Decision-Based Weather Needs for the Air Route Traffic Control Center Traffic Management Unit

November 19, 1999

During the past two years Aviation Weather Directorate (ARW) has undertaken to identify the aviation weather information needs of the Air Route Traffic Control Center (ARTCC) Traffic Management Unit (TMU). To accomplish this task, a decision-based user needs identification process was developed and followed. Various staff members visited a number of ARTCC's and interviewed TMU and Center Weather Service Unit (CWSU) personnel and gathered information on their respective roles and responsibilities, tasking, and information needs. An emphasis was placed on the TMU personnel decision-making process and the information needed to facilitate that decision-making process and improve upon it.

This document represents the results of this effort; it has been extensively coordinated within the Federal Aviation Administration (FAA) and National Weather Service (NWS). It should be emphasized that the document identifies the TMU needs irrespective of the state-of-the-art of aviation weather forecasting technology.

David Whatley
Director of Aviation Weather Directorate, ARW-1

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Purpose And Document Outline

This document defines the aviation weather needs for Center Traffic Management Unit personnel. These weather needs were derived after a study of Center TMU operations as well as services and products currently provided by the Center Weather Service Unit. A decision-based user needs identification methodology was developed. Analysis of the data led to the conclusion that the availability of weather information for decision making was critical to the Center TMU due to the strategic nature of their mission. For all other entities within the National Airspace System (NAS), weather needs are described only to the extent that these personnel have a need to coordinate with the Center TMU for decision-making purposes.

The present study may serve as a basis for modification of FAA Order 7210.38A, CWSU, as well as other related documents listed below. FAA Orders are by design procedural and not requirements documents.

A number of documents and recommendations have preceded this study; these identify the requirements themselves or procedures associated with a requirement. These documents include but are not limited to:

- FAA ORDER 7032.9, TMS Air Traffic Operational Requirements
- FAA ORDER 7210.3, Facility Operations
- FAA ORDER 7032.15, Air Traffic Weather Needs and Requirements: Appendix 2, Paragraph 2.3, High Level Needs
- Operational Concept of the Aviation Weather System (1994): Paragraph 3.2.5, Paragraph 4.2
- A Concept of Operations for the NAS in 2005, DRAFT 3/28/97
- National Transportation Safety Board (NTSB) recommendations on the dissemination of hazardous weather to all users of the airspace (A-77-68)

The Traffic Management System (TMS) operational mission is described in Section 2.0. The methodology of this study is described in Section 3.0. Section 4.0 illustrates Center TMU operational decisions that can be influenced by weather. Section 5.0 describes a rationale for attributing specific weather phenomena, in space and time, which affect Center TMU decisions. This leads to the development of the derived weather needs. The summary in Section 6.0 focuses on the follow-on steps planned with associated coordination/actions. These actions will lead to the development of requirements, identification of solutions, and modification of procedures to satisfy the identified weather needs. The derived weather needs are traced, in part, to various official FAA documents as identified above. Appendix A describes attributes of weather phenomena (such as resolution and accuracy in space and time) which must be considered in the requirements in order to satisfy the derived need. These attributes are "strategic" in nature and are based on operational rationales that support them. Appendix B contains a glossary of terms.

2. Traffic Management System (TMS) Operational Mission

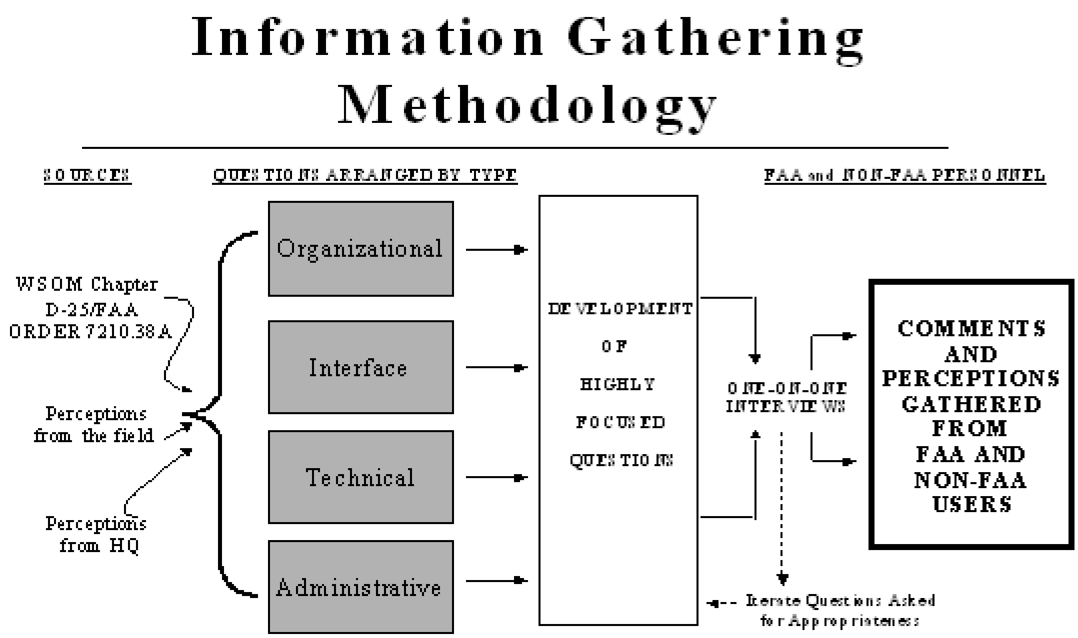
The overall operational mission governing Air Traffic's (AT) role in the NAS is to provide for the separation of aircraft and the safe and efficient utilization of that airspace. As currently documented the TMS supports the air traffic control mission by providing disciplined traffic flow. By increasing airspace efficiency, controller personnel can handle more aircraft while reducing delays. On a daily operational level, this is satisfied by collaborative decision making between centers, Terminal Radar Approach Control (TRACONs), selected towers, the Air Traffic Control System Command Center (ATCSCC), and users. Demand is balanced with system capacity. The result is intended to be a safe, orderly, and expeditious flow of traffic with minimal delays. Weather, and the availability of applicable weather information, can play a key role in the decision making process.

Center TMU weather needs was established after an analysis of TMU operations. While only the Center TMU mission was addressed in this study, their particular weather needs, and the weather product requirements (to be determined) to satisfy them, may be applicable as decision making tools across the entire aviation community. For example, access by Air Traffic Control Specialists (ATCS), ATCSCC, En Route Flight Advisory Service (EFAS), and industry to the types of weather information required by Center TMU will serve two purposes: (1) the weather information will be aviation tailored (applicability in some cases to more than just the Center TMU), and (2) other decision makers will be able to utilize the same information (product may satisfy (in part) other users' weather needs)[1]. The development of specific weather needs for users other than Center TMU is beyond the scope of this study.

3. Methodology

The goal of this study was to determine Center TMU weather needs, not the justification of the current process for the provision of weather information. The information gathering methodology (shown in Figure 1) began with the development of questions to determine the operational needs for weather by the Center TMU.

Figure 1 Information Gathering Methodology



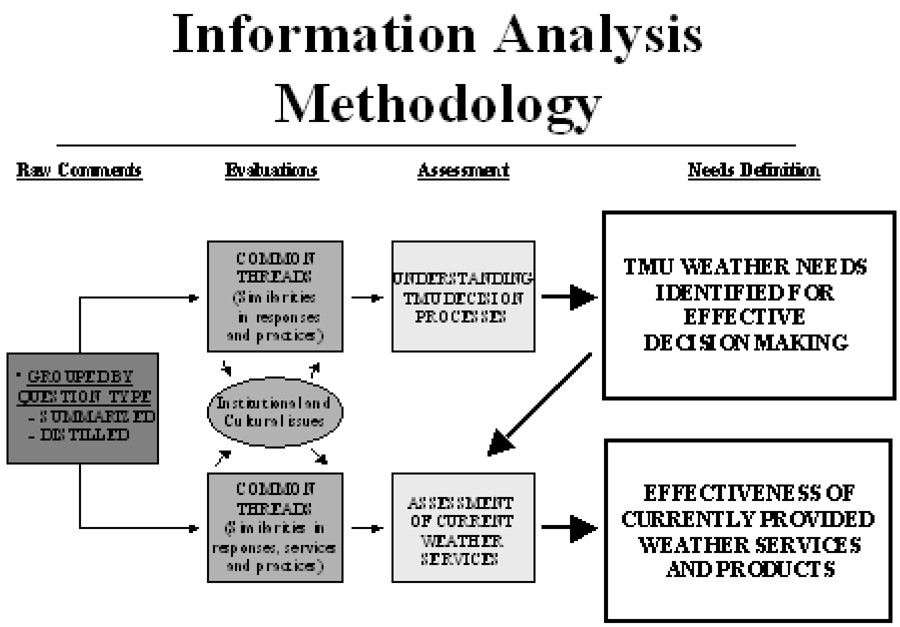
The questions were arranged to examine organizational, interface, technical, and administrative aspects of FAA and non-FAA processes, and were based on perceptions from the field, perceptions from FAA headquarters, and with documented procedures. Interviews with FAA and non-FAA personnel were conducted individually to eliminate group biases. Comments and associated perceptions were gathered as initial inputs for the information analysis methodology. A listing of facilities visited:

- Dallas/Ft. Worth ARTCC, TRACON, AFSS, American Airlines Meteorological Department, Southwest Airlines Dispatch
- Chicago ARTCC, TRACON, Kankakee AFSS, United Airlines Meteorological Department
- Kansas City ARTCC
- ATCSCC
- Leesburg AFSS
- Aviation Weather Center, Kansas City
- NWS Headquarters
- Comments and considerations requested from ATA, ALPA, APA, NBAA, AOPA, RAA, NASAO

[1] Note: ATCS refers to all center, terminal, and tower controllers, and EFAS refers to all FSS/AFSS specialists.

The responses and direct comments shown in Figure 2 were summarized by question type, and evaluated for ‘common threads.’ Institutional and cultural issues were considered. This evaluation led to an understanding of Center TMU decision processes and the identification of weather needs for effective decision making. Weather services and product requirements to help satisfy these identified needs were then developed. The effectiveness of current services was also compared with identified needs.

Figure 2 Information Analysis Methodology



Before any needed product or service could be identified, an objective rationale for it was determined based on air traffic operational characteristics. Further, identified weather needs were not constrained by current levels of technology or availability of weather products and services. If technology can only partially satisfy these needs, it was classified as unmet.

The work group attempted to remain within the true definition of requirements by avoiding suggestions of how the provision of weather information should be satisfied and to focus on what capability is needed to accomplish TMU missions. Therefore, certain generic terms are used throughout the document. For example, the weather requirements have been developed to satisfy Center TMU operational mission needs by a ‘weather unit’. This is intended to be a generic title until the requirements are reviewed and solutions defined to implement the service. The term ‘products’ is also generic and can refer to graphical, alphanumeric or verbal presentations and may range from highly structured to conversational.

4. Operational Weather Related Decisions By Traffic Management

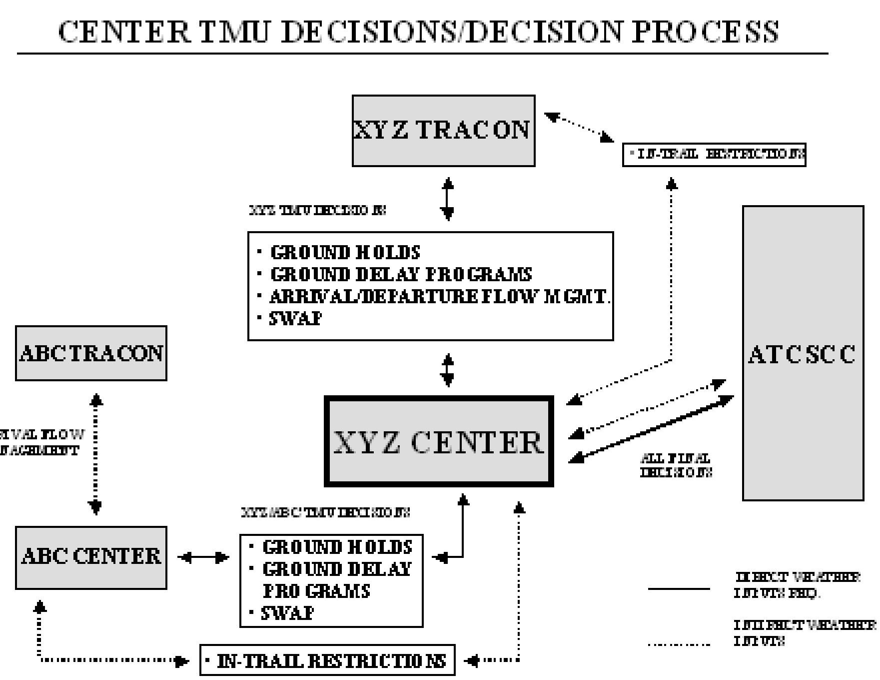
Center TMU operations involve the ability to assess and adjust traffic flow within each Center’s airspace as well as nationally. Many of these decisions are collaborative in nature between the TMU, local TRACON personnel, another Center, or ATCSCC (see Figure 3). These include arrival and departure flow management decisions, implementation of ground holds and ground delay programs, severe weather avoidance plans (SWAP), and in-flight restrictions.

Factors that influence the decision-making process include training, knowledge of the airspace and the aircraft in it, Center focus (Table 1), and current and forecast weather conditions. To this last point, all flight component capacity values (i.e., count of aircraft per unit time over the Center, terminal area, segments, departure/arrival airport/fixes, en route fixes, and sectors) can be affected by predicted and actual weather conditions. The availability and incorporation of timely and accurate weather information/forecasts, either directly or indirectly, has a significant bearing on how safely, effectively, and efficiently traffic is adjusted.

Table 1: Definitions of ARTCC Operational Focus

Overflight	Traffic crossing the ARTCC airspace from domestic or international locations on major east-west jet routes and whose centers do not include major hub/pacing airports
Oceanic Traffic	Traffic crossing the ARTCC airspace originating from international locations, arriving at U.S. points of entry such as JFK, IAD, SFO, SEA, etc.
Hub	An ARTCC whose main focus is on a major hub/pacing airport, or airports, located somewhere within its boundaries, and is the destination for major international and domestic air traffic.
Overnight	ARTCCs that have freight hauler air traffic whose main operations are during the overnight hours, after the operational hours of the current CWSU
Numerous Secondary	ARTCCs that have at least one major hub/pacing airport within its boundaries and contains a number of non-hub airports with commercial air traffic, i.e., ORD with DPA, MDW, and LAX with SAN, ONT, etc.

Figure 3 Center TMU Decisions/Decision Process including weather inputs



Ground hold decisions can be based on weather observations/forecasts that indicate that the safe movement of air traffic may be compromised or that capacity may be constrained. Ground hold decisions result in delayed departures from selected locations to the affected airport. Ground delay decisions can be driven by the same weather causing the ground hold or by other operationally significant weather. SWAPs and in-trail restrictions can result from a ground hold, ground delay, or other arrival/departure flow management decisions. They can be additionally affected by adverse weather occurring en route.

5. Development Of Derived Weather Needs For The Center TMU

From an air traffic perspective, operationally significant airspace is defined for three distinct areas: the terminal area, the gate area, and the center area. The terminal area can be defined as the area within 10 nautical miles (nmi) of the center of the runway complex and is important because controllers have few alternatives for maneuvering assigned aircraft. Since most weather-related accidents occur in the approach and departure phases of flight, defining the terminal area in this fashion will ensure appropriate coverage of observed or forecast weather in the immediate vicinity of departure and arrival ends of all runways. The gate area can be defined as existing from the top of the descent to terminal area boundary including the approach gates (posts). This area is designated by the associated center and approach control and can vary in size. Selection of appropriate posts will allow aircraft to arrive ahead of or behind the weather.

Each ARTCC has known or anticipated traffic patterns that have led to the current center area boundaries, which allow for safe and efficient use of that airspace. Knowledge of weather that may affect these traffic patterns is critical to management of that area's traffic.

Operationally significant time is defined for four distinct periods; current, up to 1 hour in the future, from 1 to 4 hours in the future, and from 4 to 8 hours in the future. Current observations of weather in the terminal, gate, or center area are important for overall situational awareness and verification of predicted weather events.

Weather expected to occur up to 1 hour in the future is important for short term tactical planning, especially in the terminal and gate areas. For example, weather expected in a terminal area influences runway selection. If the operational runway changes, movement of aircraft towards a particular post may change and Center TMU personnel need to know whether the post associated with the new runway is available. This allows coordination with appropriate air traffic entities, formulation of a plan and its implementation.

Weather expected beyond 1 hour in the future is important for strategic planning. Because the majority of flights within the United States are 4 hours or less, Center TMU decisions using forecasts from 1 up to 4 hours affect the most aircraft.

Weather expected from 4 to 8 hours has a significant affect on airport capacity planning. Implementation of plans resulting from this information occurs as the onset of weather event approaches. The ending range of 8 hours is operationally significant because maximum flight times for domestic travel are between 6 and 7 hours.

5.1 Decision/Weather Relationship

A relationship can be defined between each Center TMU decision and specific weather phenomena judged important in influencing that decision. For example, the Center TMU is envisioned to use terminal area forecasts up to 1 hour for ceilings and visibility to help determine (with collaboration with the TRACON TMU) the spacing of aircraft for each runway (arrival and departure flow management). This collaboration may lead to in-trail restrictions to prevent over-saturation of the terminal area capacity. A forecast of thunderstorm activity beyond 1 hour will help the Center TMU determine whether a ground delay needs to be implemented at selected locations. Center TMU may also use this forecast to direct aircraft already airborne to unaffected sectors. The forecast cessation of icing will affect both holding altitudes and approach corridors. Forecasts of winds and temperatures aloft for the 4–8 hour period over the center area are envisioned to be used as planning tools to determine expected flight times, aircraft merging, sequencing, and spacing.

It is important to realize that the Center TMU will look at all forecast elements taken together rather than individually. For example, forecast thunderstorm activity in a center area may lead to a "pro-actively planned" SWAP as the event is verified. However, the new routing may lead aircraft into areas of potential forecast clear air turbulence (CAT). Use of CAT forecasts in this case may result in improved routing decisions, over decisions using thunderstorm forecasts alone.

For analytic purposes and determination of unique “decision/weather relationships,” each decision must stand alone: otherwise, it would be very difficult to determine which weather phenomena are most influential in that decision.

Table 2 illustrates such relationships using the Center TMU decisions that were described in Section 4.0.
Certain patterns become apparent. All listed decisions require current observations as well as forecasts of certain weather phenomena. Arrival and departure flow management decisions can be influenced by gate forecasts containing a short to mid-term emphasis and terminal forecasts containing short, mid-term, and long-term emphasis. Examples include observed and/or forecast icing at holding altitudes, thunderstorm activity in a particular sector, and surface winds. Thunderstorm activity can additionally affect arrival and departure rates if they are forecast to occur over center area routes.

Center area-wide forecasts containing mid--to long-term emphasis of CAT, winds/temperatures aloft, and/or thunderstorm activity can influence SWAPs and in-trail restrictions. If the center has an overflight focus (Table 1) forecasts of appropriate weather phenomena should extend for several hours to ensure efficient aircraft spacing across the entire center area. The decision/weather relationships are consistent with the definition, because these phenomena have the greatest impact on enroute traffic flow.

There also is a need for the Center TMU to obtain real-time modifications and/or reinterpretations of the weather information before the product or forecast is updated to make proactive and strategic adjustments. This is apparent, based on Table 2, due to the consistent appearance of the need for observational information and very short-term changes in that information across all decision/weather relationships.

5.1.1 WEATHER NEED: Current weather and temporally and spatially tailored aviation forecast products to support Center TMU operations

The Center TMU needs to receive hazardous aviation weather products as well as available observations and forecast weather. Additionally, as derived from Table 2, the TMU has a need for three amendable forecast products, each corresponding to an area of operational emphasis; a center area forecast, a terminal approach control area forecast (concept of a ‘gate forecast’), and a terminal area forecast. Products are required to describe both adverse and other weather of aviation interest forecast to occur during short (up to 1 hour), mid (from 1 up to 4 hours), and long-term (4-8 hour) time periods. Specific emphasis of each product should follow those illustrated in Table 2. Forecast emphasis may additionally be driven by unique activities within the geographic area for which the forecast is valid (Table 1).

The three amendable forecast products require information which is consistent, timely, accurate, and appropriately scaled for coverage and resolution (Appendix A and Section 0).

5.1.2 WEATHER NEED: Interactive, real-time, value-added weather inputs to address “problem of the minute/hour/day”

Because weather phenomena and trends continually change, constant assessment of the atmosphere is required from a weather provider. The Center TMU has access to some weather information (graphic and alphanumeric) via briefing terminals. However, products have different update cycles, some require interpretation, and forecasts have time delays for preparation and dissemination. A weather provider can discern trends in adverse weather[2] not readily apparent to the Center TMU or available before the next product update cycle.

[2] Examples of this include trends in wind speed/direction, thunderstorm growth and decay and related adverse weather, storm movement, and the increasing or decreasing of visibility.

5.1.3 SUPPORTING NEEDS (Non-Weather)

Several supporting needs have been identified upon which the success of premium weather needs (section - 4.1.1 and 4.1.2) depends. However, these are non-meteorological needs such as products orientation, the need for scheduled products to increase situational awareness, FAA ownership, Quality Assurance, exchanges in technology, unique local needs, training, dissemination, management, and command/control.

This table describes the relationships between the described TMU decisions versus the weather need to base those decisions related to different characteristics.

Table 2: Decision/Weather Relationships

CENTER TMU DECISIONS	WEATHER NEEDS AND USE		
	WEATHER	CHARACTERISTICS	CENTER TMU USE
Arrival and Departure Flow Management (Dictated by the acceptance rate of airport and approach fixes or the airport/ approach/ARTCC departure rate)	Thunderstorm activity	T_0, T_1, T_2, T_3, G_0, G_1, G_2, G_3 C_0, C_2, C_3	Determine flight component capacity values.
	Icing	G_0, G_1, G_2 ,G_3 ,C_0, C_2, C_3	Determine airspace closed to certain aircraft
	Surface Winds	T_0, T_1, T_2 ,T_3	Determine terminal capacity based on runway(s) to be used
	Jet Stream Location	C_0, C_2, C_3	Determine utility of airspace
	Ceiling/Visibility	T_0, T_1, T_2, T_3, G_0, G_1, G_2	Determine spacing of aircraft for the expected runway configuration based on terminal and/or gate capacity values
	Low-Level wind shear	T_0, T_1, T_2	
	Turbulence	T_0, T_1, T_2, G_0, G_1, G_2	
	Present Weather including but not limited to RA, FZ RA, FZ DZ, PL, SN	T_0, T_1, T_2 ,T_3	
Severe Weather Avoidance Plan (SWAP)	Thunderstorm activity	T_0, T_1, G_0, G_1, G_2, C_0, C_2, C_3	Determine routes or areas that will be impacted. Initiate TMU programs.
	CAT	C_0, C_2, C_3	Determine alternative use airspace or routes
	Jet Stream Location	C_0, C_2, C_3	
In-trail restrictions (metering)	Thunderstorm activity	T_0, T_1, G_0, G_1, G_2, C_0, C_2	Determine affected airspace/adjust traffic flow to mitigate flight component capacity restrictions
	Ceiling/Visibility	T_0, T_1, T_2, G_0, G_1, G_2,	Adjust traffic flow
Ground Holds and Ground Delay programs	Thunderstorm activity	T_0, T_1, T_2, T_3, G_0 ,G_1, G_2,G_3, C_0, C_2 ,C_3	Determine the implementation or termination of a ground hold. Determine flight component capacity values over affected airspace. Determine Expect Delay Clearance Times (EDCT) at departure airports.
	Ceiling/Visibility	T_0, T_1, T_2, T_3	
	Surface Winds	T_0, T_1, T_2, T_3	
	Present Weather including but not limited to RA, FZ RA, FZ DZ, PL, SN	T_0, T_1, T_2, T_3	

LEGEND:

C_i = Center Area Observation or Forecast;
G_i = Gate Observation or Forecast;
T_i = Terminal Area Observation or Forecast;

i = 0 for current observations
i = 1 for up to 1 hour forecasts
i = 2 for 1 up to 4 hour forecasts (C2 is 0 up to 4 hour forecasts)
i = 3 for 4 - 8 hour forecasts

ASSUMPTIONS:

- All Center TMU decisions require, either directly or indirectly, current and/or forecast weather information.
- TMU decisions will incorporate all available weather information. This table highlights only the major weather needs.
- Weather needs described under "Weather" can be for weather occurring at departure airports, destination airports, and/or en route.
- With the advent of Free Flight, winds aloft forecasts will be required for Center TMU decision making
- Weather needs/focus in a given product is driven by Center operations
- For example: Ceiling and visibility forecasts for Departure Flow Management decisions will have a priority over other weather elements if departure minimums are low at the airport in question. Otherwise, low-level wind shear could become a priority. In the end, all collaborations are done with the ATCSCC for final decision making.

6. Summary

This document verifies the necessity for aviation-specific weather forecast products and services for center traffic management units. Availability of these products and services is a requirement for more effective decision making. This document described a process for deriving the decision-based weather needs. This process was based on identifying the Center TMU mission decisions, analyzing the effect of weather on those decisions, and deriving the information needs of Center TMU decision making.

There are three advantages to the decision-based process. The first is the establishment of connections between specific Center TMU mission decisions with weather information affecting those decisions. Secondly, resolutions, accuracies, and forecast metrics have been developed for each weather phenomena in accordance with Center TMU operational needs based on time of forecast and area of occurrence. Thirdly, resolution, accuracy, and metrics have not been constrained by current or predicted levels of technology.

The next step will be to identify (1) how the required products and services will be developed, (2) by whom, (3) in what form the ultimate users receive them, and (4) how the process will be managed on a day-to-day level. A collaborative effort between the FAA and aviation weather providers will determine solution(s) and their implementation, and in collaboration with service provider procedural documents to describe solutions and implementation architecture to modify the following FAA Orders:

- FAA ORDER 7210.38A, CWSU
- FAA ORDER 7110.65K, Air Traffic Control
- FAA ORDER 7032.9, TMS Air Traffic Operational Requirements
- FAA Training Order (3120)
  - Other training documentation
- Other documents requiring revision including:
  - Aeronautical Information Manual (AIM)
  - International Flight Information Manual
- Weather Service Operations Manual (WSOM), Chapter D-25, Issuance 96-10
- FAA/NWS Memorandum of Agreement (MOA)

Appendix A: Required Forecast Product Elements with Associated Rationale

This appendix describes attributes of weather phenomena that can occur during different phases of aircraft operation (such as resolution and accuracy in space and time) which must be considered in the requirements in order to satisfy the derived need. These attributes are "strategic" in nature and are based on operational rationales that support them. Legends with definitions follow the tables.

Table A-1 Terminal Area Forecast for up to 1 hour

Forecast Element	Operational Need for Resolution and Accuracy of Forecasts	Minimum Percentage of Cases within Range	Rationale
Thunderstorm Activity	5nmi ±2nmi; ±10min for an area depiction of the aviation hazard. This includes: Hail: Any occurrence Microburst: Decrease in headwind/tailwind of 30kts or greater with peak shear of 28 kts/nmi or greater Tornado: Any occurrence Convective Turbulence: Light to moderate intensity or greater Icing: Any occurrence Reflectivity: 30dbz or greater	90% POD; 90% of all cases; 5% POF	Rationale A
Ceiling	±100ft up to 1,000ft, ±200ft from greater than 1,000ft up to 3,000ft, ±500ft from 3,000ft to 10,000ft for a forecast of clouds covering 5 oktas or greater.	90% POD; 80% of all cases	Rationale B
Visibility	Forecast visibilities to the nearest 1/2 statute mile ±1/4 statute mile up to 3 statute miles. Include the weather causing the restriction.	90% POD; 80% of all cases	Rationale B
Surface Winds	Forecast speed to the nearest 5kts, ±5kts, and direction to the nearest 5 degrees, ±5 degrees	90% POD; 80% of all cases	Rationale E
Low-Level Wind Shear and turbulence (non-convective)	Forecast for a volume of airspace of wind shear gain/loss of 15kts/nmi or greater, ±10% horizontally, ±10 min begin/end of the forecast horizontal area bounded by terminal area boundaries.	90% POD; 90% of all cases	Rationale C
Present Weather	Forecasts for the onset or cessation of weather ±10 min	90% POD; 90% of all cases	Rationale F

Table A-2 Terminal Area Forecast for 1 hour up to 4 hours

Forecast Element	Operational Need for Resolution and Accuracy of Forecasts	Minimum Percentage of Cases within Range	Rationale
Thunderstorm Activity	10nmi ±5nmi; ±20min for an area depiction of the aviation hazard. This includes: Hail: Any occurrence Microburst: Decrease in headwind/tailwind of 30kts or greater with peak shear of 28 kts/nmi or greater Tornado: Any occurrence Convective Turbulence: Light to moderate intensity or greater Icing: Any occurrence Reflectivity: 30dbz or greater	90% POD; 80% of all cases; 5% POF	Rationale A
Ceiling	±200ft up to 1,000ft, ±400ft from greater than 1,000ft up to 3,000ft, ±1,000ft from 3,000ft to 10,000ft for a forecast of clouds covering 5 oktas or greater.	90% POD; 70% of all cases	Rationale B
Visibility	Forecast visibilities to the nearest 1/2 statute mile ±1/4 statute mile up to 3 statute miles. Include the weather causing the restriction.	90% POD; 70% of all cases	Rationale B
Surface Winds	Forecast speed to the nearest 10kts, ±10kts, and direction to the nearest 10 degrees, ±10 degrees	90% POD; 70% of all cases	Rationale E
Low-Level Wind Shear and turbulence (non-convective)	Forecast for a volume of airspace of wind shear gain/loss of 15kts/nmi or greater, ±10% horizontally, ±20 min begin/end of the forecast horizontal area bounded by terminal area boundaries.	90% POD; 80% of all cases	Rationale C
Present Weather	Forecasts for the onset or cessation of weather ±20 min	90% POD; 80% of all cases	Rationale F

Table A-3 Terminal Area Forecast for 4 to 8 hours

Forecast Element	Operational Need for Resolution and Accuracy of Forecasts	Minimum Percentage of Cases within Range	Rationale
Thunderstorm Activity	10nmi ±5nmi; ±30min for an area depiction of the aviation hazard. This includes: Hail: Any occurrence Microburst: Decrease in headwind/tailwind of 30kts or greater with peak shear of 28 kts/nmi or greater Tornado: Any occurrence Convective Turbulence: Light to moderate intensity or greater Icing: Any occurrence Reflectivity: 30dbz or greater	90% POD; 80% of all cases; 10% POF	Rationale A
Ceiling	±200ft up to 1,000ft, ±400ft from greater than 1,000ft up to 3,000ft, ±1,000ft from 3,000ft to 10,000ft for a forecast of clouds covering 5 oktas or greater	90% POD; 70% of all cases	Rationale B
Visibility	Forecast visibilities to the nearest 1/2 statute mile ±1/4 statute mile up to 3 statute miles. Include the weather causing the restriction.	90% POD; 70% of all cases	Rationale B
Surface Winds	Forecast speed to the nearest 10kts, ±10kts, and direction to the nearest 10 degrees, ±10 degrees	90% POD; 70% of all cases	Rationale E
Low-Level Wind Shear and turbulence (non-convective)	Forecast for a volume of airspace of wind shear gain/loss of 15kts/nmi or greater, ±10% horizontally, ±30 min begin/end of the forecast horizontal area bounded by terminal area boundaries.	90% POD; 80% of all cases	Rationale C
Present Weather	Forecasts for the onset or cessation of weather ±30 min	90% POD; 80% of all cases	Rationale F

Table A-4 Gate Area Forecast for up to 1 hour

Forecast Element	Operational Need for Resolution and Accuracy of Forecasts	Minimum Percentage of Cases within Range	Rationale
Thunderstorm Activity	10nmi ±5nmi; ±10min for a volumetric depiction of the aviation hazard. This includes: Hail: Any occurrence Microburst: Decrease in headwind/tailwind of 30kts or greater with peak shear of 28 kts/nmi or greater Tornado: Any occurrence Convective Turbulence: Light to moderate intensity or greater Icing: Any occurrence Reflectivity: 30dbz or greater Echo Tops: Vertical extent of ±2,000ft above FL290 and ±1,000ft below FL290	90% POD; 80% of all cases; 5% POF	Rationale A Rationale G
Icing (non-convective)	Forecast intensities (light, moderate, severe) for each of the three icing types (rime, clear, mixed) for a volume of airspace ±500ft for the upper and lower altitude limits, ±10% horizontally, ±10 min begin/end of the forecast horizontal area bounded by identified VORs/DMEs.	90% POD; 80% of all cases	Rationale C Rationale D Rationale G
Turbulence (non-convective)	Forecast for a volume of airspace of wind shear gain/loss of 15kts/nmi or greater ±500ft for the upper and lower altitude limits, ±10% horizontally, ±10-min begin/end of the forecast horizontal area bounded by identified VORs/DME.	90% POD; 80% of all cases	Rationale C Rationale G
Ceiling	±200ft up to 3,000ft, ±400ft from 3,000ft to 10,000ft, for a forecast of clouds covering 5 oktas or greater.	90% POD; 80% of all cases	Rationale B
Visibility	Forecast visibilities to the nearest 1/2 statute mile ±1/4 statute mile up to 3 statute miles. Include the weather causing the restriction.	90% POD; 80% of all cases	Rationale F

Table A-5 Gate Area Forecast for 1 hour up to 4 hours

Forecast Element	Operational Need for Resolution and Accuracy of Forecasts	Minimum Percentage of Cases within Range	Rationale
Thunderstorm Activity	15nmi ±7nmi; ±20min for a volumetric depiction of the aviation hazard. This includes: Hail: Any occurrence Microburst: Decrease in headwind/tailwind of 30kts or greater with peak shear of 28 kts/nmi or greater Tornado: Any occurrence Convective Turbulence: Light to moderate intensity or greater Icing: Any occurrence Reflectivity: 30dbz or greater Echo Tops: Vertical extent of ±2,000ft above FL290 and ±1,000ft below FL290	90% POD; 80% of all cases; 5% POF	Rationale A Rationale G
Icing (non-convective)	Forecast intensities (light, moderate, severe) for each of the three icing types (rime, clear, mixed) for a volume of airspace ±1,000ft for the upper and lower altitude limits, ±10% horizontally, ±20 min begin/end of the forecast horizontal area bounded by identified VORs/DMEs.	90% POD; 80% of all cases	Rationale C Rationale D Rationale G
Turbulence (non-convective)	Forecast for a volume of airspace of wind shear gain/loss of 15kts/nmi or greater ±1,000ft for the upper and lower altitude limits, ±10% horizontally, ±20-min begin/end of the forecast horizontal area bounded by identified VORs/DME.	90% POD; 80% of all cases	Rationale C Rationale G
Ceiling	±400ft up to 3,000ft, ±1,000ft from 3,000ft to 10,000ft, for a forecast of clouds covering 5 oktas or greater.	90% POD; 70% of all cases	Rationale B
Visibility	Forecast visibilities to the nearest 1 statute mile ±1/2 statute mile up to 3 statute miles. Include the weather causing the restriction.	90% POD; 70% of all cases	Rationale F

Table A-6 Gate Area Forecast for 4 to 8 hours

Forecast Element	Operational Need for Resolution and Accuracy of Forecasts	Minimum Percentage of Cases within Range	Rationale
Thunderstorm Activity	15nmi ±7nmi; ±30min for a volumetric depiction of the aviation hazard. This includes: Hail: Any occurrence Microburst: Decrease in headwind/tailwind of 30kts or greater with peak shear of 28 kts/nmi or greater Tornado: Any occurrence Convective Turbulence: Light to moderate intensity or greater Icing: Any occurrence Reflectivity: 30dbz or greater Echo Tops: Vertical extent of ±2,000ft above FL290 and ±1,000ft below FL290	90% POD; 80% of all cases; 10% POF	Rationale A Rationale G
Icing (non-convective)	Forecast intensities (light, moderate, severe) for each of the three icing types (rime, clear, mixed) for a volume of airspace ±1,000ft for the upper and lower altitude limits, ±10% horizontally, ±30 min begin/end of the forecast horizontal area bounded by identified VORs/DMEs.	90% POD; 80% of all cases	Rationale C Rationale D Rationale G

Table A-7 Center Area Forecast for 0 up to 4 hours

Forecast Element	Operational Need for Resolution and Accuracy of Forecasts	Minimum Percentage of Cases within Range	Rationale
Thunderstorm Activity	20nmi ±10nmi; ±20min for a volumetric depiction of the aviation hazard. This includes: Hail: Any occurrence Microburst: Decrease in headwind/tailwind of 30kts or greater with peak shear of 28 kts/nmi or greater Tornado: Any occurrence Convective Turbulence: Light to moderate intensity or greater Icing: Any occurrence Reflectivity: 30dbz or greater Echo Tops: Vertical extent of ±2,000ft above FL290 and ±1,000ft below FL290	90% POD; 5% POF	Rationale D Rationale G
Jet Stream Location and Characteristics	Forecast speed to the nearest 10kts ±10kts above 50kts and direction to the nearest 10 degrees ±10 degrees for the volume of airspace ±2,000ft from the upper and lower altitude limits for the forecast horizontal area bounded by identified VORs/DMEs	90% POD; 80% of all cases	Rationale D Rationale G
CAT	Forecast intensities (moderate, severe, extreme) and character (isolated, occasional, frequent, continuous) for a volume of airspace ±1,000ft for the upper and lower altitude limits, ±10% horizontally, ±20min begin/end of the forecast horizontal area bounded by identified VORs/DMEs	90% POD; 80% of all cases	Rationale D Rationale G
Icing	Forecast intensities (light, moderate, severe) for each of the three icing types (rime, clear, mixed) for a volume of airspace ±1,000ft for the upper and lower limits, ±10% horizontally, ±20 min begin/end of the forecast horizontal area bounded by identified VORs/DMEs.	90% POD; 80% of all cases	Rationale D Rationale G
Ceiling	±400ft up to 3,000ft, ±1,000ft from 3,000ft to 10,000ft, ±2,000ft above 10,000ft for a forecast of clouds covering 5 oktas or greater.	90% POD; 70% of all cases	Rationale B

Table A-8 Center Area Forecast for 4 to 8 hours

Forecast Element	Operational Need for Resolution and Accuracy of Forecasts	Minimum Percentage of Cases within Range	Rationale
Thunderstorm Activity	20nmi ±10nmi; ±30min for a volumetric depiction of the aviation hazard. This includes: Hail: Any occurrence Microburst: Decrease in headwind/tailwind of 30kts or greater with peak shear of 28 kts/nmi or greater Tornado: Any occurrence Convective Turbulence: Light to moderate intensity or greater Icing: Any occurrence Reflectivity: 30dbz or greater Echo Tops: Vertical extent of ±2,000ft above FL290 and ±1,000ft below FL290	90% POD; 70% of all cases; 10% POF	Rationale D Rationale G
Jet Stream Location and Characteristics	Forecast wind speed to the nearest 10kts ±15kts above 50kts and direction to the nearest 10 degrees ±20 degrees for the volume of airspace ±2,000ft from the upper and lower altitude limits for the forecast horizontal area bounded by identified VORs/DMEs	90% POD; 70% of all cases	Rationale D Rationale G
CAT	Forecast intensities (moderate, severe, extreme) and character (isolated, occasional, frequent, continuous) for a volume of airspace ±1,000ft for the upper and lower altitude limits, ±10% horizontally, ±30 min begin/end of the forecast horizontal area bounded by identified VORs/DMEs	90% POD; 70% of all cases	Rationale D Rationale G
Icing	Forecast intensities (light, moderate, severe) for each of the three icing types (rime, clear, mixed) for a volume of airspace ±1,000ft for the upper and lower limits, ±10% horizontally, ±30 min begin/end of the forecast horizontal area bounded by identified VORs/DMEs.	90% POD; 70% of all cases	Rationale D Rationale G

LEGEND AND DEFINITIONS FOR TABLES A-1– A-8

Forecast Element Product contents that can affect Center TMU decision making (see Table 2)

Operational Need for Resolution and Accuracy Forecasts Requirement, with accompanying rationale, based on strategic user need.

Minimum Percentage of Cases within Range Forecast performance metrics.

Example 1: 90% Probability of Detection (POD); 90% of all cases for thunderstorm activity for the Terminal Area up to 1 hour forecast

This is defined as the detection of 90% of any thunderstorms in the Terminal

Area (up to 1 hour) and of those, 90% will be within the stated resolutions and accuracy criteria. The probability of false alarm (POF) shall not exceed 5%.

Example 2: 90% POD; 80% of all cases for Terminal Area ceiling forecasts for up to 1 hour

If a forecast for 1,500ft is forecast, then the verified ceiling (5 oktas or greater coverage) has to be within 1,000 to 3,000 feet 90% of the time, and of those, 80% are to be between 1,300 and 1,700ft (±200ft)

NOTE: The verification of thunderstorm attributes is event driven. Non-verification will be measured using percentages of false alarms. For all other forecast elements, verification of the weather in space and time must occur over 80% of the forecast time period in order to achieve product integrity for end users. The percent of time of verification will be greatest for short term forecast products in the terminal area and least for longer term forecast products in the center area.

Information Characteristic Requirements

In order to satisfy the derived need, which must be considered in the requirements, different attributes of weather phenomena can occur during different phases of aircraft operation, for example: resolution and accuracy in space and time. The different characteristic requirements are described below, and will be used to illustrate the rationale for general and specific forecast element characteristics.

Consistency Analysis of the current state of the atmosphere and forecasts of future states should be dependable at a given point in time for all aviation weather products and users.

Timeliness Aviation weather analyses and forecasts should be updated on time scales relevant to aviation users' operational needs, many of which are generally measurable in fractions of hours rather than multiples of hours. Many aviation weather phenomena that have critical impacts on aviation safety and operational efficiency can be short-lived, and users' reaction must be rapid.

Clarity Aviation weather information must be unambiguous to the specific user for whom it is designed. This arises due to a wide range in training, experience, and operational need between various users.

Accuracy Aviation weather information must depict the current or future states of the atmosphere with sufficient accuracy to support the operational decisions for which it is used.

Reliability Users must be assured of product availability in accordance with published schedules (for scheduled products) and, for unscheduled products, in accordance with specific user need.

Quality Assurance Users need to be provided with information on product accuracy and stability.

Coverage Aviation weather information is needed for the appropriate geographical areas, altitudes, and times that meet the users needs.

Resolution Spatial resolution of products must be commensurate with the scale of aviation weather phenomena.

Rationale for General Forecast Element Characteristics

General Proximity of operationally significant weather to the runway is directly proportional to the affect on airport operations. Accuracy can have a direct affect on arrival and departure flows and rates with greater accuracy required for tactical planning. Accuracy values are (in general) ½ the resolution and then rounded down for safety.

All Terminal Area Forecasts Minimum percentage of cases within range, including verification, are highest for the terminal area because basing traffic decisions on weather requires an extremely high accuracy rate for forecast confidence and weather occurring in the terminal area can be most critical in the determination of airport capacity. Furthermore, the resolution, accuracy, and minimum percentage of cases within range are required to be increasingly restrictive for more tactical utilities because less lead time or combined with less spatial area is available for decision making (less maneuverability).

All Gate Area Forecasts Requirements for resolution, accuracy, and minimum percentage of cases within range are not as critical as in the terminal area because greater lead time or greater spatial area is available for decision making before the onset of an event (aircraft have more room to maneuver). Volume of affected airspace is required to determine ascending/descending flight path deviations and holding patterns.

All Center Area Forecasts Requirements for resolution, accuracy, and minimum percentage of cases within range are not as critical as in the gate area because greater lead time or greater spatial area is available for decision making before the onset of an event (aircraft have more room to maneuver).

Rationale for Specific Forecast Element Characteristics

Rationale A The spatial and temporal resolution and accuracy criteria as required for each forecast would ensure coverage of the event over the life of the forecast. This will segment each forecast area (e.g., minimum of 4 quadrants in the terminal) which can be referred to for movement and coverage of various phenomena attributes.

Due to the short-lived nature of these events across the terminal airspace and their complex vertical structure, only an area depiction (x, y, t) is required and it will be assumed that the entire volume from the ground to the top of the terminal airspace (generally no more than 3,000ft) is affected. For gate and center area airspace, volumetric depiction of the aviation hazard (x, y, z, t) is required to determine segments of affected airspace.

Any occurrence of hail, tornado, or icing can be operationally hazardous to a majority of aircraft (safety/maneuverability/performance). Additionally, a decrease in headwind/tailwind of greater than 30kts, convective turbulence of light to moderate intensity and reflectivity of 30dbz are thresholds for the identification of operationally hazardous airspace. The reflectivity threshold was determined based on an approximate rate of rainfall at which the visibility generally would fall through a VFR threshold to IFR and thereby cause a change in the anticipated airport capacity rate.

Rationale B Values for resolution and accuracy are based on thresholds for visual, contact, and instrument approach minimums (i.e., when will each be lost which all lead to changes in anticipated airport capacity). Accuracy requirements of ceiling heights were based on approach minimum restrictions. The accuracy criteria are sufficient to allow the determination of which non-precision approaches are available for airport capacity determination. Higher accuracy criteria are required closer to the ground due to the increasing importance and impact on airport capacity. Ceiling accuracy to 10K feet will ensure terminal area coverage.

Rationale C Volumetric depiction of the aviation hazard (x, y, z, t) is required to determine segments of affected airspace.

Rationale D The utility of thunderstorm activity, icing, jet stream location/characteristics, and/or CAT forecasts with a coarser resolution and/or decreased accuracy than those presented for each would degrade the TMUs ability to plan safe and efficient en route structure. This is further constrained by the requirement to mesh en route and terminal (gate) operations.

TMU may wish to route traffic above convective tops if not above 40K ft. Due to service ceiling of 45K feet and vertical separation restrictions, the accuracy of thunderstorm activity vertical extent is required to be no greater than ±2,000ft.

Rationale E The utility of surface wind forecasts with a coarser resolution and/or decreased accuracy than those presented would degrade the TMUs ability to identify the operational runway(s) to be used. Knowledge of the operational runway(s) is an input in the determination of terminal flight component capacity.

Rationale F The present weather elements were selected based on the reduction in visibilities and/or an increase in breaking distances that would accompany it. Either of these would lead to a reduction in terminal flight component capacity.

Rationale G Resolution and accuracy requirements driven by vertical separation standards. Separation standards are 1,000ft up to FL 290 and 2,000ft above FL 290.

Appendix B: Glossary

AFSS	Automated Flight Service Station
AIM	Aeronautical Information Manual
ALPA	Air Line Pilots Association
APA	Allied Pilots Association
ARTCC	Air Route Traffic Control Center
ARW	Aviation Weather Directorate
AOPA	Aircraft Owners and Pilots Association
AT	Air Traffic
ATA	Air Transport Association
ATCS	Air Traffic Control Specialists
ATCSCC	Air Traffic Control System Control Center
CAT	Clear Air Turbulence
CWSU	Center Weather Service Unit
dbz	Decibel with respect to equivalent radar reflectivity
DME	Distance measuring equipment
EDCT	Expect Delay Clearance Time
EFAS	En Route Flight Advisory Service
FAA	Federal Aviation Administration
FSS	Flight Service Station
ft.	Feet
IFR	Instrument Flight Rules
MOA	Memorandum of Agreement
NAS	National Airspace System
NASAO	National Association of State Aviation Officials
NBAA	National Business Aviation Association
NTSB	National Transportation Safety Board
NWS	National Weather Service
POD	Probability of detection
POF	Probability of false alarm
RAA	Regional Airline Association
SWAP	Severe Weather Avoidance Plan
TMS	Traffic Management System
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
VFR	Visual Flight Rules
VOR	Very High Frequency Omni-Directional Range
WSOM	Weather Service Operations Manual