larger sectors. Ideally, a goal is to increase the frequency of a single service provider having responsibility for controlling or managing a given airspace. When sector workload is predicted to increase, impact on users is minimized by adjusting the NAS, through adjustments in airspace and/or sector staffing configurations, before implementing traffic planning strategies (i.e., changing traffic flows). Changes to flight plans, including those resulting from traffic planning strategies, should be implemented only as a last resort.

Shifting service providers' roles to more strategic ones, making a clearer distinction between strategic and tactical workload, and enabling service providers to manage larger airspaces on their own, should be accomplished in an evolutionary manner. Thus, the operational concepts, and specifically, the roles and responsibilities of the service providers, need to be defined in easy-to-implement steps so that procedures and capabilities build upon one another.

Overview of Layered Strategic Planning in the En Route Environment

NAS information can be organized hierarchically into different levels of aggregation, with longer-term stability for the information with higher levels of aggregation (for example, the characteristics of a flow are more stable further out into the future than the characteristics of an individual flight path in that flow). Problems and situations that require strategic planning appropriate for each level of aggregation can then be identified, based on the information available at that level and the following factors: the geographic scope, the time scope, and the causes and complexity. As shown in Figure ES-1 and Table ES-1, these factors are used to define the types of overlapping problems and situations associated with each level of information aggregation.

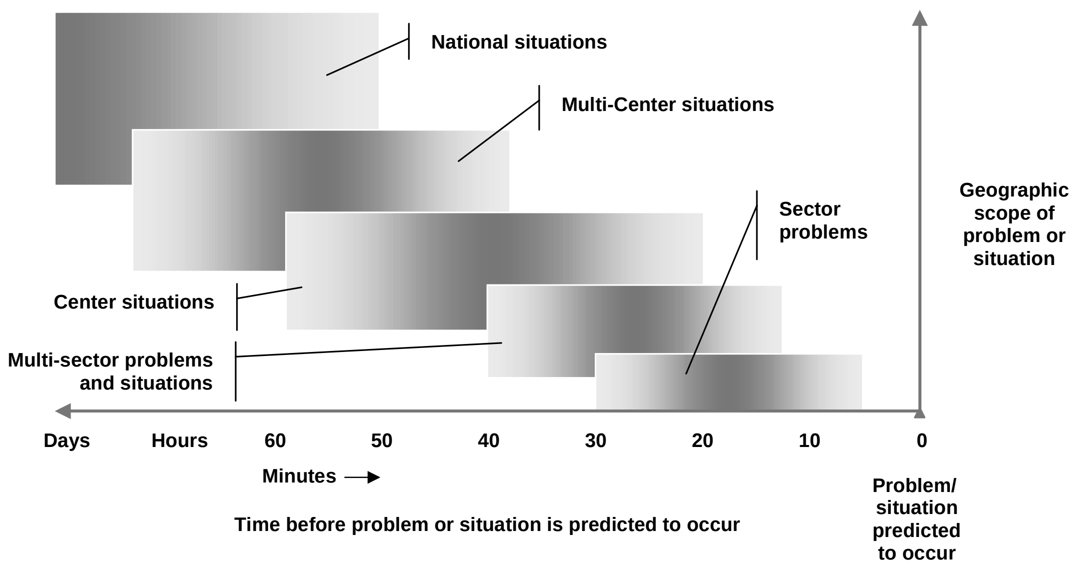

Figure ES-1. Problem and Situation Hierarchy

Table ES-1. Problem and Situation Types That Require Strategic Planning in the NAS

Problem/ Situation Type	Geographic Scope	Time Scope	Causes and Complexity
National situations	Many (including non-adjacent) Centers across the U.S.	Long-range strategic time frame (example: predicted approximately 50 minutes to many days into the future)	Excessively complex situations, involving a large constrained airspace or constrained airports
Multi-Center situations	Multiple sectors that cross the boundaries of more than one adjacent Center	Long-range strategic time frame (example: predicted approximately 40 minutes to hours into the future)	Excessively complex situations, involving a large constrained airspace or a constrained airport
Center situations	A single Center with minimal effect on the Center's input and output rates or flows	Mid- to long-range strategic time frame (example: predicted approximately 20 to 60 minutes into the future)	Complex situations, involving a medium-sized constrained airspace, merging traffic streams, or a set of interrelated predicted problems called a cluster
Multi-sector situations and problems	More than one adjacent sector within a single Center	Short- to mid-range strategic time frame (example: predicted approximately 12 to 40 minutes into the future)	Complex situations, involving a small constrained airspace or a cluster, and strategic problems
Sector problems	One sector	Tactical to short-range strategic time frame (example: predicted approximately 5 to 30 minutes into the future)	Predicted problems for several aircraft

In response to this problem and situation hierarchy, a ***layered strategic planning*** concept has been developed to provide overlapping planning layers that are associated with the different types of problems and situations. Overlapping planning layers provide flexibility in handling the daily variations in traffic patterns and loads, as well as the different types of traffic planning activities (such as changing status of SUAs and severe weather, etc.) that occur in the NAS. The planning layers in the Command Center domain are defined as follows:

- The national planning layer is the overall Traffic Flow Management (TFM) function within the NAS, coordinating planning efforts involving many Centers.
- The multi-Center planning layer coordinates TFM planning efforts among multiple sectors across adjacent Center boundaries.

The planning layers in the Center domain are defined as follows:

- The Center planning layer coordinates TFM planning efforts within a single Center.
- The multi-sector planning layer coordinates TFM planning efforts involving more than one adjacent sector within a single Center and performs strategic problem and situation resolutions.
- The sector planning layer ensures aircraft separation, resolving predicted aircraft-specific problems before they occur.

Through advanced planning, each layer helps to ensure that the workload for the layer below remains operationally acceptable.

By handling problems and situations at the appropriate layer, strategic planning can reduce the number of predicted problems to be handled in the sector planning layer. Strategic planning ensures that sector workload is operationally acceptable, while allowing time to pass for some predicted aircraft-specific problems to become more certain before maneuvering aircraft. As a result, NAS users are involved in maintaining safety through planning, with less possibility that flights will be maneuvered unnecessarily.

The goal of layered strategic planning is to resolve problems and situations at the appropriate layer, by adjusting the service provider resources to handle constrained airspace and the variations in traffic patterns and loads, and by involving users in strategic planning. In the layered strategic planning concept, NAS safety is maintained while NAS efficiency and the accommodation of user preferences are increased.

This document takes the first steps toward defining a future operational concept of layered strategic planning for ATM service providers that enhances current operations. Topics addressed include: an overview of layered strategic planning; descriptions of service provider roles and responsibilities in the Center; and descriptions of the capabilities needed to support the service providers in accomplishing their tasks. Issues requiring evaluation in both laboratory and operational environments are also identified. The analysis of these issues and the refinement of these ideas will require extensive participation of service providers and airspace users.

Summary

The layered strategic planning concept makes use of various layers of strategic service providers. The available service provider configurations and the corresponding changes in service provider roles and responsibilities allow for the concepts to evolve over time. The concept of layered strategic planning is performed today in the Command Center and Center domains; the concept described in this document extends today's implementation of layered planning to achieve the following:

- Increased accommodation of user-preferred trajectories and fewer diversions from those preferences.
- Increased collaboration with users, based upon increased information sharing to minimize impact of flow strategies on users.
- Improved allocation of problems and situations for resolution at the appropriate layer and time.
- Improved safety and service provider productivity.
- Evolution from predominately tactical Air Traffic Control (ATC) services to the strategic provision of ATC services.
- Dynamic adjustment of the workload responsibility using a combination of time parameters (time scope) and airspace allocation (geographic scope).

The analysis of the issues identified in this document will determine the operational feasibility and relative benefits of the layered strategic planning concept. Once these are identified, the next step is to address the necessary transition steps; that is, what is an efficient and cost-effective evolution plan to realize these services and capabilities? As new system capabilities become available, as traffic increases, as a greater percentage of flights desire to fly non-structured routes, and as aircraft avionics are improved, the concepts and related systems must be capable of seamlessly and effectively accommodating these changes.

Section 1

Introduction

1.1 Background

The Federal Aviation Administration (FAA) manages and develops the National Airspace System (NAS) to support safe and efficient air traffic operations. To fulfill this responsibility, the FAA must research and analyze future air traffic projections of growth, as well as the ability of the NAS to handle those projections. This research and analysis helps the FAA gain insight into which procedural and automation improvements will be required to maintain NAS safety and efficiency as the traffic loads, patterns, and characteristics change. One key result of recent research and analysis has been the wide recognition that many NAS improvements are required to maintain safety and efficiency for the projected changes in traffic [1, 2, 3].

The FAA and the aviation community have developed a concept of operations called Free Flight to accommodate the predicted growth in air traffic while maintaining safety and efficiency in the NAS [4]. The FAA operational concept has been developed for the midterm time frame (nominally a period of time that centers around 2005) and builds on Free Flight Phase 1 (FFP1) capabilities that are scheduled for implementation by 2002 [5, 6].

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) has supported the FAA in providing a more detailed description of the midterm operational concept for the en route domain of the NAS. CAASD's detailed description includes a number of issues that must be resolved before the concept (that emphasizes a migration to strategic planning from tactical control) can be considered viable for implementation. In fiscal year (FY) 1999, CAASD began addressing these issues for both the midterm concept [7] and a possible evolution to the midterm [8].

One of the major issues to be resolved in the en route concept involves an underlying concept called "layered strategic planning." This concept associates overlapping planning layers with the different types of problems and situations that occur hierarchically in the NAS. This type of planning provides flexibility in handling the daily variations in traffic patterns and loads, as well as the different types of traffic planning events (such as accounting for changes in Special Use Airspace [SUA] activity and severe weather) that routinely occur. To explore more extensive layered strategic planning as an enhancement to today's implementation of layered planning, a detailed concept for layered strategic planning in the Air Route Traffic Control Center (ARTCC, or Center) is needed. This document incorporates extensive feedback from FAA personnel on the en route concepts presented in earlier documents to describe the use of layered strategic planning in the en route environment. It defines the issues associated with layered strategic planning that must be resolved in laboratory and en route site operational exercises. The concept is expected to evolve to reflect changing procedures and capabilities.

1.2 Purpose and Scope of this Document

The purpose of this document is to identify the various types of planning problems and situations associated with the en route environment in the NAS, and then describe a layered strategic planning approach to efficiently handle these problems and situations. This document describes a planning concept with overlapping layers in the Air Traffic Control System Command Center (ATCSCC, or Command Center) and Center domains that are designed to provide for the strategic resolution of various problems and situations. This layered concept describes the roles and responsibilities associated with the layers in the Center domain, and the capabilities needed to support various planning tasks. Although specific scenarios are not included, the concept provides examples of how the tasks associated with the planning layers within the Center domain can be assigned to en route service providers. The roles, responsibilities, and capabilities necessary for specific planning layers will be explored in future laboratory validation efforts.

Although transition airspace is defined as the subset of en route sectors near the terminal airspace boundaries, the roles, responsibilities, and capabilities required for layered planning in transition airspace differ from those in the remaining en route airspace, and as a result, are beyond the scope of this document. As the ongoing transition airspace research clarifies the needed roles, responsibilities, and capabilities, concept documents such as this one will need to be updated. In addition, the application of layered strategic planning to support surface and terminal operations, as well as non-radar airspace, are not covered in this document. Where necessary, this document describes a portion of the Traffic Flow Management (TFM) operational concept to describe the layers that perform TFM roles. Describing the full range of TFM responsibilities is also beyond the scope of this document.

1.3 Organization of this Document

Section 2 provides an overview of the future NAS environment and operational concepts. Section 3 defines the types of en route problems and situations occurring in the NAS that would benefit from strategic planning to ensure that the NAS operates safely and efficiently, and then provides an overview of the layered strategic planning concept that best addresses these different types of problems and situations. Section 4 describes the roles and responsibilities associated with the Center domain of the layered strategic planning concept, and Section 5 describes the capabilities needed to support the planning layers in the Center domain. Examples of how the roles and responsibilities for the planning layers could be assigned to en route service providers are provided in Section 6. Section 7 identifies issues for analysis and evaluation, and Section 8 provides a summary.

1.4 Typographic Conventions

Because much of the layered strategic planning concept described in this document is new, it requires study and evaluation before it can be explored as a viable concept. In addition to describing the issues associated with the layered strategic planning concept in Section 7, gray issue boxes like the one below are placed in Sections 2 through 6 to associate the details of the layered strategic planning concept with individual issues. For the benefit of those reading this document electronically, links to other sections are shown underlined, in color, as demonstrated with the link to Section 7 in the issue box below. Other links shown underlined and in color include links to figures and tables within the document, and to items in the List of References and the List of Terms.

Issue: Sample – Reference in Section 7

Section 2

Overview of the Future NAS Environment and Operational Concepts

This section presents an overview of the expected future **en route** environment and explains the rationale behind the use of layered strategic planning in the future operational concept. This overview provides the necessary background for developing layered strategic planning for the NAS.

Each year, user demand for aviation services continues to grow. Historically, satisfying this demand has resulted in reliance on procedures and restrictions such as structured airways, separation rules, and flow constraints. Today, NAS users have more information enabling them to make informed decisions that contribute to improved NAS management. Furthermore, users are demanding fewer delays and more routing and scheduling flexibility so they can operate more efficiently. Similarly, the FAA is responding to its own fiscal constraints by investigating ways to improve the efficiency of NAS operations. Due to financial realities, the NAS will have to accommodate future traffic increases with a more flexible service provider workforce. At the same time, maintaining or improving aviation safety is of paramount concern to both the FAA and the public. Consequently, new technologies and procedures are needed to accommodate increases in air traffic and improve safety.

The future **en route** concepts have been developed with the goals of accommodating user preferences, handling increased traffic, and improving aviation safety. The concepts incorporate emerging technological advances and identify capabilities that will be used by Air Traffic Management (ATM) service providers to better manage their workload.

Using new technologies to assist in workload management requires an understanding of the tasks performed by the ATM service providers, particularly the **en route** sector controllers. It is envisioned that most of the tasks performed today will also be performed in the future; however, the allocation of the tasks will differ. In some cases, different service providers or decision support capabilities may perform one or many tasks. Consequently, a portion of this document presents the roles of the different planning layers to meet changing traffic workloads.

Today, an en route sector may be staffed by either a Radar (R) controller working alone, or by an R controller supported by a collocated Flight Data (D) controller. The R and D controllers typically share the load of separating aircraft. The R controller generally monitors the radar situation display and handles control actions of a more immediate nature, while the D controller monitors flight progress strips and helps the R controller as necessary. In some sectors, there may be additional positions such as Radar Coordinators, Radar Flight

Data controllers, and Non-Radar positions. In addition to the staff at the en route sector, the Traffic Management Coordinators (TMCs) at each Center perform strategic planning tasks to ensure that the workload at the sector remains manageable. The Traffic Management Specialists (TMSs) at the Command Center perform longer-range strategic planning tasks involving more than one Center to manage situations and workload for those Centers.

Through the FAA's Free Flight Phase 1 and 2 programs, capabilities will be available to improve the accuracy of aircraft path (trajectory) predictions. The deployment of new decision support capabilities will improve the en route service provider's ability to identify and resolve potential situations and problems. This document defines the term **'situation'** as a volume of airspace that is predicted to become complex due to predicted demand exceeding capacity (possibly due to severe weather or other traffic planning events) and as a result, would benefit from strategic planning. This document defines the term **'problem'** as the predicted loss of separation between aircraft and other aircraft, SUA, complex traffic airspace, terrain and obstructions, or severe weather; or predicted non-compliance with traffic planning constraints [9].

Issue: Problem and Situation Prediction Time/Trajectory Accuracy – Section 7.1.1

Decision support capabilities will also help service providers determine whether user requests for flight plan changes will be problem-free. If a user request is predicted to have a problem, service providers can use decision support capabilities to automatically check that request periodically and notify the service provider as soon as the request is problem-free. Decision support capabilities will also include inter-sector and inter-facility automated coordination that will reduce the service provider workload associated with verbal communication. With the accumulated benefits of automated capabilities, service providers are available to provide Air Traffic Control (ATC) services to more aircraft.

As service providers become accustomed to using automated decision support capabilities, their job will evolve from one with tactical emphasis to a more strategic one. This longer range outlook should also be supported by improved trajectory estimation—and therefore improved strategic problem prediction—resulting from information downlinked from equipped aircraft [10]. It is anticipated that an improvement in problem prediction, a reduction of tactical problems, and an evolution toward a more strategic NAS will enable service providers to manage increases in traffic and possibly larger sectors. Ideally, a goal is to increase the frequency of a single service provider having responsibility for controlling or managing a given airspace. When sector workload is predicted to increase, impact on users is minimized by adjusting the NAS, through adjustments in airspace and/or sector staffing configurations, before implementing traffic planning strategies (i.e., changing traffic flows). Changes to flight plans, including those resulting from traffic planning strategies, should be implemented only as a last resort. The options for handling dynamic changes in traffic demand are discussed in the paragraphs that follow.

The range of responsibilities (from tactical to strategic) could be adjusted such that the more tactical responsibilities are assigned to one service provider and the more strategic responsibilities are assigned to another. The time horizons that define whether a task is tactical or strategic could also be adjusted. An option for accommodating increases in traffic is to adjust the sector configuration. With a capability to predict airspace traffic density, sector configurations could be adjusted in such a way that traffic could be balanced among neighboring sectors, avoiding unnecessary modifications to traffic flows. A dynamically reconfigurable airspace to support these options would be desirable, but some constraints may exist. Although the amount of service provider training may vary depending on how airspace is defined (e.g., super high sectors), training requirements may limit the extent of possible reconfigurations. Nevertheless, airspace reassignments cannot be chaotic and must appear seamless to service providers and users. Furthermore, equipment such as radar and radio transmitters that are associated with particular Centers may limit the ability to adjust sector configurations. With these constraints in mind, transition to dynamically reconfigurable airspace must be evolutionary [11].

Issues: Transfer of Control – Section 7.3.7 Airspace Boundary Adjustment – Section 7.4.3

Shifting service provider's roles to more strategic ones, making a clearer distinction between strategic and tactical workload, and enabling service providers to manage larger airspaces on their own, should be accomplished in an evolutionary manner. Thus, the operational concepts, and specifically, the roles and responsibilities of the service providers, need to be defined in easy-to-implement steps so that procedures and capabilities build upon one another.

The decision support capabilities used by service providers to accomplish their assigned duties should also be implemented in an evolutionary manner. Specifically, the problem prediction capability has already been identified as a capability required for the en route airspace. However, the transition airspace, which consists of the set of en route sectors near the terminal airspace boundaries, is a complex airspace in which the controller is often working towards multiple goals. Adapting decision support capabilities such as the problem prediction capability for transition airspace may facilitate the sequencing and merging of traffic, meeting meter fix times or miles-in-trail constraints, and maintaining separation while trying to maximize throughput.

Research is currently ongoing to determine the capabilities needed to support transition airspace activities, determine the applicability of previously developed capabilities to meet those needs, and postulate new types of capabilities. As this research progresses, the operational concept documents will need to be updated to reflect the research findings. Furthermore, roles and responsibilities for the service providers in transition airspace sectors may differ somewhat from those in the remainder of the en route airspace. As these roles and responsibilities for the transition airspace become clearer, operational concept documents will need to be updated.

Section 3

Overview of Layered Strategic Planning in the En Route Environment

Given the nature of air traffic, safety and efficiency are affected by how well NAS users and service providers develop plans to handle NAS uncertainty, such as the uncertainty associated with future flight paths, pilot (and airline Aeronautical Operational Control, or AOC) intent, and service provider intent. In this section, the hierarchical nature of air traffic management is described, along with the types of problems and planning situations that emerge from the levels of information aggregation in the hierarchy. An overview of the response to hierarchical problems and situations through layered strategic planning is provided.

3.1 Hierarchical Nature of Air Traffic Management

The nature of air traffic in the NAS is complex in that it results from individual and collective transportation decisions from many viewpoints, including personal, business, and management decisions, each having the common goals of flight safety and efficiency. A need for hierarchical management emerges from the complex nature of air traffic. The informational and organizational perspectives of this hierarchical management [12] are described below.

From an ***informational*** perspective, the hierarchy of air traffic emerges from levels of information aggregation (for example, individual flights aggregate into local flows and local flows aggregate into national flows). Although some detailed information is lost with each higher level of aggregation, new information is gained from the patterns that become apparent at each higher level (Figure 3-1). In addition to providing a new view of the air traffic, each higher level of aggregation provides longer-term stability for the information at that level than for the information at the level below (Figure 3-2). As an example, the characteristics of a flow are more stable further out into the future than the characteristics of an individual flight path in that flow.

From an ***organizational*** perspective, the ATM hierarchy should reflect the informational hierarchy of air traffic in the NAS, using localized functions within an aggregation level that adapt to the dynamic conditions for that level (Figure 3-1). The localized functions, which are interdependent and coordinated, monitor the air traffic at each level of aggregation and plan responses to any predicted changes. The significance of mapping a hierarchical organization to the hierarchical structure of the information is that the scope of a function at one aggregation level encompasses more than one of the functions at the level below it, and is therefore able to handle aspects of coordination that are beyond the scope of the individual functions at the level below. As a result, the actions taken at each level of aggregation are appropriate for the information at that level.

By identifying the informational hierarchy that emerges from the complex nature of air traffic, and then mapping ATM personnel to that hierarchy to create overlapping planning layers, uncertainty can be managed to support safety and efficiency in the NAS.

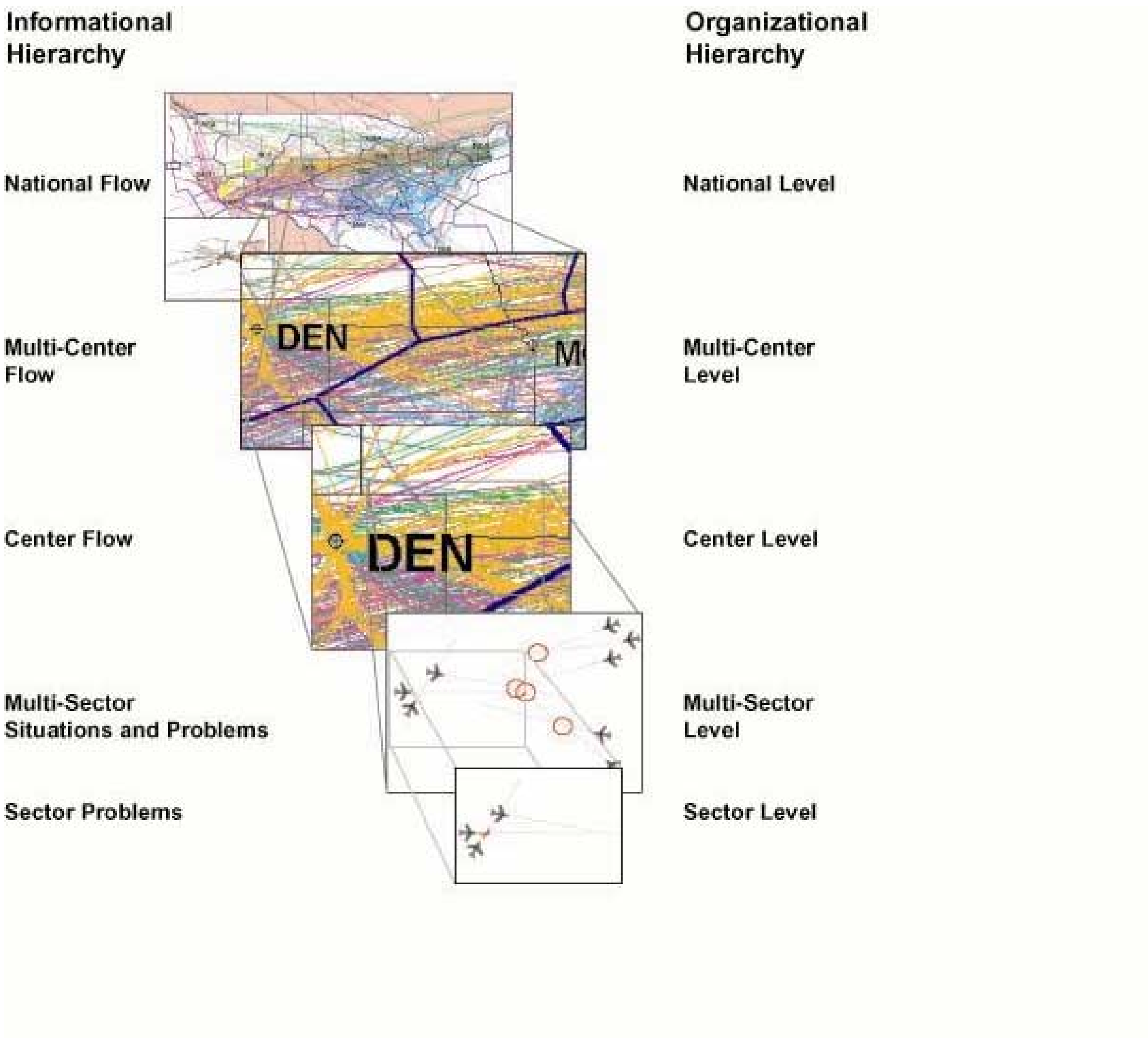

Figure 3-1. Hierarchical Air Traffic Management within the NAS

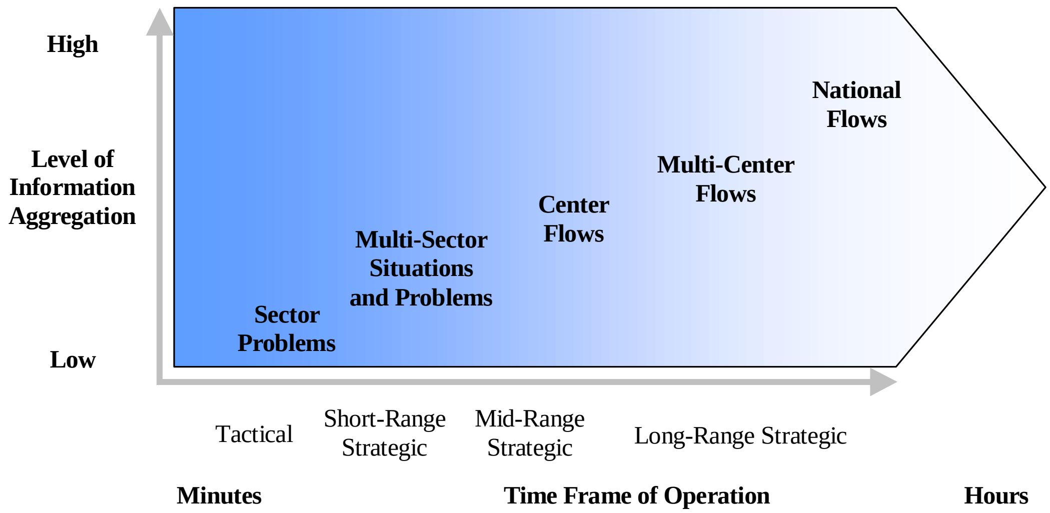

Figure 3-2. Information Stability for the Air Traffic Management Aggregation Levels

Issue: Time Frames of Operation and Information Stability for the Information Aggregation Levels – Section 7.5.1

3.2 Types of Problems and Situations that Require Strategic Planning in the NAS

NAS information can be organized hierarchically into different levels of aggregation, with longer-term stability for the information with higher levels of aggregation. Problems and situations that require strategic planning appropriate for each level of aggregation can then be identified, based on the information available at that level and the following factors:

- The ***geographic scope***, or the geographic size and location of the problem or situation, determines which types of coordination will be needed among the different planning levels. The geographic scope is considered the primary characteristic affecting the allocation of a problem or situation to the appropriate aggregation level.
- The ***time scope*** is the time frame in which there is sufficient information to predict the problem or situation with relatively high confidence. The time scope is considered secondary to the geographic scope when allocating a problem or situation to the appropriate aggregation level.

- The ***causes and complexity*** help determine the nature of the problem or situation, as well as the type of resolution that is most likely to be effective with as little impact as possible on the NAS users.

As shown in Figure 3-3 and Table 3-1, these factors are used to define the types of overlapping problems and situations associated with each level of aggregation. Some of the types of problems and situations associated with each level are briefly described below.

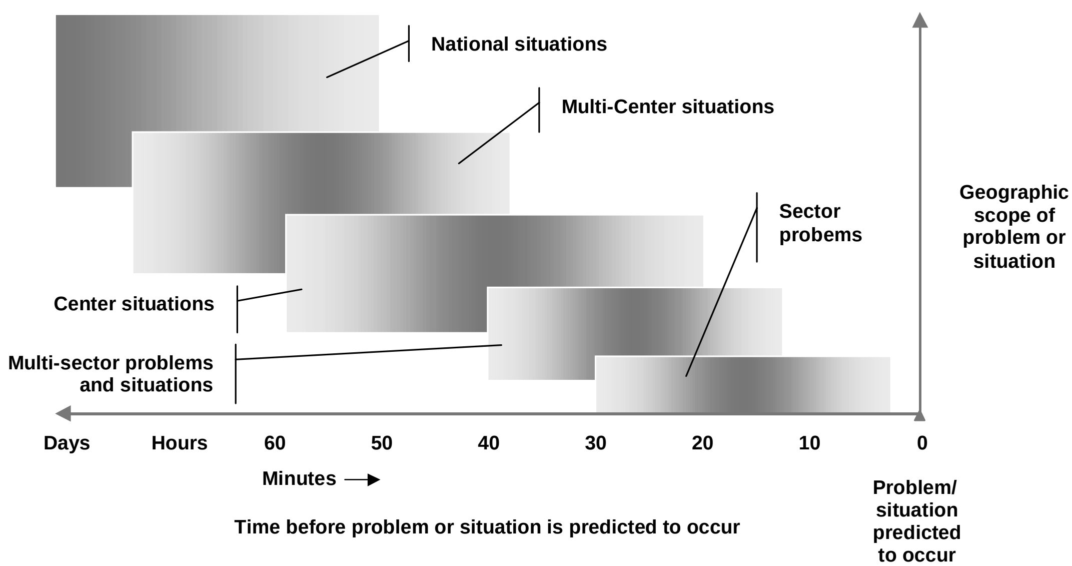

Figure 3-3. Problem and Situation Hierarchy

Issue: Types of Problems and Situations that Require Strategic Planning in the NAS – Section 7.5.2

Table 3-1. Problems and Situations Types That Require Strategic Planning in the NAS

Problem/ Situation Type	Geographic Scope	Time Scope	Causes and Complexity
National situations	Many (including non-adjacent) Centers across the U.S.	Long-range strategic time frame (example: predicted approximately 50 minutes to many days into the future)	Excessively complex situations, involving a large constrained airspace[1] or constrained airports
Multi-Center situations	Multiple sectors that cross the boundaries of more than one adjacent Center	Long-range strategic time frame (example: predicted approximately 40 minutes to hours into the future)	Excessively complex situations, involving a large constrained airspace or a constrained airport
Center situations	A single Center with minimal effect on the Center's input and output rates or flows	Mid- to long-range strategic time frame (example: predicted approximately 20 to 60 minutes into the future)	Complex situations, involving a medium-sized constrained airspace, merging traffic streams, or a set of interrelated predicted problems called a cluster
Multi-sector problems and situations	More than one adjacent sector within a single Center	Short- to mid-range strategic time frame (example: predicted approximately 12 to 40 minutes into the future)	Complex situations, involving a small constrained airspace or a cluster, and strategic problems
Sector problems	One sector	Tactical to short-range strategic time frame (example: predicted approximately 5 to 30 minutes into the future)	Predicted problems for several aircraft

1 Constrained airspaces include SUAs, severe weather areas, or other complex traffic airspaces that involve heavy or complex traffic flows, e.g. flows impacted by Navigational Aid (NAVAID) outage or runway closure.

3.2.1 National Situations

National situations typically involve a prediction that demand is expected to exceed capacity for NAS resources, such as major airports and large volumes of airspace [13]. This condition can be caused by unusually high demand when resources are operating at peak capacity, but is more likely due to a reduction in resource capacity as a result of, for example, an equipment failure, an accident at an airport, or a severe weather area. National situations can also be caused by an increase in resource capacity, such as an increase in airport capacity when the fog lifts, or an increase in capacity for a constrained airspace when severe weather dissipates. Figure 3-4 shows an example of a national situation in which a severe weather area is predicted to affect five adjacent Centers. The shaded time line below this figure indicates a range of possible lead times for predicting this type of national situation. The national strategic planning layer is involved since this situation will affect Centers beyond those in which the situation is predicted to occur.

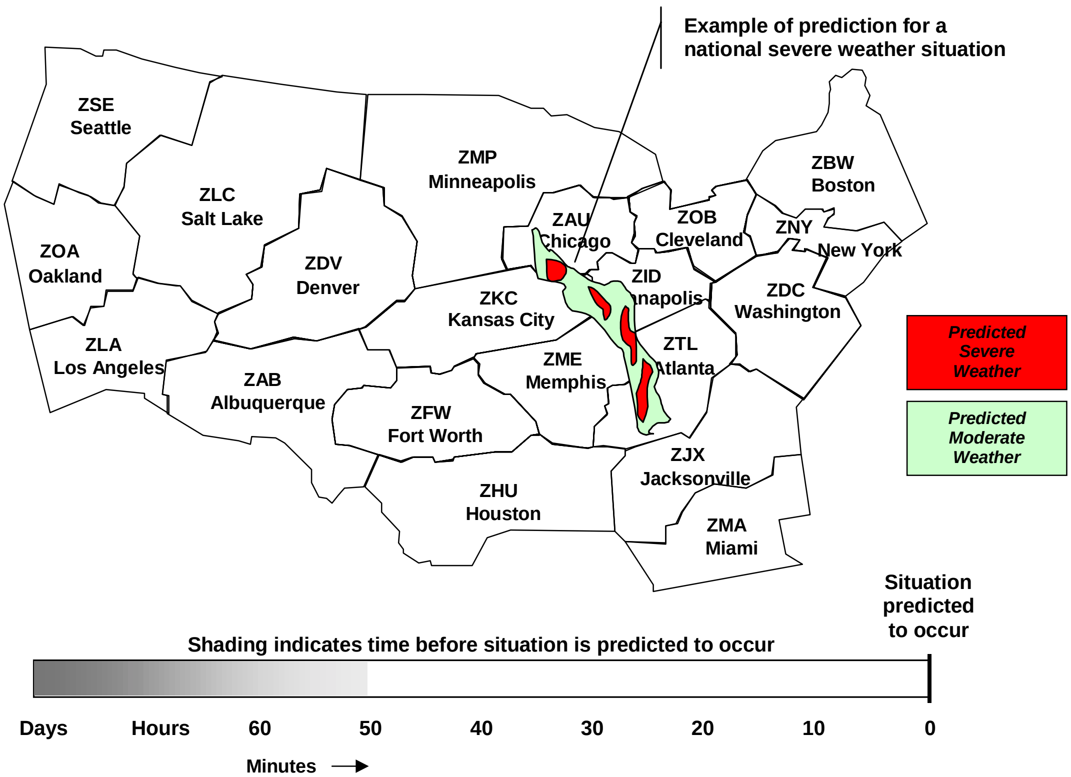

Figure 3-4. National Situation Example

3.2.2 Multi-Center Situations

Multi-Center situations are similar to national situations in that they involve a prediction that demand is expected to exceed capacity for NAS resources, such as for large volumes of airspace that cross Center boundaries, or they involve an increase in resource capacity. While the types of multi-Center situations are similar to the types of national situations, they are smaller in scope, affecting only a few adjacent Centers rather than having more of a nationwide effect. An example of a multi-Center situation is shown in Figure 3-5. In this situation, a severe weather area is expected to affect several adjacent Centers. The shaded time line below this figure indicates a range of possible lead times for predicting this type of multi-Center situation. The national planning layer is involved mainly for situational awareness since the localized situation can be resolved through coordination among the Centers directly involved with the situation.

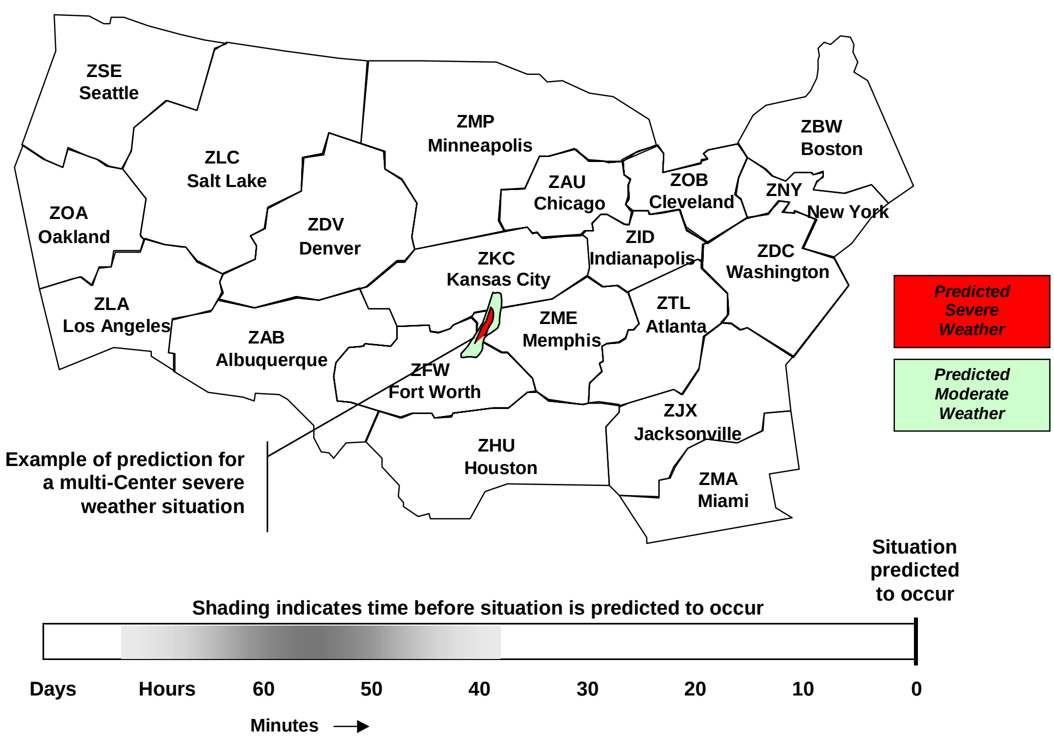

Figure 3-5. Multi-Center Situation Example

3.2.3 Center Situations

Center situations involve a local prediction that demand is expected to exceed capacity for NAS resources within a Center's airspace, such as for medium-sized volumes of airspace within a Center's boundaries, or they involve an increase in capacity for a resource within the Center. Center situations also include traffic streams that must be merged to utilize resources such as airports within the Center's boundaries, and widespread clusters of flights within the Center, where a cluster is a set of interrelated predicted problems for pairs of aircraft that may involve any number of aircraft predicted to be within close proximity in time and space [14, 15, 16, 17]. Center situations are limited in scope to involve only that Center's resources and are expected to have little effect on the handoff or acceptance rates with neighboring Centers, and therefore do not require formal coordination with other Centers. Several examples of Center situations are shown in Figure 3-6, including predictions for a medium-sized complex traffic airspace and a severe weather cell within the Center's boundaries. The shaded time line below this figure indicates a range of possible lead times for predicting these types of Center situations.

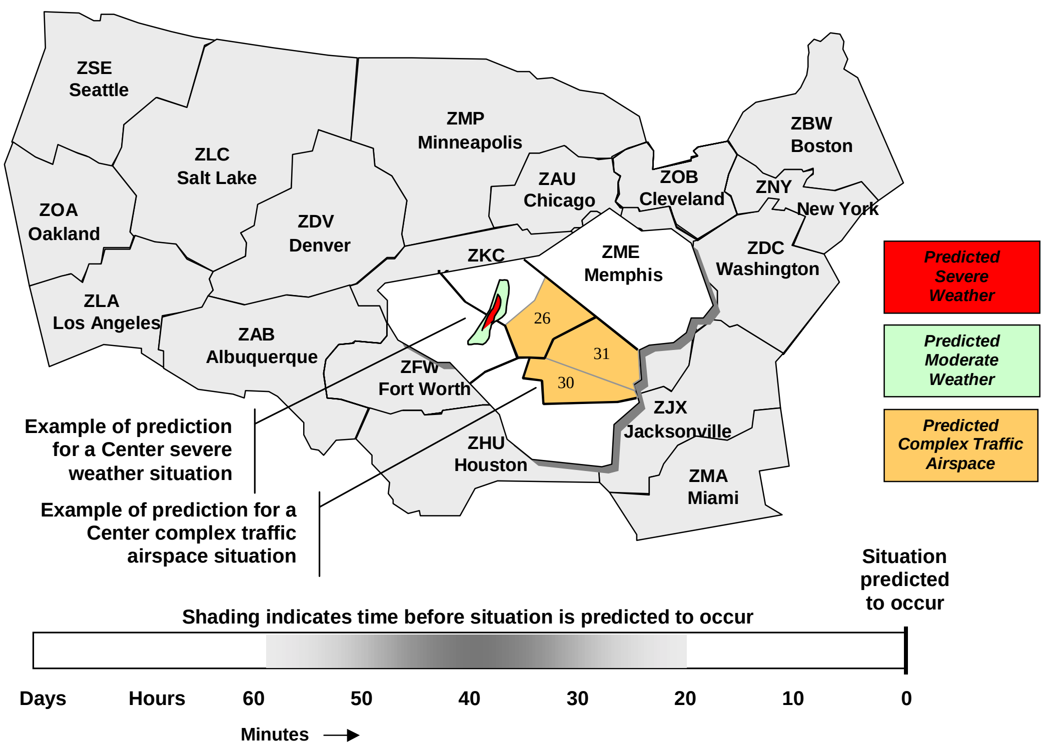

Figure 3-6. Center Situation Examples

3.2.4 Multi-Sector Situations and Problems

Multi-sector situations typically involve a prediction that demand is expected to exceed capacity for NAS resources within a small portion of a Center's airspace, such as for small volumes of airspace that affect several adjacent sectors. Multi-sector problems can involve clusters of flights in several adjacent sectors or aircraft-specific problems. Figure 3-7 shows examples of predicted multi-sector situations for a small complex traffic airspace and a small severe weather cell. The shaded time line below this figure indicates a range of possible lead times for predicting these types of multi-sector situations, as well as for predicting multi-sector problems.

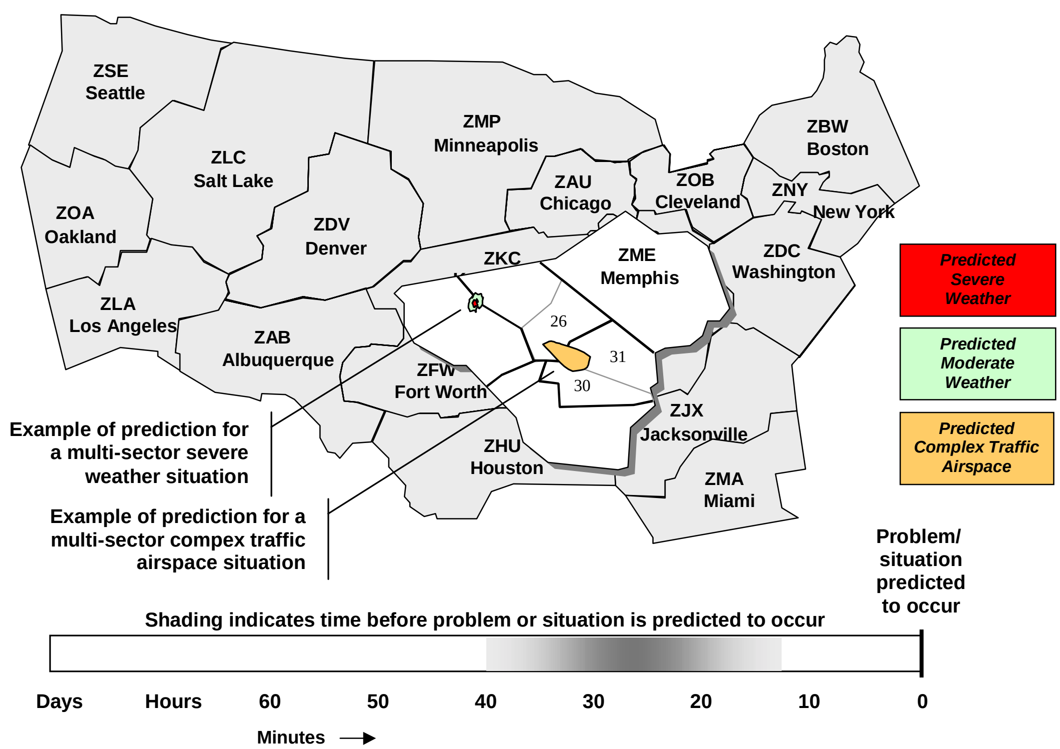

Figure 3-7. Multi-Sector Situation Examples

3.2.5 Sector Problems

Sector problems involve the prediction of aircraft-specific problems, including the predicted loss of separation between aircraft and other aircraft, SUA, complex traffic airspace, terrain and obstructions, and severe weather, or the predicted non-compliance of aircraft with traffic planning constraints. Figure 3-8 shows an example of a sector problem involving two aircraft. When a sector problem is predicted near a sector or Center boundaries, coordination with other sectors may be performed. The shaded time line below this figure indicates a range of possible lead times for predicting this type of sector problem.

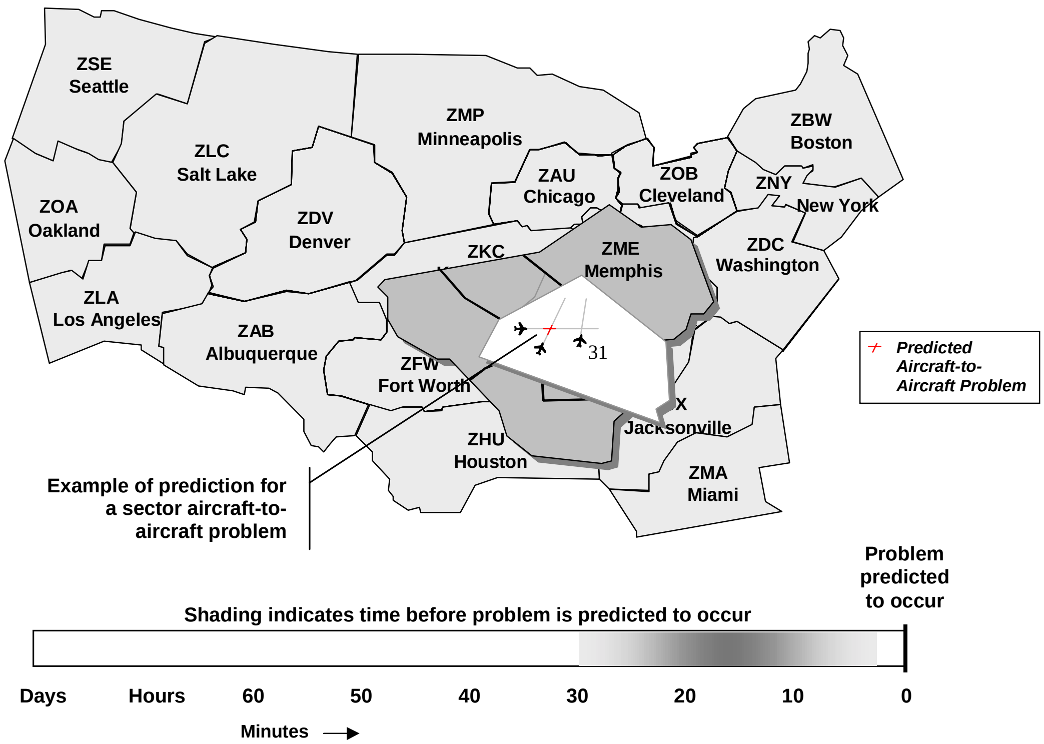

Figure 3-8. Sector Problem Example

3.3 Response to Hierarchical Problems and Situations using Layered Strategic Planning

In response to the problem and situation hierarchy described in the previous section, a ***layered strategic planning*** concept has been developed to provide overlapping planning layers that are associated with the different types of problems and situations shown in Figure 3-3. Overlapping planning layers provide flexibility in handling the daily variations in traffic patterns and loads, as well as the different types of traffic planning activities (such as changing status of SUAs and severe weather, etc.) that occur in the NAS. The planning layers in the Command Center domain [13] are defined as follows:

- The national planning layer is the overall TFM function within the NAS, coordinating planning efforts involving many Centers. The national planning layer is also a primary point of contact for collaboration with the AOCs.
- The multi-Center planning layer coordinates TFM planning efforts among multiple sectors across adjacent Center boundaries.

The planning layers in the Center domain are defined as follows:

- The Center planning layer coordinates TFM planning efforts within a single Center [13].
- The multi-sector planning layer coordinates TFM planning efforts involving more than one adjacent sector within a single Center and performs strategic problem and situation resolutions.
- The sector planning layer ensures aircraft separation, resolving predicted aircraft-specific problems before they occur.

Through advanced planning, each layer helps to ensure that the workload for the layer below remains operationally acceptable.

The guiding principle behind the layered strategic planning concept is that problems and situations are resolved by the planning layer that can best handle them, performing as much strategic planning as possible based on the stability of the available information. Because problems and situations are resolved more strategically in the highest possible planning layer, the number of actions required in lower layers to maintain safety (and the resulting system inefficiencies) is reduced. In addition, more strategic planning can increase the opportunity for NAS users to be involved in flight planning, increasing the accommodation of user preferences.

By handling problems and situations at the appropriate layer, strategic planning can reduce the number of predicted problems to be handled in the sector planning layer. Strategic planning ensures that sector workload is operationally acceptable, while allowing time to pass for some predicted aircraft-specific problems to become more certain before maneuvering aircraft. As a result, NAS users are involved in maintaining safety through planning, with less possibility that flights will be maneuvered unnecessarily.

The goal of layered strategic planning is to resolve problems and situations at the appropriate layer, by adjusting the service provider resources to handle constrained airspaces and the variations in traffic patterns and loads, and by involving users in strategic planning. In the layered strategic planning concept, NAS safety is maintained while NAS efficiency and the accommodation of user preferences are increased.

Issue: Response to Hierarchical Problems and Situations Using Layered Strategic Planning – Section 7.5.3

The overlapping planning layers can be adjusted to meet changing traffic conditions by adjusting the staffing for the different layers. The national and multi-Center planning layers are active for all types of traffic conditions to manage situations and workload across the Center boundaries. Although the Center, multi-sector, and sector planning layers are also active for all types of traffic conditions, the sector planning layer has a lighter workload during light traffic conditions. As the traffic conditions become heavier, staffing for the different strategic planning layers is adjusted to accommodate the changing traffic conditions.

For all types of traffic conditions, the national and multi-Center planning layers coordinate with the Center planning layer, which also coordinates with the multi-sector planning layer. In addition, the multi-sector and sector planning layers coordinate with each other. Plans and strategies are coordinated to lower levels for implementation, and feedback to those plans are coordinated to higher levels.

The operational concept for the national and multi-Center planning layers in the Command Center domain are described in more detail in *Operational Concept for Collaborative Traffic Management in 2005* [13]. The operational concept, or the roles, responsibilities, and capabilities, for the remaining layers in the Center domain of the layered strategic planning concept are discussed in the following sections.

Section 4

Roles and Responsibilities for Layered Strategic Planning in the Center Domain

The need for layered strategic planning in response to hierarchical situations within the NAS is identified in Section 3. While layered planning is performed today in both the Command Center and Center domains, this document extends today's implementation of the layered strategic planning concept as described below.

The roles and responsibilities for the national and multi-Center planning layers in the Command Center domain are described in more detail in [13] and therefore not repeated here. This section describes the roles and responsibilities associated with the Center domain of the layered strategic planning concept, which includes the Center, multi-sector, and sector planning layers. The general roles for these layers are as follows:

- The C*enter planning layer* performs flow planning in the mid- to long-range strategic time frame, monitoring demand and capacity within the Center and adjusting traffic flows to manage changes in traffic patterns and loads. Strategies are coordinated with the national planning layer, and the national layer is involved when a situation or a strategy extends beyond the Center's boundaries. The Center planning layer contributes knowledge of local conditions and analysis of local effects to the national planning layer for management of larger situations. The Center planning layer also communicates all strategies to the multi-sector and sector planning layers for implementation [13].
- The *multi-sector planning layer* performs service provider resource planning and flight planning in the short- to mid-range strategic time frame. Service provider resource planning includes the adjustment of sector configurations, personnel assignments, and time intervals of responsibility for service providers to manage changes in traffic patterns and loads. Flight planning in this layer includes adjusting smaller traffic flows and handling strategic problems to maintain an operationally acceptable workload for the sector planning layer.
- The *sector planning layer* performs flight plan amendments in the tactical to short-range strategic time frame, fine-tuning plans originating from the Center and multi-sector layers by resolving predicted problems.

Some of the types of problems and situations that are resolved by the planning layers are listed in Table 4-1.

Table 4-1. Types of Problems and Situations Resolved by Center Domain Planning Layers

Problem or Situation Type	Resolution by the Strategic Planning Layers		
	Sector	Multi-Sector	Center
Capacity changes for a Center resource (equipment outage, runway closure)			•
Heavy or complex traffic flows		•	•
Constrained airspace[2]		•	•
Merging and sequencing traffic streams[3]			•
Sector traffic overload		•	•
Clusters		•	•
Aircraft-specific problems for individual aircraft	•	•	
Traffic planning constraint compliance	•	•	
User requests			
AOC requests			•
Pilot requests	•	•[4]	

2 Constrained airspaces include SUAs, severe weather areas, or other complex traffic airspaces that involve heavy or complex traffic flows, e.g. flows impacted by NAVAID outage or runway closure.

3 The Center planning layer develops the plans for merging and sequencing traffic streams, such as those headed for an airport's arrival fix (if an airport is near a Center boundary, this could be handled by the multi-Center-planning layer). The resulting flight plan amendment requests are then electronically coordinated with the multi-sector and sector planning layers as appropriate for implementation.

4 The multi-sector layer only receives pilot requests if they are transmitted via data link.

Issues:

Multiple Layers of Strategic Planning – Section 7.3.2

Service Provider Configurations and Workloads – Section 7.3.3

Resolving problems and situations in the different planning layers involves identifying the problem or situation, evaluating and selecting the appropriate resolution or strategy, and then implementing that resolution or strategy. The types of strategies available in each planning layer include strategies for adjusting service provider resources and for adjusting air traffic flows. The strategies involving service provider resources are preferred because they allow the NAS to adjust to the traffic patterns and loads without affecting flights unnecessarily. The strategies for adjusting traffic flows address the remaining situations that cannot be resolved by adjusting service provider resources. Table 4-2 identifies the types of resolutions and strategies available for handling the problems and situations in the planning layers. Table 4-3 describes the types of coordination required for the planning layers within the Center to analyze problems and situations, as well as to develop and implement the appropriate resolutions and strategies.

The roles and responsibilities for each planning layer are described by the types of situations and strategies associated with that layer, and by the coordination among the layers. The capabilities required to support these roles and responsibilities are described in Section 5.

Table 4-2. Resolutions and Strategies Available for Center Domain Planning Layers

Resolution or Strategy Type	Availability for the Strategic Planning Layers		
	Sector	**Multi-Sector**	**Center**
Define a complex traffic airspace for situational awareness, coordination, and strategy development for:			
Medium-sized complex traffic airspace situations			•
Small complex traffic airspace situations		•	
Coordinate complex traffic airspace with affected sectors to prevent additional flights from being maneuvered into the airspace through flight plan amendments		•	•
Identify flight-specific constraints for as few flights as necessary to reduce airspace complexity			•
Develop flight plan amendments for as few flights as necessary to reduce airspace complexity		•	•
Balance loads for sectors and fixes to maintain manageable sector workload		•	•
Activate predefined airspace configuration to combine or decombine sectors, or adjust sector boundaries to maintain manageable sector workload		•	

Issues:

Complex Traffic Airspace Definition – Section 7.4.1

Service Provider-Defined SUA and Complex Traffic Airspace – Section 7.4.4

Transfer of Control – Section 7.3.7

Airspace Boundary Adjustment – Section 7.4.3

Table 4-2. Resolutions and Strategies Available for Center Domain Planning Layers (concluded)

Resolution or Strategy Type	Availability for the Strategic Planning Layers		
	Sector	Multi-Sector	Center
Adjust sector configurations, staffed positions, and time intervals of responsibility for service providers to maintain manageable sector workload		•	
Coordinate strategies within the Center for medium-sized severe weather or aircraft cluster situations			•
Create proposed flight plan amendments for some of the flights involved to break complex cluster situations into cluster situations that can be handled by the multi-sector planning layer			•
Coordinate strategies among adjacent sectors involved with small-scale severe weather or aircraft cluster situations		•	
Create proposed flight plan amendments or trial plans for a few flights to break small-scale cluster situations into aircraft-specific situations that can be handled by the sector planning layer		•	
Implement flight plan amendments in response to severe weather or complex traffic airspace	•	•	
Resolve predicted problems strategically, before flights enter the airspace assigned to the planning layer	•	•	

Table 4-3. Coordination Among the Center Domain Planning Layers

To From	Center	Multi-Sector	Sector
Center	Situations and proposed strategies for coordination	Situations and proposed strategies for coordination Proposed flight plan amendments for implementation of strategies	Proposed flight plan amendments for implementation of strategies
Multi-Sector	Feedback on situations and proposed strategies Feedback on proposed flight plan amendments for implementation of strategies	Situations and proposed strategies for coordination Proposed flight plan amendments for coordination of resolutions and strategies	Proposed flight plan amendments for implementation of resolutions and strategies
Sector	Feedback on proposed flight plan amendments for implementation of strategies	Feedback on proposed flight plan amendments for implementation of resolutions and strategies	Proposed flight plan amendments for coordination and implementation of resolutions and strategies Handoffs

Issue: Information Flow for Flight Plan Amendment Requests from the TMC and the Multi-Sector Planner – Section 7.5.4

Section 5

Capabilities to Support Layered Strategic Planning in the Center Domain

This section describes the capabilities needed to support the roles and responsibilities defined in Section 4 for the strategic planning layers within the Center domain. Although the focus is on the Center domain, many of these capabilities may also be useful in the Command Center domain. These capabilities must permit seamless operations across sector and Center boundaries and must integrate with additional capabilities required to perform all controller tasks described in the FAA Handbook 7110.65 [18]. Once fielded, they will assist the strategic planning layers within the Center in maintaining safety while efficiently handling varying sector workloads that become more complicated with the increasing complexity of traffic patterns.

Service provider notification (at the appropriate strategic planning layer) is based on the type of problem, the service provider time interval of responsibility, and the service provider airspace assignment. Types of problems include aircraft-to-aircraft and all others, which can be categorized as aircraft-to-airspace. The time interval of responsibility is associated with the service provider's time frame of operation (tactical, short-range strategic, etc.). The airspace assignment is a single sector for service providers in the sector planning layer, and airspace covering more than one sector for service providers in the multi-sector planning layer. Table 5-1 summarizes the problem assignment rules based on the problem type and the time frame of operation.

Table 5-1. Problem Assignment Rules Based on Time Frame of Operation

Problem Type	Tactical	Short- to Mid-Range Strategic	Mid- to Long-Range Strategic
Aircraft-to-Aircraft	Sector where predicted	Sector or multi-sector planning layer where predicted	N/A
Individual Aircraft-to-Airspace	Sector where aircraft is located	Sector or multi-sector planning layer where aircraft is located	Multi-sector planning layer where aircraft is located
Multiple Aircraft-to-Airspace	N/A	Multi-sector planning layer where predicted	Multi-sector planning layer or Center planning layer where predicted

The capabilities described address the following operational areas:

- Situational awareness
- Problem prediction and notification
- Problem resolution
- Traffic planning
- Workload management
- Communications

Table 5-2 correlates the strategic planning layers identified in Section 3 with specific capabilities that enable improvements in these areas. The specific capabilities are described in more detail following the table. Laboratory and field evaluations are necessary to determine the capabilities that best support each layer of strategic planning.

Table 5-2. Capabilities Available for Center Domain Planning Layers

Capability	Availability for the Strategic Planning Layers		
	Sector	Multi-Sector[5]	Center
Situational Awareness			
Dynamic SUA status	●	●	●
Severe weather information and forecast[6]	●	●	●
Terrain and obstruction location	●	●	
Complex traffic airspace	●	●	●
Traffic planning constraints[7]	●	●	●
Flight monitoring and trajectory prediction	●	●	●
NAS information database	●	●	●
ATC-induced delays	●	●	●

5 The multi-sector planning layer views all of the Center's airspace and can zoom in on situations predicted to involve several adjacent sectors.

6 Initially, this capability shows current weather areas. Later, this capability shows current and forecasted (up to two hours) weather areas, including information about the predicted speed and direction of the weather area.

7 Traffic planning constraints are flow directives defined by the national, multi-Center, and Center planning layers.

Table 5-2. Capabilities Available for Center Domain Planning Layers (continued)

Capability	Availability for the Strategic Planning Layers		
	Sector	Multi-Sector	Center
Problem Prediction and Notification			
Aircraft-to-aircraft	•	•	
Aircraft-to-SUA	•	•	
Aircraft-to-complex traffic airspace[8]	•	•	
Aircraft-to-terrain and obstructions	•	•	
Aircraft-to-severe weather	•	•	
Aircraft-to-traffic planning constraint	•	•	
Problem Resolution			
Manual trial planning, including probed altitude, speed, and fix menus and complex traffic airspace probe	•	•	
Automated replan (re-evaluation) of trial plans	•	•	
Automated trial planning	•	•	

8 Complex traffic airspace can be manually defined by a service provider or automatically defined by the supporting capability. When a complex traffic airspace is automatically defined by a traffic planning capability, that capability lists the flights that are predicted to contribute to the traffic complexity in the airspace. After a complex traffic airspace has been identified, the aircraft-to-complex traffic airspace problem prediction capability notifies a service provider if trial plans proposed by that service provider are predicted to enter the previously defined complex traffic airspace.

Table 5-2. Capabilities Available for Center Domain Planning Layers (continued)

Capability	Availability for the Strategic Planning Layers		
	Sector	Multi-Sector	Center
Traffic Planning			
Traffic planning strategy evaluation (manually defined reroutes as flight plan amendment requests for SUA, complex traffic airspace, etc.) with flight group selection and automated determination of flights intersecting complex traffic airspace		•	•
Dynamic cluster prediction, notification, and simplification		•	•
Traffic sequencing and merging (Center planning layer creates metering list and sector planning layer implements resulting flight plan amendments)	•		•
Workload Management			
Time-based problem and situation allocation to strategic planning layers[9]	•	•	•
Activation/deactivation of strategic planning layers		•	
Sector overload prediction		•	•

9 The supervisor uses this capability to allocate problems and situations to the sector, multi-sector, and Center planning layers. Before the automated problem resolution capability becomes operational, predicted problems are allocated to the service provider that is responsible for the airspace in which the problem is predicted to occur; after the automated problem resolution capability is operational, problems are allocated to the service provider with flight control of the aircraft to be maneuvered.

Table 5-2. Capabilities Available for Center Domain Planning Layers (concluded)

Capability	Availability for the Strategic Planning Layers		
	Sector	Multi-Sector	Center
Communications			
Two-way data link between aircraft and ground systems	•	•	
Automated coordination (implementation of trial plans for predicted problem resolution)	•	•	
Electronic coordination of traffic flow strategies and workload allocation strategies	•	•	•

5.1 Situational Awareness

Service providers use a workstation and display to monitor an airspace for traffic, situational awareness, and potential problems. This display provides a configurable capability that allows tactical and strategic service providers supporting different layers of planning and control to:

- Maintain awareness of the current and future traffic and airspace situation
- Evaluate predicted problems and predicted complex traffic airspace
- Evaluate flight plan amendments for resolving predicted problems
- Evaluate strategies for resolving predicted complex traffic airspace

The en route workstation supports service providers for each layer to maintain situational awareness for the assigned airspace. The workstation provides a "scroll through time" capability that can show the current and predicted future traffic and airspace situations up to two hours in the future.[10]

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10 The capability to adjust specific user preferences, such as window size, will be available.

The decision support capabilities that will improve situational awareness and that can be displayed on the workstation include the following:

- Dynamic SUA status
- Severe weather information and forecast
- Terrain and obstruction location
- Complex traffic airspace
- Traffic planning constraints
- Flight monitoring and trajectory prediction
- NAS information database
- ATC-induced delays

5.1.1 Dynamic Special Use Airspace (SUA) Status

Uses: Knowing the status of SUA allows service providers and system users to:

- Support the definition of user-preferred routes.
- Support planning of reroutes to avoid active SUAs.

Capabilities: SUA is defined as a volume of airspace with upper and lower altitude levels as well as start and end times. When the airspace is active, it is not available for use by non-participating civilian and military aircraft. The service provider workstation dynamically displays SUA and identifies when an SUA is active.

Service providers and users have real-time information identifying when SUA is scheduled and therefore not available for use by non-participating aircraft. This information is accessible a minimum of 24 hours in advance with status updates in real-time. SUA schedules are maintained in the NAS information database and can be modified in real time by designated ATM service providers.

Issues:
NAS Information System Update Responsibility – Section 7.2.1
Service Provider-Defined SUA and Complex Traffic Airspace – Section 7.4.4

5.1.2 Severe Weather Information and Forecast

Uses: Providing information on the current and forecast location and movement of severe weather:

- Supports service providers when either providing severe weather advisories or collaborating with users to avoid severe weather.
- Supports service providers at all layers in defining efficient reroutes around severe weather.

Capabilities: The capability to forecast and display severe weather enables service providers to observe current and predicted severe weather using graphic displays of multiple levels of reflectivity data and other weather products. This data is displayed for either a composite set of altitudes or any of three selected altitude levels. The weather information is available as overlays, which allows the service provider to select one or more levels for display. The data represents discrete weather cells, a weather line, or a weather line including discrete cells. The weather is displayed using polygons and includes an indication of the "top" or "bottom" of the weather based on the selected weather severity level.

The weather information includes indications of the projected speed and direction of movement (each of which may be different), as well as the expected growth or decay of the weather lines or cells. The weather predictions include a "confidence factor," indicating the probability that the predicted weather lines, cells, and movements will occur.

In addition to severe weather lines and cells, this capability identifies forecast turbulence and icing areas. Turbulence and icing forecasts are amended based on pilot reports. Winds aloft are also included in the weather information for the selected altitude. The "winds" display can be selected or deselected separately from other weather information.

The severe weather information and forecasts are updated at a rate related to the movement of the weather so the service provider receives an accurate indication of the weather movement. The time of interest is different for the different planning layers. Service providers receive automatic notification that severe weather exists based on its predicted time of occurrence and location. Service providers can then configure their displays to depict the severe weather.

Issue: Weather Forecast – Section 7.3.9

5.1.3 Terrain and Obstruction Location

Uses: To ensure safe operations, service providers issue instructions to avoid encounters with terrain and obstructions. Likewise, flight planners plan their flights to avoid terrain and obstructions.

Capabilities: The system incorporates terrain and obstruction data for use in problem prediction, as well as for graphically displaying terrain and obstructions to service providers on request.

5.1.4 Complex Traffic Airspace

Uses: Providing ATC services for traffic in complex traffic airspace increases service provider workload and can reduce system throughput. Consequently, the forecast of complex traffic airspace:

- Supports service providers and users in planning efficient routes to avoid or simplify complex traffic airspace.
- Helps supervisors plan sector configurations and service provider assignments to handle expected workload(s).
- Provides information that helps prevent layered strategic planning from increasing traffic complexities when planning reroutes.

Capabilities: The capability to forecast and display complex traffic airspace enables service providers to identify: 1) the complex traffic airspace, and 2) aircraft that contribute to complex traffic. The following factors are considered in the complex traffic airspace definition and may be displayed to and adjusted by the service provider:

- *Aircraft count*–the number of aircraft in a volume of airspace.
- *Airspace density*–the aircraft count per unit volume of airspace.
- *Aircraft interaction*–predicted problem counts, sizes of clusters, number of crossing streams.
- *Aircraft maneuverability*–the availability of small airspace[11] around each aircraft for minor maneuvers to resolve separation problems should they become necessary.
- *Airspace availability*–the portion of airspace that is restricted or constrained, and therefore unavailable for planning flight reroutes.
- *Aircraft profile mix*–the mix of aircraft with different equipage and performance characteristics.

A complex traffic airspace includes lateral and vertical bounds, as well as a start time and end time. A confidence factor indicating the likelihood that complexity will occur is included in the prediction and displayed to the service provider. The predicted time for and location of the complex traffic airspace are used to identify the strategic planning layer

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11 The airspace surrounding each aircraft is defined using aircraft performance characteristics.

responsible for resolving the complex traffic. In some cases, the locations of the aircraft contributing to the complex traffic airspace are used in the problem notification decision process.

All service providers receive automatic notification of complex traffic airspace to maintain situational awareness and to ensure consistency among service provider actions. In addition, this decision support capability automatically notifies the appropriate strategic planning layer and the service provider(s) responsible for resolving the complex traffic situation. Service providers may manually define a complex traffic airspace, including its time duration. Manually-defined complex traffic airspace is displayed automatically based on the same conditions as those used for an automatically defined airspace. Complex traffic airspace can be labeled to define the nature of the complex traffic.

Although aircraft may be permitted to enter complex traffic airspace, service providers may restrict aircraft from entering the airspace to prevent an increase in complexity. To assist the service provider in assessing the impact of such actions, a decision support capability is available that will determine the impact on the complex airspace if additional aircraft are cleared into the airspace.

Issues:

Complex Traffic Airspace Definition – Section 7.4.1

Complex Traffic Airspace Notification – Section 7.4.2

5.1.5 Traffic Planning Constraints

Uses: Traffic planning constraints are employed as a result of traffic planning strategies developed in response to complex traffic or when the demand for a resource exceeds its capacity. Traffic planning constraints must be disseminated to service providers to manage traffic accordingly, and to service providers and users to plan efficient reroutes.

Capabilities: Today's system imposes traffic planning constraints and static restrictions to prevent an airspace or facility (e.g., airport) from exceeding its capacity and to facilitate the transition between en route and terminal airspace. Such constraints include meter fix times and miles-in-trail restrictions. In the future, collaboration between service providers and users to modify flight schedules when complex traffic airspaces or capacity limitations exist, may reduce the need for many flow constraints. Nevertheless, some traffic planning constraints will continue to exist, such as issuing airspace boundary crossing times.

When conditions warrant, strategic planning at various layers may identify traffic planning constraints. The system displays these constraints, including current and projected status, and time duration. The defined time for and location of the constraints are used to determine which service providers receive automatic notification.

5.1.6 Flight Monitoring and Trajectory Prediction

Uses: Flights are monitored and trajectories are extrapolated to:

- Support the automatic prediction of aircraft-specific problems
- Identify predicted trajectories for use in problem and situation resolution

Capabilities: The flight monitoring and trajectory prediction capability automatically monitors and predicts the trajectories of all flights in the en route airspace. This capability uses the current aircraft position (determined using a combination of radar-derived information and position information broadcast from the aircraft) along with the predicted trajectory to determine if the aircraft is in conformance.[12]

The trajectory is a four-dimensional prediction derived from the aircraft's flight plan that accounts for aircraft performance characteristics and environmental conditions (winds and temperature). Real-time aircraft-provided information obtained through data link when available will be used to refine trajectories. This aircraft information might include weight, true airspeed, and course data. Trajectories are predicted to identify and resolve tactical and strategic problems and to support traffic planning. For those aircraft whose current positions are not in conformance, the predicted trajectories are modified as necessary to incorporate the current position and flight direction.

Issue: Problem and Situation Prediction Time/Trajectory Accuracy – Section 7.1.1

Transition Airspace: Transition airspace lies in the vicinity of terminal airspace and is used to make the transition from low altitude en route airspace to terminal-area arrival airspace. However, due to traffic concentrations as well as climbing and descending aircraft, transition airspace may require a different implementation of trajectory prediction capabilities. As an example, the threshold of non-conformance for an aircraft within transition airspace may be different than the threshold for an aircraft in other parts of the ***en route*** airspace. Therefore, for aircraft operating in transition airspace, decision support

[12] Conformance is a condition established when an aircraft's current position is within a region constructed around the aircraft's predicted position, according to the trajectory associated with the aircraft's current flight plan.

capabilities may require a higher level of tracking accuracy or better information on aircraft intent. Analysis is required to determine the needed trajectory prediction accuracy associated with transition airspace.

5.1.7 NAS Information Database

Uses: The NAS information database contains information required by service providers to manage air traffic and by users to plan and execute their operations. The NAS information database is used to provide real-time information on:

- Airports and runways in use
- Infrastructure (including Navigational Aids, or NAVAIDs, and planned outages for the Global Positioning System, or GPS)
- Communication frequencies
- SUA status
- Severe weather
- Complex traffic airspace
- Traffic planning constraints
- Other NAS status information

Capabilities: The NAS information database is a repository of information needed by service providers and system users. Database information entries are primarily updated automatically by NAS systems as data changes.

System users can query the NAS information database for information on an as-needed basis (e.g., status of SUA and facilities). A user can also subscribe to information items so whenever the database is updated, the information is automatically made available to that user.

Using the latest real-time information on which to perform analyses, the database is the data source for many NAS systems. Also, the database is updated based on the output of many systems.

Issues:
NAS Information System Update Responsibility – Section 7.2.1
NAS Information System User Notification – Section 7.2.2

5.1.8 ATC-Induced Delays

Uses: This capability is used by the service providers to maintain awareness of the amount of delay absorbed by each aircraft resulting from ATC-initiated flight plan amendments. This information is considered by the service providers when making decisions on which aircraft to maneuver under conditions of predicted problems and complex traffic. Workload and time permitting, service providers may collaborate with pilots and AOCs, allowing delayed flights to make up time if traffic conditions allow. Changes to speed, route, or altitude agreed upon by the pilot and service provider reduce the time required to complete the flight.

Capabilities: This capability will maintain a record of the number of minutes of delay absorbed by each aircraft resulting from ATC-initiated flight plan changes.

Issue: Choice of Aircraft to Maneuver – Section 7.3.8

5.2 Problem Prediction and Notification

Future decision support capabilities predict and notify service providers of the following types of problems:

- Aircraft-to-aircraft
- Aircraft-to-SUA
- Aircraft-to-complex traffic airspace
- Aircraft-to-terrain and obstructions
- Aircraft-to-severe weather
- Aircraft-to-traffic planning constraints

When the decision support capabilities identify a potential problem, the appropriate service provider receives a notification. This notification includes a confidence factor that indicates the likelihood that the problem will occur. The confidence factor, along with the time of the predicted problem, is available for the service provider to use in prioritizing various problems.

Implementing a flight plan amendment for a problem resolved strategically requires forwarding the solution ultimately to the service provider in the sector layer who is currently responsible for the aircraft. If the aircraft has data link capability, and if the flight plan amendment implementation is strategic, a service provider in the multi-sector planning layer may transmit a new clearance to the aircraft via data link.

Issues:

Delineation of Service Provider Roles – Section 7.3.1

Issuing and Coordinating Plans – Section 7.3.5

5.2.1 Aircraft-to-Aircraft

Uses: Aircraft-to-aircraft problem prediction is used by sector and multi-sector layers to ensure separation between aircraft. Sector layer service providers use aircraft-to-aircraft problem prediction within a single sector for the tactical to short-range strategic time frame (for instance, with up to 20-minute lead times for predicting problems). Multi-sector layer service providers use aircraft-to-aircraft problem prediction within several adjacent sectors for the short- to mid-range strategic time frame (for example, with 20- to 40-minute lead times for predicting problems).

Capabilities: Aircraft-to-aircraft problem prediction continually checks the trajectories of all flights to determine if aircraft trajectories are predicted to violate separation standards. When trajectories are predicted to violate separation standards, the decision support capability initially displays the predicted problem to the appropriate sector or multi-sector service provider, depending on the location of the problem and the time frame in which the problem is predicted to occur. A graphic display of the problem is available when requested by the service provider.

Issue: Problem and Situation Prediction Time/Trajectory Accuracy – Section 7.1.1

5.2.2 Aircraft-to-SUA

Uses: Aircraft-to-SUA problem prediction is used by service providers supporting sector and multi-sector layers to:

- Ensure separation of aircraft from SUA.
- Support planning of reroutes as early as possible to avoid active SUAs or make use of inactive SUAs with minimal deviations to user-preferred routes.

Capabilities: The aircraft-to-SUA problem prediction capability continually checks the trajectories of all aircraft to determine if any aircraft is predicted to enter an active SUA. When there is a predicted aircraft-to-SUA problem, the decision support capability initially displays problems to the service providers supporting the appropriate layer depending on the current location of the aircraft and the time interval of responsibility. A graphic display of the predicted problem is available on request.

When an SUA becomes inactive, the decision support capability determines which aircraft trajectories will be in its vicinity and notifies the applicable service providers. Service providers then collaborate with users to identify whether a reroute would be beneficial.

5.2.3 Aircraft-to-Complex Traffic Airspace

Uses: Aircraft-to-complex traffic airspace problem prediction for manual or automated trial planning is to prevent additional flights from entering complex traffic airspace. The complex traffic airspace can relate to a severe weather area or to dense traffic.

Capabilities: This capability provides for the checking of aircraft trial plans to determine if any are predicted to enter complex traffic airspace. The decision support capability displays the information to the service provider, as appropriate.

5.2.4 Aircraft-to-Terrain and Obstructions

Uses: Aircraft-to-terrain and obstruction problem prediction is used by sector and multi-sector layers to ensure separation of aircraft from terrain and obstructions.

Capabilities: Aircraft-to-terrain and obstruction problem prediction checks the trajectories of all aircraft to determine if the trajectory progresses below minimum safe altitudes. With this type of prediction, the decision support capability displays the problem information to service providers depending on the current location of the aircraft and the time interval of responsibility. A graphic display of predicted problems is available on request.

5.2.5 Aircraft-to-Severe Weather

Uses: Aircraft-to-severe weather problem prediction is used by:

- Sector and multi-sector service providers to assist in separating aircraft from severe weather.
- Sector and multi-sector service providers support the planning of aircraft reroutes as early as possible to avoid severe weather with minimum deviations from user-preferred routes.

Capabilities: Aircraft-to-severe weather problem prediction provides continual checking of aircraft trajectories to determine if any aircraft is predicted to enter areas of severe weather. For severe weather cells, service providers are notified depending on the current location of the aircraft and the time interval of responsibility. For severe weather lines, the sector and multi-sector service providers are notified depending on the current location of the aircraft and the time interval of responsibility. In all instances, the service providers may collaborate with users to identify an agreeable solution. A graphic display of predicted problems is available on request.

5.2.6 Aircraft-to-Traffic Planning Constraints

Uses: Aircraft-to-traffic planning constraint problem prediction is used by sector and multi-sector service providers to determine whether an aircraft is complying with traffic planning constraints or other restrictions (e.g., meter fix times or miles-in-trail criteria).

Capabilities: The aircraft-to-traffic planning constraint capability notifies sector or multi-sector service providers when an aircraft trajectory is not in compliance with a traffic planning constraint. With this type of prediction, the decision support capability displays the problem to service providers depending on the current location of the aircraft and the time interval of responsibility.

5.3 Problem Resolution

There are several decision support capabilities that support the development of resolutions for predicted problems. These capabilities include:

- Manual trial planning
- Automated replan (re-evaluation) of trial plans
- Automated trial planning

The trial planning capability supports the development of new flight plan amendments to resolve a predicted problem or generate a response to a user request. Trial planning has two components. It first supports the generation of a new trial plan. It additionally analyzes the new trajectory to determine if it is problem-free. In cases where a problem remains, trial planning also permits the periodic re-evaluation of a trajectory (replan) and notifies the service provider when the replan is problem-free.

5.3.1 Manual Trial Planning

Uses: This capability is used by sector and multi-sector service providers to define proposed trial plans to be analyzed by automation for predicted problems.

Capabilities: For individual flight plan changes, the capability allows a service provider to graphically modify a current plan to define a proposed trial plan. For aircraft with data link, the automation system also accepts the direct input of a requested flight plan change. Trial plan modifications are based on altitude, lateral direction, or speed changes. The decision support capability analyzes trial plans for predicted problems. This also includes the identification of trial plans predicted to enter complex traffic airspace or severe weather areas. Results of the analysis are provided graphically to the service provider.

For manually defined trial plans, the system provides a graphic depiction of where problem(s) are predicted. In cases where there are no predicted problems, the trial plan is depicted as problem-free.

5.3.2 Automated Replan (Re-evaluation) of Trial Plans

Uses: The automated replan capability permits the re-evaluation of a trial plan for which initially there were one or more problems. For example, when a pilot requests a direct routing, there may initially be a prediction for conflicting traffic. The replan capability would periodically re-evaluate a trial plan and determine when the pilot request can be accommodated.

Capabilities: When invoked by the service provider, the automated replan capability checks a previously generated plan at an adaptable frequency to determine if the trial plan is problem-free or still has predicted problems. The automated check continues until the trial plan is problem-free, at which time the service provider is notified that the trial plan is problem-free. This automated check continues until one of the following occurs:

- The trial plan becomes problem free and is activated by the service provider.
- The request is canceled (or the proposed new trial plan is deleted) by the service provider.
- The trial plan no longer makes sense due to the flight's current position, as determined using the conformance results from the flight monitoring and trajectory prediction capability.
- A time-out (system adaptation parameter) is exceeded.

5.3.3 Automated Trial Planning

Uses: This capability supports sector and multi-sector service providers by automatically defining proposed trial plans to resolve predicted problems.

Capabilities: For automatically generated trial plans, the service provider is notified when one or more trial plans are problem-free or if no problem-free trial plans were found. If no problem-free trial plans were identified, the service provider can request the display of the trial plans that have predicted problems. The service provider can then use this information to better understand the situation when manually resolving the problem.

5.4 Traffic Planning

The decision support capabilities that will improve traffic planning include:

- Traffic planning strategy evaluation with flight group selection and automated determination of flights intersecting complex traffic airspace
- Dynamic cluster prediction, notification, and simplification
- Traffic sequencing and merging

The scope of this paper includes a selected subset of capabilities to support traffic planning tasks but does not include the full range of TFM capabilities [13].

5.4.1 Traffic Planning Strategy Evaluation

The traffic planning strategy evaluation capability assists the multi-sector and Center service providers in creating and evaluating strategies to resolve predicted complex traffic by assessing the impact of possible temporary route constraints to be implemented via flight plan amendments (for example, moving a traffic stream around a severe weather area) [19]. This capability also assists the multi-sector and Center service providers in evaluating the termination of existing route constraints when they are no longer needed.

When complex traffic airspace is predicted, the service provider uses capabilities such as flight group selection, automated determination of flights intersecting complex traffic airspace, and a future situation display to analyze its causes and effects. The service provider can then use this traffic planning strategy evaluation capability to create tentative strategies for a group of flights and analyze those strategies to understand: 1) how they affect the complexity, and 2) the impact they have on users. When using traffic planning strategies, user preferences such as routes and arrival sequences (as defined through collaborative decision making with users) are easier to incorporate into flight plan amendments. After a complex traffic airspace situation has been resolved, the service provider uses the traffic planning strategy evaluation capability to terminate existing strategies that are no longer needed.

Uses: Traffic planning strategy evaluation is used by the multi-sector and Center service providers to:

- Ensure that traffic patterns do not generate a high number of predicted problems that will require extensive problem resolution.
- Create traffic planning strategies in collaboration with AOCs (Center service providers only) to manage traffic patterns, resolving areas of predicted complex traffic.
- Analyze the effects of these potential strategies on the complex traffic airspace and the users.
- Identify a particular strategy for implementation.
- Identify when a strategy is no longer needed.

- Store information about the strategies that have been evaluated and implemented, enabling the post examination of strategy effectiveness for given areas of complex traffic.

Capabilities: Traffic planning strategy evaluation enables the service providers to identify traffic planning strategies that may consist of one or more of the following components:

- Group of aircraft for which an action will be performed (e.g., all aircraft predicted to pass through severe weather); this could be a group name assigned using the flight group selection capability (Section 5.4.1.1).
- Start and end times for action (e.g., perform action on aircraft predicted to enter area of complexity between *2200Z* and *2300Z*).
- Constraints which may include: metering, miles-in-trail, limiting or restricting complex traffic, moving flows around or through an airspace, and moving flows to different altitudes (e.g., aircraft may need to *climb to a higher altitude* to avoid severe weather).
- Parameters for the selected action (e.g., *100 percent* of the selected aircraft need to climb to at-or-above *FL390*).

This capability automatically translates traffic planning strategies to a set of proposed changes for individual aircraft flight plans, allowing the service provider to develop strategies in collaboration with users to modify the resulting flight plan amendments as necessary. In addition, this capability automatically predicts the effects on the complex traffic airspace and the users (such as delay, distance traveled, and additional maneuvers), using the trial plans associated with the strategy. This capability supports strategy selection by displaying information that compares the effects of alternative strategies. When a strategy is selected, this capability transmits the requested trial plans associated with the strategy to the appropriate service providers(s) for implementation.

After a strategy has been implemented, this capability periodically evaluates the current and projected levels of complexity for the affected airspace to ensure that the projected airspace complexity is reduced, and assists in determining when a strategy is no longer required. This capability supports feedback from sector layer service providers to determine whether or not strategies are effective.

Issue: Temporary Route Constraints – Section 7.3.10

5.4.1.1 Flight Group Selection

Uses: The flight group selection capability is used by the multi-sector and Center service providers to identify specific groups of flights (including non-departed flights), such as those flights that are expected to pass through severe weather or complex traffic airspace to:

- Gain an understanding about the causes and effects of predicted complex traffic airspace.
- Develop strategies to resolve predicted complex traffic airspace.
- Identify strategies to avoid severe weather.

Capabilities: The flight group selection capability allows the multi-sector and Center service providers to specify criteria for selecting flights that belong to a group. Criteria include aircraft type, aircraft identifiers, region of airspace traversed, fix or boundary line to be crossed, route to be used, origin airport, and destination airport. This capability allows the multi-sector and Center service providers to:

- Identify a group name or to automatically generate a group name for a specific combination of these criteria.
- Update the list of aircraft specified by this group as traffic patterns change.
- Allow this group to be recalled later.

This capability automatically accesses flight information pertaining to the criteria and identifies the group of aircraft by determining which flights satisfy the selected criteria. In addition, the flight group selection capability automatically updates the flights associated with a selected group, as well as updating the situation display when:

- The service provider changes the flight group criteria.
- A flight enters an airspace and, as a result, satisfies the group's criteria.
- A selected flight from the group leaves an airspace or no longer satisfies the group's criteria.

5.4.1.2 Automated Determination of Flights Intersecting Complex Traffic Airspace [19]

Uses: The identification of flights that are predicted to intersect a complex traffic airspace supports the multi-sector and Center service providers in planning flow reroutes so that aircraft can avoid the complex traffic airspace.

Capabilities: When a complex traffic airspace is defined, the flights that are predicted to intersect that airspace will be automatically identified for the service provider. The intersecting flights identified will be within the time period specified for the complex traffic airspace.

5.4.2 Dynamic Cluster Prediction, Notification, and Simplification

Uses: The dynamic cluster prediction, notification, and simplification capability assists multi-sector and Center layer service providers by identifying airspace volumes that are predicted to become complex due to clusters (sets of interrelated aircraft-to-aircraft problems for pairs of aircraft). Because these clusters, which may involve any number of aircraft predicted to be within close proximity in time and space [14, 15, 16, 17], are predicted 20 to 40 minutes into the future, the service providers have ample time to simplify the clusters before the individual problems within the clusters are notified at the multi-sector or sector layers.

Capabilities: Dynamic cluster prediction identifies airspace volumes in which clusters are predicted to make the airspace volume complex. The capability identifies the trial plans necessary to simplify the cluster and to ensure that the flights within the cluster are not so tightly coupled that aircraft maneuverability becomes overly constrained. The capability supports the multi-sector and Center service providers in cluster problem prediction and simplification.

Issues:

Complex Traffic Airspace Definition – Section 7.4.1

Types of Problems and Situations that Require Strategic Planning in the NAS – Sector 7.5.2

5.4.3 Traffic Sequencing and Merging

Uses: The traffic sequencing and merging capability assists Center service providers with the management of converging traffic. This capability is used to:

- Sequence traffic flows into an airspace boundary or fix.
- Merge multiple flows of traffic.
- Provide information about the scheduled traffic sequence to sector service providers.

Capabilities: The traffic sequencing and merging capability accepts information from the service provider to identify the airspace boundary or fix to which traffic must be sequenced and merged. The capability: 1) automatically accesses information about airspace boundaries, fixes, non-departed flights, and projected trajectories, 2) identifies the set of aircraft to be sequenced by determining which flights are projected to cross the airspace boundary or fix, and 3) proposes a sequence of traffic into a specified airspace boundary or fix, allowing for the merging of multiple streams of traffic when necessary.

Criteria used to define the sequence of traffic include demand for the resource, estimated delays for the users, and user preferences [20].

5.5 Workload Management

The multi-sector layer service providers who perform resource planning (i.e., the supervisors) and the Center layer service providers monitor current and predicted traffic to ensure that service provider configurations can safely handle the workload. These layered strategic service providers have a graphic display of traffic for all sectors within their areas of responsibility. In addition, the supervisor requires workload management decision support capabilities to identify: 1) problems associated with sector workload and 2) methods for ensuring that the sector and multi-sector service providers can safely handle the workload. These capabilities include:

- Time-based problem and situation allocation to strategic planning layers
- Activation/deactivation of strategic planning layers
- Sector overload prediction

5.5.1 Time-Based Problem and Situation Allocation to Strategic Planning Layers

Uses: The service provider's time interval of responsibility can be adjusted by the supervisor to manage sector, multi-sector, and Center service provider workload.

Capabilities: The capability to adjust the time-based notification for sector, multi-sector, and Center service providers allows for balancing of allocations between sector, multi-sector, and Center service providers to aid in balancing service provider workload. For each "what if" scenario, the system identifies the impact on projected workload. The supervisor implements the new problem/situation notification time interval after collaborating with all sector, multi-sector, and Center service providers affected by the time-based notification adjustment.

Issues:

Time Frames of Operation and Information Stability for the Information Aggregation Levels – Section 7.5.1

Delineation of Service Provider Roles – Section 7.3.1

5.5.2 Activation/Deactivation of Strategic Planning Layers

Uses: The sector configuration adjustment capability is used by the supervisor in the multi-sector planning layer to analyze sector and multi-sector layer service provider workloads using predicted traffic loads, predicted problems, and airspace complexity predictions. This capability will tailor airspace allocations to service providers to accommodate changing traffic demands and allow the supervisor to:

- Select from a set of predefined service provider-to-airspace allocations developed through off-line analysis of typical traffic patterns. This off-line analysis is accomplished by recording traffic under various conditions and running this recorded traffic through an off-line sector configuration analysis tool to evaluate how various configurations accommodate the traffic. Those allocations that are determined to best handle the traffic are saved in a database for selection by the supervisor to be implemented as needed.
- Implement the predefined sector boundary configuration that will best handle predicted traffic. Collaboration with the affected sectors is performed prior to the planned change in configuration.

Capabilities: When a change in sector or multi-sector airspace allocation is necessary to accommodate predicted workload, the supervisor selects from the list of available airspace allocation options. The supervisor and Center layer service providers can evaluate one or more of these airspace allocations with respect to predicted traffic to determine which will best accommodate the workload. For each "what if" scenario, the system predicts the projected workload. The supervisor selects the best airspace allocation and implements it.

As technologies evolve, this capability may eventually lead to providing the supervisor with the ability to dynamically make small adjustments to sector boundaries within the limits of communications, surveillance, and service provider training constraints as a method for dynamically adjusting traffic flow, aircraft counts, and workload among service providers.

Issue: Airspace Boundary Adjustment – Section 7.4.3

5.5.3 Sector Overload Prediction

Uses: Sector overload prediction supports the multi-sector and Center service providers in planning for airspace allocation, service provider staffing, and traffic flow adjustments to ensure that workload levels are balanced and manageable.

Capabilities: The sector overload prediction capability allows the multi-sector and Center service providers to perform "what if" analyses to understand future projected workloads for sectors. The information supports decision making for traffic flow reroutes so that airspace affected by planned reroutes will not cause unmanageable workloads. The capability also supports decisions related to airspace allocations so that workloads are balanced among service providers. [19]

5.6 Communications

Today, voice is the primary medium for communications. With automation and avionics system enhancements, additional electronic air-ground and ground-ground communications are available.

Electronic air-ground communications in the form of *data link* support communications between the sector and multi-sector layer service providers and the aircraft (pilots). Data link is expected to: 1) alleviate congestion on the voice frequencies; 2) reduce the miscommunication of information such as clearances, instructions, and user requests; and 3) improve the ability of users to exchange complex information about routes, aircraft characteristics, weather, and other conditions. Data link is also expected to increase the number of aircraft that can be safely managed by a service provider.

Electronic *ground-ground* communications in the form of automated coordination and other electronic coordination allows service providers to rapidly exchange information, perform coordination between en route service providers, and collaborate between various layers of service providers. Electronic communications reduce the amount of time and number of misinterpretations associated with verbal communications and improves the understanding of varying situations. It allows service providers to efficiently resolve potential problems and facilitates the understanding of potentially complex situations and the development of proposed strategies.

The following subsections describe communications capabilities.

5.6.1 Two-Way Data Link Between Aircraft and Ground Systems

Uses: Data link expedites and improves the delivery of:

- *Service provider problem resolution instructions and clearances to aircraft (pilots).* Problem resolution instructions developed either by a service provider or through collaboration with a pilot are exchanged through the use of data link.
- *Pilot requests to service providers.* Desired flight plan changes are data linked directly to the automation system for display to a service provider and for trial planning.
- *Weather data to the cockpit.* Weather information contained in the NAS information database is data linked to applicable aircraft.

- *Aircraft information to the ATM system.* Aircraft position updates, speed, winds aloft, and intent information are data linked directly to the automation system for use in trajectory modeling.
- *Aircraft frequency changes.* Sector/Center frequency changes are data linked directly to an aircraft for an automatic or pilot-initiated frequency change.

Capabilities: Data link communications with aircraft require automation system components and a communications infrastructure. The document titled *Requirements Document for En Route Controller-Pilot Data Link Communications (CPDLC) Service* [21] identifies data link functional requirements. As a summary, brief descriptions of the required communications systems follow.

Automation and avionics systems originate or are the destination for data link messages. These systems include a user interface, information management functions, message recording and retention functions, clock functions, and a data link communications interface.

The communications infrastructure comprises broadcast and addressed communications functions. Broadcast communications occur over a free-radiating media, which carries information for simultaneous receipt by multiple users (e.g., today's Automatic Terminal Information System). Addressed communications are used for direct communications between two specific users or end systems.

Since the benefits associated with data link depend on ATM and system user equipage, laboratory analysis is required to evaluate which service provider configurations are the most appropriate to use with the expected future data link capability to support layered strategic planning.

Issues:

Service Provider Configurations and Workloads – Section 7.3.3

Issuing and Coordinating Plans – Section 7.3.5

5.6.2 Automated Coordination

Uses: The automated coordination capability allows service providers to electronically transmit a problem resolution to other service providers for information or implementation. Automated coordination:

- Allows service providers to exchange trial planning information in both textual and graphical format, and
- Provides an efficient method for service providers to electronically perform coordination and implementation of flight plan amendments.

Capabilities: The automated coordination capability is an electronic means of communicating proposed flight plan change information (trial plans) between sector and multi-sector service providers. Any service provider can initiate an automated coordination action to: 1) request another service provider to implement a trial plan, or 2) to pass flight information to other service providers. When the initiating service provider is not the service provider currently controlling the aircraft involved, automated coordination is used to request the implementation of a trial plan by the service provider currently controlling the aircraft. When the initiating service provider is currently controlling the aircraft, the automated coordination is used to pass intent information to other service providers.

Issue: Delineation of Service Provider Roles – Section 7.3.1

5.6.3 Electronic Coordination for Traffic Flow Strategies and Workload Allocation Strategies

Uses: Electronic ground-ground communications are used to communicate information, coordinate actions, and to collaborate on workload allocation strategies and traffic flow strategies between the multi-sector and Center layer service providers, and to coordinate resulting proposed flight plan amendments with the sector layer service providers. In this subsection, the term "electronic communications" includes the following communication, coordination, and collaboration actions:

- *Exchange plan information.* New plans developed due to a potential problem or a flight plan change request from an aircraft (pilot) are electronically forwarded to providers responsible for the applicable aircraft.
- *Disseminate traffic planning constraints.* TFM imposed traffic planning constraints are dispatched electronically to applicable service providers.
- *Automatically handoff aircraft.* When aircraft are about to cross a sector or Center boundary, relevant information is provided to the next service provider.
- *Facilitate the acceptance of user preferences.* Flight planning activities and service providers collaborate to accommodate user preferences.

- *Disseminate NAS information.* System information included in the NAS information database will be automatically disseminated to applicable users and service providers.

Capabilities: Electronic coordination allows service providers and users to rapidly receive, exchange, and respond to all pertinent information. Electronic coordination of complex traffic airspace, traffic flow strategies, proposed airspace allocation, and proposed flight plan amendments all support collaboration between the multi-sector and Center layer service providers and implementation by the sector layer service providers. The electronic coordination must support both textual and graphic data information exchange, and also enable two-way communications. Electronic coordination with sector layer service providers would be used for implementation of airspace allocation and specific flight plan amendments.

Issue: Transfer of Control – Section 7.3.7

Section 6

Service Providers to Implement Layered Strategic Planning in the Center Domain

The roles, responsibilities, and capabilities are described in Sections 4 and 5 for each planning layer that has been designed to handle the types of hierarchical problems and situations in the NAS (Section 3). In today's NAS, the strategic planning layers are mapped mostly to existing service providers that perform overlapping strategic planning. This section describes that mapping, filling the gap in today's overlapping planning layers with a "multi-sector planning" function for flight planning in the short- to mid-range strategic time frame. To simplify the discussion in the remainder of this document, this "multi-sector planning" function is referred to as "multi-sector planner"; the actual service provider allocation of the multi-sector planning tasks has not yet been determined because it requires further study and evaluation. Table 6-1 provides a summary of the layer-to-service provider mapping described in this section.

Situations in the national and multi-Center layers are handled by TMSs at the Command Center. These service providers in the Command Center domain collaborate with NAS users to perform long-range strategic flight planning, and provide direction and facilitate coordination for the service providers in the lower planning layers. The TMSs exist in today's NAS and are discussed in more detail in *Operational Concept for Collaborative Traffic Management in 2005* [13].

Situations in the Center layer are handled by TMCs at the Center, who collaborate with NAS users to perform mid- to long-range strategic flow planning for the Center. The TMCs coordinate with the TMSs at the Command Center and with the service providers in the multi-sector planning layer within the Center to resolve situations with as little impact as possible on the NAS users, while maintaining NAS safety and efficiency. The TMCs exist in today's NAS [13].

Problems and situations in the multi-sector layer are addressed by supervisory and multi-sector planning functions within the Center. The supervisory tasks include ***service provider resource planning*** in the short- to mid-range strategic time frame, using traffic and sector workload predictions to plan how the available service provider resources within that area can be best used to meet the projected demand. Multi-sector planning tasks include ***flight planning*** in the short- to mid-range strategic time frame, using traffic predictions and employing flow strategies to plan how the airspace can best be utilized to meet the demand. The multi-sector planning tasks also include handling proposed flight plan amendments from the TMCs and resolving problems predicted for the short- to mid-range strategic time frame. It is anticipated that the above supervisory tasks will be carried out by Area Supervisors. Possible allocations of the multi-sector ***flight planning*** tasks to service provider(s) include the following: 1) an allocation of all multi-sector flight planning tasks to the TMC, the supervisor, or the strategic service provider; 2) an allocation of the multi-sector flight planning tasks among two or more of these different service providers; or 3) an allocation of some or all of the multi-sector flight planning tasks to a position that is not staffed in today's NAS.

Table 6-1. Service Providers to Implement Layered Strategic Planning

Planning Domain	Planning Layer	Service Provider	Role	Location
Command Center domain	National layer	TMSs	Flight planning in the long-range strategic time frame	Command Center
	Multi-Center layer	TMSs	Flight planning in the long-range strategic time frame	Command Center
Center domain	Center layer	TMCs	Flight planning in the mid- to long-range strategic time frame	Centers
	Multi-sector layer	Supervisors	Service provider resource planning in the short- to mid-range time frame	Areas in Centers
		Multi-sector planner	***Flight planning in the short- to mid-range strategic time frame***	***Adjacent sectors***
	Sector layer	Strategic service providers	Flight planning in the short-range strategic time frame	Sectors in Centers
		Tactical service providers	Flight planning in the tactical time frame	Sectors in Centers

Issues:

Delineation of Service Provider Roles – Section 7.3.1

Multiple Layers of Strategic Planning – Section 7.3.2

User Collaboration – Section 7.3.4

Issuing and Coordinating Plans – Section 7.3.5

Multi-Sector Planner and TMC Roles and Responsibilities – Section 7.3.6

Problems in the sector planning layer are handled by the strategic and tactical service providers for the sectors. The strategic service provider resolves problems, responds to electronic requests in the short-range strategic time frame, and implements traffic planning constraints. The tactical service provider ensures safe aircraft separation, responds to pilot requests in the tactical time frame, and may also implement traffic planning constraints. The strategic and tactical service providers exist in today's NAS as the D and R controllers, respectively.

As shown in Figure 6-1, the en route service providers for the overlapping layers are staffed to meet changing traffic conditions. As an example, the TMC, supervisor, multi-sector planner, and tactical service providers could be staffed for a Center during light traffic conditions. As traffic conditions become heavier and more short-to-mid-range strategic problems and situations arise, more multi-sector planners within the Center would then be staffed. As traffic conditions warrant, strategic service providers are added in specific sectors to support the tactical service providers by performing short-range strategic planning and problem resolution.

The procedures for coordinating among the service providers vary depending on traffic load and which service providers are available. As shown in the sample for light conditions in Figure 6-1, the multi-sector planners coordinate directly with the tactical service providers to implement flight plan amendments. In the samples for moderate and heavy traffic conditions, the multi-sector planner can either coordinate directly with the tactical service provider or with the strategic service provider, who may need to forward some of those flight plan amendments to the tactical service provider for implementation (for example, when the amendment must be communicated via voice because the affected flight does not have data link).

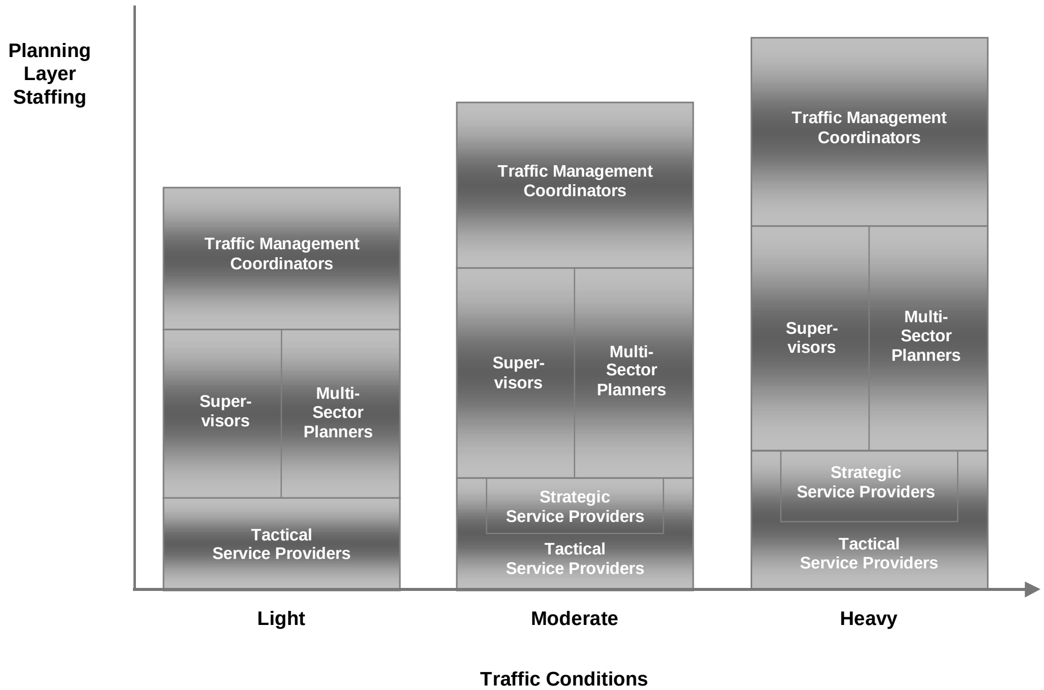

Figure 6-1. Sample Staffing Adjustments for Service Providers during Different Traffic Conditions

Capabilities necessary to support the service providers are available. A high-level view of the types of capabilities that are allocated to the different service providers is shown in Figure 6-2. In the layered strategic planning concept, the tactical and strategic service providers and the multi-sector planner resolve problems predicted in their assigned time frames. The multi-sector planner simplifies clusters and small complex traffic airspaces, while the TMC simplifies widespread clusters and large complex traffic airspaces. The supervisor is aware of predicted problems, clusters, and complex traffic airspaces, and uses the service provider configuration adjustment capabilities necessary for adjusting the service provider resources (for example, the sector configuration designating which service providers will be active) to meet the demand. As shown in Figure 6-2, all of the service providers have situational awareness and electronic coordination capabilities.

The service providers described in this section for each planning layer illustrate how the planning layers could be staffed, how they might coordinate with each other, and which types of capabilities would be required to support the intended roles for each service provider. Other allocations of service providers to planning layers could also be defined, with the associated coordination and capabilities. Examining issues such as those described in the next section will help to further define the layered strategic planning concept and the service provider(s) associated with each layer.

Issues:
Service Provider Configurations and Workloads – Section 7.3.3
Issuing and Coordinating Plans – Section 7.3.5
Information Flow for Flight Plan Amendment Requests from the TMC and the Multi-Sector Planner – Section 7.5.4

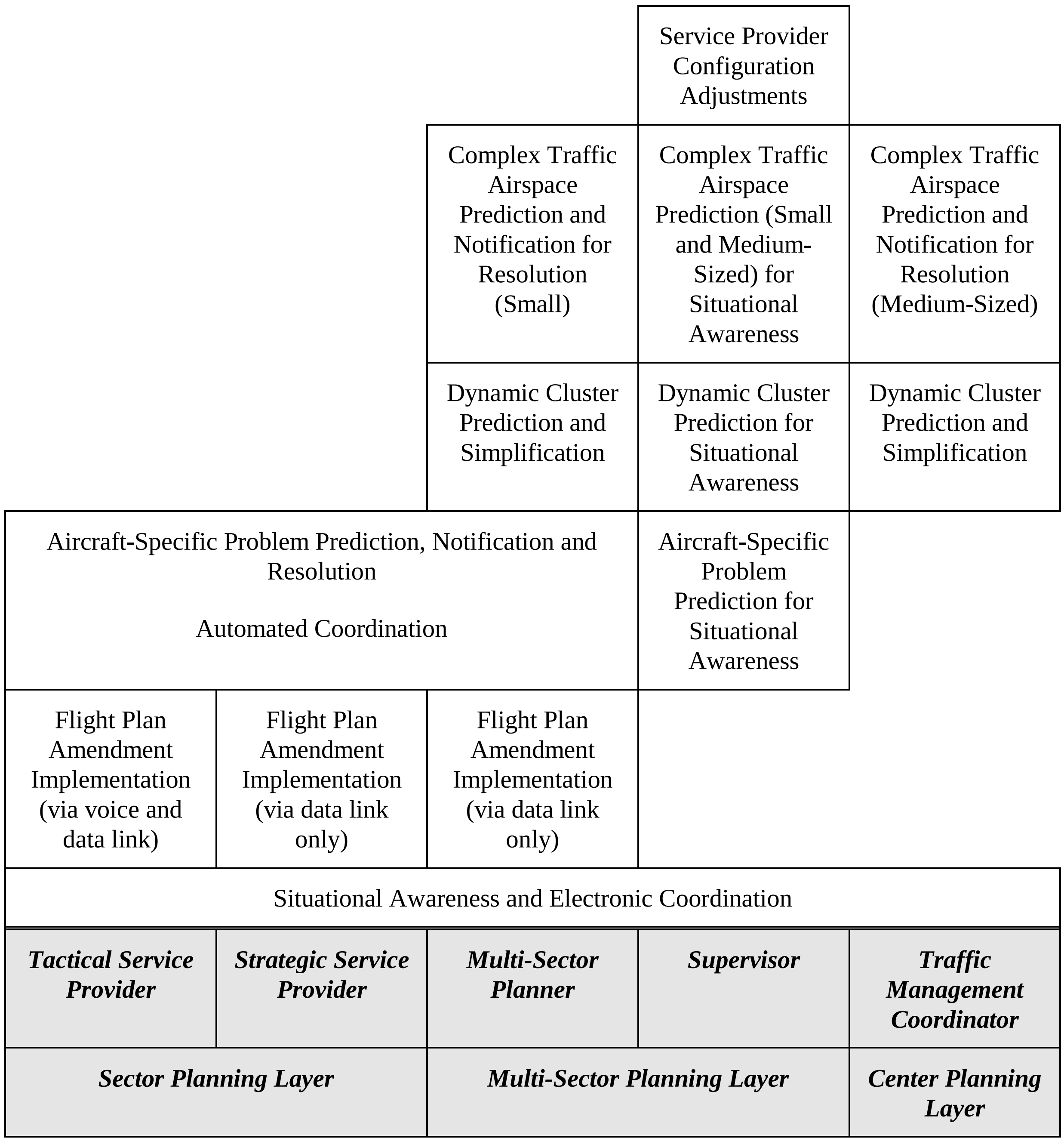

Figure 6-2. Types of Capabilities Available for Different Service Providers

Section 7

Issues for Analysis and Evaluation

The layered strategic planning concept described in this document raises a number of issues. This section describes those issues, along with recommendations for resolving them. All issues should be resolved before the concept is implemented in an operational environment. Many require evaluations on prototype systems in the laboratory, followed by operational evaluations in the field. Some of these issues have begun to be addressed in past CAASD validation plans [7] and others can be addressed in CAASD laboratories beyond FY 2001. Also, Eurocontrol has started to address similar issues related to the en route multi-sector planning, and has reported laboratory results and lessons learned [22]. To simplify the issues discussed in this section, the “multi-sector planning” function introduced in Section 6 is referred to as “multi-sector planner” in this section.

7.1 General Issues

7.1.1 Problem and Situation Prediction Time/Trajectory Accuracy

Issue: As greater accuracy is achieved for trajectory prediction, as aircraft using advanced Flight Management Systems (FMSs) maintain greater conformance with flight plans, and as NAS/AOC information sharing is enhanced how far into the future will automation be able to predict problems and situations with a high degree of confidence? How much time before a predicted problem or situation does it make sense to change an aircraft’s flight plan? Early maneuvering would require only a minor change to the trajectory; however, a long lead time makes the prediction less accurate. How many aircraft in en route airspace will be controlled by advanced FMSs in the future? For the different planning layers,what are the tradeoffs among prediction lead time, prediction accuracy, and prediction notification time?

Recommendation: Perform evaluation studies for various traffic scenarios to understand and define the relationships between trajectory accuracy, prediction lead time, prediction accuracy, and prediction notification time.

7.2 NAS Information System Issues

7.2.1 NAS Information System Update Responsibility

Issue: What information is needed to support the various planning layers and how should it be entered into the NAS information system? For example, should the strategic service provider, the multi-sector planner, or the TMC enter data relating to complex traffic airspace, when all en route service providers have access to the data? Should the information updates be automated?

Recommendation: Conduct evaluations to determine how information can be automatically revised in the NAS information system using planned decision support capabilities. What remaining information will require manual input, and what is the workload impact? Achieve consensus on the information that needs to be manually updated and which service provider has that responsibility.

7.2.2 NAS Information System User Notification

Issue: When capacity or NAS conditions change, is it sufficient to notify other facilities (including the Command Center) and users via the NAS information system? Is it necessary to have a guarantee that information gets to where it is needed?

Recommendation: For users with access to the NAS information system, updating the database will provide the information automatically to all users subscribed to specific information. For users who do not have access to the database, another method will be required, such as allowing an independent enterprise to access the database and provide the information to this class of user. A study is needed to define information updates that must be guaranteed to be provided to a user or system.

7.3 Service Provider Issues

7.3.1 Delineation of Service Provider Roles

Issue: The strategic planning layers within the Center domain are mapped to Center service providers, including the tactical service provider, the strategic service provider, the multi-sector planner, the supervisor, and the TMC. There is an issue related to the assignment of responsibility for resolving problems and situations predicted to occur in the future time intervals. Specifically, service providers in the strategic planning layers have responsibility for resolving different problems and situations predicted to occur in the same airspace during different time intervals.

Strategic planning tasks can be assigned to different service providers as described in Section 6. Which tasks are appropriate for the geographic scope and time scope associated with each position? Will the strategic planning tasks assigned to the positions vary depending on the traffic conditions and which service provider configuration is active (for instance, whether or not a multi-sector planner is responsible for a sector of airspace)? Can the TMC perform some of the multi-sector planning tasks for low traffic loads when a multi-sector planner is not needed, or does a multi-sector planner always need to be active (the number of sectors assigned to the multi-sector planner would then vary with the traffic load)? If a TMC performs some of the multi-sector planning tasks, are those tasks restricted to ones involving current knowledge, skills, and abilities (such as smaller severe weather areas and complex traffic airspaces), or can the TMC perform tasks related to simplifying clusters of problems?

Responsibility to resolve predicted problems and situations can be assigned to different service providers through problem notification based on the amount of time before a problem or situation is predicted to occur. Operationally acceptable time intervals for different service provider configurations and levels of sector workload must be determined through evaluations. Also, in cases where a multi-sector planner's airspace includes two or more sectors, the concept that strategic or tactical service providers can have the responsibility for different time intervals (resulting in a multi-sector planner having different time intervals for different sectors) requires evaluation. A similar situation will exist when the TMC has different time periods for airspace handled by different multi-sector planners and strategic service providers.

Recommendation: Perform evaluations to understand tactical and strategic service provider workload issues associated with resolving problems based on the problem notification time parameter assignments. Perform evaluations to understand workload implications related to strategic service providers, multi-sector planners, and TMCs being responsible for the same airspace during different time intervals.

7.3.2 Multiple Layers of Strategic Planning

Issue: With the assignment of situations in a larger airspace (for example, equal to the airspace assigned to three strategic service providers but for a non-overlapping time interval, such as 30 to 50 minutes in the future) to a single multi-sector planner, the multi-sector planner could be notified of predicted clusters that are more strategic in nature because they are predicted further out in time. To what degree would having overlapping multi-sector planners and strategic service providers duplicate or change the role of the TMCs? Would an expanded TMC role (with multiple TMCs each assigned a portion of the Center airspace) be the same as overlapping multi-sector planners and strategic service providers?

Recommendation: Perform evaluations to determine the utility of more extensive layered strategic planning. Also, evaluate the relationships among the roles and responsibilities for the strategic service provider, the multi-sector planner, and the TMC.

7.3.3 Service Provider Configurations and Workloads

Issue: Several interrelated issues are associated with service provider configurations and workloads, as follows:

- What is the coordination workload associated with various service provider configurations and roles?
- What are the factors that contribute to predicting the workload for the positions within a service provider configuration?

- How should a capability operate that analyzes the effect of different service provider configurations on predicted traffic patterns and loads?
- How should the various service provider configurations be allocated to manage different traffic patterns and loads?
- How do staffing needs change based on different traffic patterns and loads?
- If there are multiple multi-sector planner or TMC service providers, are additional capabilities required to facilitate the collaboration among multi-sector planners and among the TMCs?

Recommendation: Service provider workloads, including workload caused by coordinating with other service providers, must be evaluated and quantified to understand the utility of the various proposed service provider configurations as a function of workload and traffic conditions, and to support benefit-to-cost analyses. The different metrics that may contribute to the workload must be evaluated for inclusion in the capability that predicts workload and analyzes the effects of potential service provider configurations. The ability of the configurations to handle different types of traffic conditions should be analyzed to determine which situations the different configurations can handle with minimal impact on the NAS users. The need for multiple multi-sector planner and TMC service providers should be analyzed for different types of traffic conditions. The capabilities necessary to maintain situational awareness and to support collaboration among multiple multi-sector planners and TMC service providers should be investigated.

7.3.4 User Collaboration

Issue: When negotiating revisions to a flight plan, how much collaboration between a user and a service provider is beneficial? Assuming that several resolutions are problem-free, should the service provider offer options to the pilot (a choice among two or more resolutions)? If data link is available and two or more flight plan revisions are data linked to the cockpit, could the pilot just downlink acceptance for one of them, thereby activating that revision? If a strategic service provider is providing predicted problem resolutions, should more than one resolution be sent to a tactical service provider for suggestion to a pilot?

These concepts need to be evaluated, including the lead time for handling the flight plan changes by both the pilot and the service provider. How much time would be required to provide this increased user flexibility? What predicted problem lead time would be required before this capability could reasonably be provided? How much would service provider workload increase to provide this user flexibility?

Recommendation: Perform evaluations to address the workload, lead time requirements, and the benefits of providing increased user flexibility through collaboration.

7.3.5 Issuing and Coordinating Plans

Issue: The tactical service provider is the only service provider who communicates via voice with pilots of aircraft in that sector. With the implementation of air-ground data link, should other service providers communicate with the pilot via data link? In particular, should a strategic service provider or a multi-sector planner communicate with the pilot via data link on more strategic issues? Should these other service providers issue a flight plan amendment via data link to an aircraft if the amendment takes effect outside the current tactical service provider's sector or time interval of responsibility? How might this affect the plans of tactical service providers who control the aircraft?

Recommendation: Perform evaluations on the use of data link by the tactical and strategic service providers and the multi-sector planner for flight plan amendments as a function of the time that the change would be initiated (during the tactical or strategic time interval). The evaluations need to determine the frequency that a control action from one of these service providers interferes with a planned action of another service provider. The evaluations need to compare the workload impact versus the situational awareness of the tactical and strategic service providers for cases in which the multi-sector planner issues amendments directly to pilots via data link, or transfers the trial plans to a tactical service provider for implementation.

7.3.6 Multi-Sector Planner and TMC Roles and Responsibilities

Issue: Are the levels of responsibility indicated for the strategic service provider, the multi-sector planner, and the TMC operationally feasible? What are the boundary conditions? If the problem prediction capability provides a confidence factor indicating the likelihood that a predicted problem is expected to occur, then the strategic service provider or the multi-sector planner can use that information to decide when to resolve a problem. If the problem is resolved, only to re-occur later, then the service provider will begin waiting until the confidence factor for a problem is higher before attempting to resolve problems. Similarly, if a situation predicted in the strategic time frame is shown with a confidence factor, then the multi-sector planner or the TMC can use that information to decide when to resolve the situation.

Recommendation: Evaluate methods of indicating a confidence factor for predicted problems to strategic service providers and multi-sector planners, and for predicted situations to multi-sector planners and TMCs. Evaluate the workload issues related to the lead time with which predicted problems and situations are resolved.

7.3.7 Transfer of Control

Issue: In today's system with automated handoff, a gaining controller normally receives track control and communications responsibility for an aircraft prior to the sector boundary; however, transfer of control responsibility occurs at the sector boundary. Could transfer of control occur along with the transfer of track control and communications? With this capability, controllers could dynamically accommodate changing workloads without actually changing sector boundaries. Should the system automatically initiate handoffs?

Recommendations:

- Identify the system implications if transfer of control occurred with the transfer of track control and communications.
- Identify the benefits of allowing service providers to dynamically transfer control as appropriate.
- Identify the procedural changes required.
- Identify whether the system should automatically initiate handoffs or the receiving sector should assume control.

7.3.8 Choice of Aircraft to Maneuver

Issue: When a problem is predicted, the service provider must decide which aircraft to maneuver to resolve the problem. All other factors being equal, it would be preferable to avoid maneuvering an aircraft that had already been delayed as a result of previous ATC-initiated maneuvers. This concept proposes that the NAS maintain a record of ATC-initiated maneuvers imposed on each aircraft, and display this information to the service provider as appropriate. What is the appropriate method for displaying this information? What information should be maintained: number of ATC-initiated maneuvers, number of minutes of delay imposed, other?

Recommendation: Evaluations are recommended for the following:

- Determine which types of information are needed by the service providers to maintain fairness when imposing flight plan changes and delays.
- Evaluate when, where, and how to display these types of information.
- Survey service providers and NAS users to develop initial recommendations for this type of capability.
- Conduct laboratory evaluations involving service providers and users to validate and refine the survey results.

7.3.9 Weather Forecast

Issue: Enhanced severe weather forecasts are necessary, including projections of intensity and movement. The level of information, update frequency, and method of display for service provider use must be studied. Also, studies are required to identify criteria for impenetrable weather.

Recommendation: Perform evaluations to address the following questions and issues:

- How should severe weather be displayed?
- What update frequency for the display of severe weather is necessary? Does the update frequency change as a function of the predicted time of the weather, the severity of predicted weather, and movement of predicted weather? What constitutes impenetrable weather?
- Does the severe weather update frequency change based on the service provider type displaying the weather (e.g., tactical service provider or TMC)?
- How should multiple possibilities/probabilities and potential risks associated with the future be displayed: individually or as a group?

7.3.10 Temporary Route Constraints

Issue: To resolve complexity, temporary route constraints may be imposed to either prevent traffic conflicts or to provide better information on aircraft intent for use in detecting problems. When should temporary route structures be implemented? When can the use of these temporary route structures be terminated?

Recommendation: Perform evaluations to determine when and where temporary route structures are most applicable.

7.4 Airspace Issues

7.4.1 Complex Traffic Airspace Definition

Issue: The monitoring of complex traffic airspace and the alleviation of predicted airspace complexity is the responsibility of the multi-sector and Center layer service providers. How should complex traffic airspace be defined? Should the definition be different for different layers? Can clusters [14, 15, 16] or solution complexity metrics [17] help define complex traffic airspace? Similar issues were addressed by Eurocontrol in development of a "Tactical Load Smoother" tool to support multi-sector planning [23].

Recommendation: Perform evaluations to address the following questions and issues:

- Evaluate the various factors contributing to complex traffic airspace for multi-sector and Center layer service providers, including those previously identified as clusters and solution complexity metrics.
- Evaluate the usefulness of these contributing factors in predicting complex traffic airspace for the multi-sector and Center layer service providers.
- Determine which factors are most effective for identifying and resolving complex traffic airspace for the multi-sector and Center layer service providers.
- Define a metric or a set of metrics that identifies levels of airspace complexity.

7.4.2 Complex Traffic Airspace Notification

Issue: The monitoring of complex traffic airspace and the alleviation of predicted airspace complexity are the responsibility of the multi-sector and Center layer service providers. Should the service providers in the sector layer, as well as the service providers in the multi-sector and Center layers be notified of complex traffic airspace?

Recommendation: Perform evaluations to address the following questions and issues:

- Evaluate the complex traffic airspace prediction capability.
- Define parameters that determine the maximum complexity that can be handled at a given sector.
- Evaluate the lead time necessary to resolve complex traffic airspace without major disruption of current traffic flow patterns.
- Evaluate the usefulness of complex traffic airspace notification at each of the service provider positions within the Center, multi-sector, and sector planning layers.
- Evaluate the use of aircraft location information as part of the logic to decide when a service provider is notified of the problem.

7.4.3 Airspace Boundary Adjustment

Issue: Can the dynamic adjustment of airspace boundaries for the sector and multi-sector planner effectively resolve complex traffic airspace without impacting the users?

Recommendation: Perform evaluations to address the following questions and issues:

- Evaluate the dynamic adjustment of the size and combination of sectors to support the multi-sector planner. Can the multi-sector boundaries differ from sector boundaries used for the sector planning layer?
- Evaluate small boundary adjustments between multi-sector planners to balance traffic flows.
- Evaluate the effect of sector size to achieve increased efficiency. What are the advantages and disadvantages of having a smaller sector airspace volume with only one service provider versus a larger sector airspace volume with two service providers?
- With more aircraft flying user-preferred routes, traffic will be more random and will change day-to-day and hour-to-hour. The capability to dynamically adjust sector boundaries to meet changing traffic patterns needs to be evaluated. The level of flexibility in resectorizations is limited by communication frequencies, the ability of service providers to adapt to revised airspace, and by service provider training issues. The appropriate safe level of dynamic sectorization and sector boundary adjustment must be evaluated with these issues in mind.

7.4.4 Service Provider-Defined SUA and Complex Traffic Airspace

Issue: Should service providers in all layers have the capability to define an SUA or a complex traffic airspace?

Recommendation: Evaluate the usefulness of the capability for each of these types of service providers to be able to define a SUA or complex traffic airspace that would be known by all other service providers (e.g., a complex traffic airspace defined by a TMC or a multi-sector planner would need to be avoided by tactical and strategic service providers in future reroutes for predicted problem resolutions). Evaluate the impact on service provider workload and the methods for implementing this capability.

7.5 Traffic Planning Issues

7.5.1 Time Frames of Operation and Information Stability for the Information Aggregation Levels

Issue: Which time frames of operation are most suitable for the different levels of information aggregation? Which types of information are stable for the different aggregation levels and time frames?

Recommendation: Determine which types of aggregated information are stable for each of the levels. Evaluate the time frames of stability for each type of information to determine the most suitable time frame for resolving situations in each level.

7.5.2 Types of Problems and Situations that Require Strategic Planning in the NAS

Issue: Which types of problems and situations apply to each planning level? Do clusters [14, 15, 16] occur often enough and with high enough complexity to be defined as a situation that requires strategic planning in the NAS? Can solution complexity metrics [17] help define some types of situations?

Recommendation: Gather data using current problem prediction tools to examine the types of problems and situations that occur in the NAS (and their frequency). Determine the planning level(s) that could best resolve those problems and situations based on the time frame stability of the information required to resolve them.

7.5.3 Response to Hierarchical Problems and Situations Using Layered Strategic Planning

Issue: Is it appropriate to map a planning layer to each of the types of hierarchical problems and situations? Are there combinations of layers that could work together to resolve some types of problems or situations more quickly or efficiently? Are the roles and responsibilities of the planning layers efficient as defined?

Recommendation: Evaluate how effectively different combinations of planning layers can resolve predicted problems and situations. Determine the roles and responsibilities, as well as the capabilities, necessary to create each planning layer. Identify the methods for determining how each combination of planning layers works together to meet specific needs in the NAS.

7.5.4 Information Flow for Flight Plan Amendment Requests from the TMC and the Multi-Sector Planner

Issue: To implement traffic planning strategies, the TMC and the multi-sector planner may identify flights that require reroutes or other flight plan amendments. When the TMC requests flight plan amendments for those flights, the amendments could be forwarded to the multi-sector planner, or directly to the sector layer for implementation, depending on the current staffing for the sectors in which the affected flights are located. When the multi-sector planner requests flight plan amendments, those amendments could be forwarded to the sector layer for implementation, depending on the current sector staffing.

What is the information flow for flight plan amendment requests from the TMC to the multi-sector planner and the sector layer service providers? What is the information flow from the multi-sector planner to the sector layer service providers? Under what conditions do the TMC and the multi-sector planner send flight plan amendment requests to the sector layer service provider for evaluation and implementation?

Recommendation: Evaluate the impact on service provider workload when the TMC and the multi-sector planner forward flight plan amendment requests. Identify and evaluate alternative ways for ensuring that the requests are analyzed for predicted problems and modified as needed to ensure that they are problem-free.

Section 8

Summary

This document takes the first steps toward defining a future operational concept of layered strategic planning for ATM service providers that enhances current operations. Topics addressed include: an overview of layered strategic planning in the en route NAS; descriptions of service providers' roles and responsibilities; and descriptions of the capabilities needed to support the service providers in accomplishing their tasks. The latter two topics are addressed from the perspective of the en route ARTCC (Center). Issues requiring evaluation in both laboratory and operational environments are also identified. The analysis of these issues and the refinement of these ideas will require extensive participation of service providers and airspace users.

The layered strategic planning concept makes use of various layers of strategic service providers. The available service provider configurations and the corresponding changes in service provider roles and responsibilities allow for the concept to evolve over time. The concept of layered strategic planning is performed today in the Command Center and Center domains; the concept described in this document extends today's implementation of layered planning to achieve the following:

- Increased accommodation of user-preferred trajectories and fewer diversions from those preferences.
- Increased collaboration with users, based upon increased information sharing to minimize impact of flow strategies on users.
- Improved allocation of problems and situations for resolution at the appropriate layer and time.
- Improved safety and service provider productivity.
- Evolution from predominately tactical ATC services to the strategic provision of ATC services, where:
  - The tactical service provider performs tactical control and responds to user requests.
  - The strategic service provider works to resolve problems before the aircraft involved enter the sector and responds to strategic user requests transmitted via data link.
  - The multi-sector planner is responsible for resolving strategic problems and adjusting smaller traffic flows in one or more sectors.
  - The supervisor is responsible for service provider resource planning, adjusting sector configurations, personnel assignments, and time intervals of responsibility for service providers to manage changes in traffic patterns and loads.

  - The TMC performs traffic management for groups of aircraft, adjusting Center-wide traffic flows in collaboration with adjacent Centers and users.
- Dynamic adjustment of the workload responsibility using a combination of time parameters (time scope) and airspace allocation (geographic scope); the time parameters will be used to define the time interval in which each controller is responsible for predicted problems and airspace situations or for messages received via data link.

The analysis of the issues identified in Section 7 will determine the operational feasibility and relative benefits of the layered strategic planning concept. Once identified, the next step is to address the necessary transition steps; that is, what is an efficient and cost-effective evolution plan to realize these services and capabilities? As new system capabilities become available, as traffic increases, as a greater percentage of flights desire to fly non-structured routes, and as aircraft avionics are improved, the concepts and related systems must be capable of seamlessly and effectively accommodating these changes.

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Glossary

List of Acronyms

AOC	Aeronautical Operational Control
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATM	Air Traffic Management
CAASD	Center for Advanced Aviation System Development
D	Flight Data Controller
FAA	Federal Aviation Administration
FFP1	Free Flight Phase 1
FMS	Flight Management System
FY	Fiscal Year
GPS	Global Positioning System
NAS	National Airspace System
NAVAID	Navigational Aid
R	Radar Controller
SUA	Special Use Airspace
TFM	Traffic Flow Management
TMC	Traffic Management Coordinator
TMS	Traffic Management Specialist

List of Terms

Automated Coordination	A capability that supports non-voice (electronic) coordination among service providers within a Center as well as across Center boundaries.
Automated Replan of Trial Plans	A capability that periodically evaluates trial plans for predicted problems, notifying the appropriate service provider when a trial plan has become problem-free.
Center Domain	The planning layers that operate within the Air Route Traffic Control Centers (ARTCCs, or Centers), including the Center planning layer, the multi-sector planning layer, and the sector planning layer.
Center Planning Layer	Responds to Center situations and coordinates planning efforts within a single Center.
Cluster	A set of interrelated predicted problems for pairs of aircraft, which may involve any number of aircraft predicted to be within close proximity in time and space.
Command Center Domain	The planning layers that operate within the Air Traffic Control System Command Center (ATCSCC, or Command Center), including the national planning layer and the multi-Center planning layer.
Complex Traffic Airspace	Airspace expected to increase the predicted sector workload due to factors such as aircraft counts, aircraft interaction (predicted problem counts, sizes of clusters, number of crossing streams), aircraft maneuverability, airspace availability, and aircraft profile mix. A complex traffic airspace is defined by lateral, vertical, and time limits (e.g., between 1200Z and 1300Z).
Constrained Airspace	Special Use Airspaces (SUAs), severe weather areas, or other complex traffic airspaces that involve heavy or complex traffic flows, e.g. flows impacted by Navigational Aid (NAVAID) outage or runway closure.

Current Plan	The flight plan the controller has specified as the plan the aircraft is currently expected to fly.
Flight Plan	The original filed flight plan for a flight, with all later flight plan changes incorporated.
Layered Strategic Planning	A concept for strategic planning that associates overlapping planning layers with the different types of problems and situations that occur hierarchically in the NAS. Overlapping planning layers provide flexibility in handling the daily variations in traffic patterns and loads, as well as the different types of traffic planning events (such as accounting for changes in Special Use Airspace activity and severe weather) that routinely occur.
Midterm	The nominal time period, centering around the year 2005, when new operational concepts and capabilities are planned for the en route environment.
Multi-Sector Planner	The en route service provider that performs flight planning tasks for the multi-sector planning layer in the short- to mid-range time frame (including strategic problem and situation resolution).
Multi-Center Planning Layer	Responds to multi-Center situations and coordinates planning efforts among multiple sectors across adjacent Center boundaries.
Multi-Sector Planning Layer	Responds to multi-sector situations, coordinating planning efforts involving more than one adjacent sector within a single Center, and performs service provider resource planning and strategic problem and situation resolution.
National Planning Layer	Responds to national situations and coordinates planning efforts involving many Centers throughout the NAS.
Plan	Information about a flight as well as pilot and controller intentions regarding that flight.

Problem	A predicted loss of separation between an aircraft and the following: other aircraft, Special Use Airspace (SUA), complex traffic airspace, terrain and obstructions, or severe weather; or predicted non-compliance with a traffic planning constraint.
Sector Configuration	The specific definition of the sectors and their airspace boundaries for a Center.
Sector Planning Layer	Resolves predicted aircraft-specific problems before they occur.
Service Provider	FAA personnel in the Centers performing en route air traffic control, Traffic Flow Management (TFM), and service provider resource management (workload management) tasks.
Service Provider Configuration	A combination of tactical and strategic service providers and multi-sector planners.
Severe Weather	Weather conditions, based on aircraft type, that present a potential danger to a flight or to the occupants of an aircraft.
Situation	A volume of airspace that is predicted to become complex due to predicted demand exceeding capacity (possibly due to severe weather or other traffic planning events) and as a result, would benefit from strategic planning.
Strategic Service Provider	The en route service provider in the sector planning layer that resolves problems and responds to electronic requests in the short-range strategic time frame. This service provider is also responsible for implementing traffic planning constraints.
Supervisor	The en route service provider in the multi-sector planning layer that performs service provider resource planning tasks, including workload management.

Tactical Service Provider	The en route service provider in the sector planning layer that ensures aircraft separation and responds to pilot requests in the tactical time frame. This service provider may also be responsible for implementing traffic planning constraints.
Traffic Management Coordinator	The en route service provider in the Center planning layer that performs Traffic Flow Management (TFM) tasks and collaborates with Aeronautical Operational Controls (AOCs).
Traffic Management Specialist	The service provider in the national and multi-Center planning layers at the Command Center that performs Traffic Flow Management (TFM) tasks and collaborates with Aeronautical Operational Controls (AOCs).
Traffic Planning Constraints	The flow directives defined by the national, multi-Center, and Center planning layers for traffic flow planning (examples include meter fix time and miles in trail restriction).
Trajectory	The calculated prediction of an aircraft's path based on a current or proposed flight plan, weather information, aircraft and flight characteristics data, and other variables.
Trial Plan	Any proposed plan created by a service provider or by the automation.