11.3 DETERMINING FAA MID-TERM AVIATION WEATHER REQUIREMENTS FOR TRAFFIC FLOW MANAGEMENT—THE TRANSITION TO NEXTGEN

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1. INTRODUCTION

As the Federal Aviation Administration (FAA) transitions to the Next Generation Air Transportation System (NextGen), the Mid-Term National Airspace System (NAS) must be fully defined through sets of operational, functional and performance requirements. For the weather community, this begins with the determination of the weather information needs of NAS decision-makers based on their Mid-Term operational requirements. For the Mid-Term, circa 2018, the FAA faces several major challenges in determining aviation weather needs. These challenges include identification, resolution, and accuracy of the needed weather information, as well as its integration into applications or decision support tools (DST). The FAA recognized that identification of the needed weather information is crucial, because it is a key factor in determining the final implementation of the weather services needed to support NAS decision-makers.

The FAA decided that the first step in achieving Mid-Term implementation would be to identify needed weather information for Traffic Flow Management (TFM). Although the first set of performance requirements are being developed and validated for TFM, the same process will be used to develop weather performance requirements for all NAS decision-makers.

2. NEXTGEN GOALS AND OBJECTIVES

To meet NextGen goals and objectives, a transformed air transportation system must include improved weather operations (JPDO, 2010) as follows:

- The integration of improved weather information, combined with the use of probabilistic forecasts to address weather uncertainty, supports ATM decision-making to minimize the effects of weather on operations.
- Improved communications and information sharing allows all stakeholders access to a single authoritative weather source. Weather data is translated by users' DSTs into impact information presented to NAS users and service providers, such as the likelihood of flight deviation, airspace permeability, and reduction in capacity.
- Weather information integrated into decision-oriented automation is used instead of separate weather data viewed on a “stand-alone” display.

In support of the NAS operational decision-makers, particularly for TFM:

- The primary role of weather information is to support the identification of optimal aircraft trajectories that meet the safety, comfort, schedule, efficiency, and environmental impact requirements of all NAS users.
- The increased precision, resolution, and reliability of weather information supports TFM decision-making and also provides a basis for shared situational awareness for collaboration with dispatchers and other NAS stakeholders.
- Weather information is designed to integrate with and support decision-oriented products with automation capabilities that enhance user safety within the NAS.
- The update frequency of weather information is commensurate with the need to respond to rapidly changing circumstances.

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- Weather capabilities allow rapid notification (automation-to-automation) of changing weather situations thereby supporting both strategic and tactical decision-makers.

3. FAA MID-TERM WEATHER REQUIREMENTS DEVELOPMENT

The NextGen Weather Performance Requirements Team (NWPRT) was originally formed to develop functional and performance requirements for NextGen. They were asked to develop functional and performance requirements for TFM to support the development of improved weather information in the Mid-Term. The NWPRT reviewed the primary Mid-Term Concept of Operations (FAA, 2010) and several secondary concepts to determine the envisioned degree of transition that TFM operations would undergo towards NextGen operational constructs between today and the Mid-Term.

3.1 *TFM Needs*

A joint FAA and NWS TFM Weather Requirements Working Group (TRWG), was formed in August 2010 to determine Mid-Term TFM weather information needs. Subsequent conversations between the NWPRT and TRWG revealed that the development of Mid-Term weather requirements for TFM still needed to be based on the understanding that TFM would continue to use flows as they do today. This was in contrast to NWPRT assumptions and development of Far-Term (circa 2025) requirements (for TFM and other NAS operational users) that assumed trajectory-based flow management constructs.

To develop TFM specific Mid-Term requirements, it was necessary to contact the TRWG, which was looking at TFM weather information needs with the following objectives:

- Develop requirements for weather information services for NextGen Mid-Term Operational Capability (MOC)

- Establish a plan to implement solutions meeting those requirements

- Baseline the current NWS weather forecast support capability

In addition, the TRWG determined what weather events or parameters impacted NAS operations the most. The list below comprises a preliminary set of TFM weather events/parameters that have the most impact on NAS operations for the Mid-Term:

- Convection *#
- Ceiling/Visibility *
    - Marginal VFR *
    - IFR *
- Winds Surface & Aloft *#
- Icing *#
    - In-Flight Icing
    - Surface
- Turbulence #
- Volcanic Ash *#
- Microbursts/Low-level Wind Shear *
- Liquid/Frozen Precipitation *#

Note: # = en route airspace
* = Core airports

Additional meetings/discussions with the TRWG and other TFM specialists were essential as they uncovered TFM weather needs that otherwise would have not been realized. For example, microbursts would not have been considered for TFM decision-making as these events are very ephemeral (impacting airport landings/takeoffs for less than 15 minutes). Another Mid-Term need that surfaced was to expand thunderstorm observation and forecast coverage into the oceanic portions of the global domains. This results in improved predictions of capacity/demand imbalances that arise from thunderstorm activity affecting late afternoon European arrivals at Eastern U.S. hubs. Of nearly equal priority was to expand coverage north into the Canadian portion of the en route airspace domain, in order to better plan Canadian playbook routes.

Using the combined list of TFM needs, the NWPRT completed the draft Mid-Term functional and performance requirements with a format very similar to the Far-Term requirements. However, the TFM specialists declared that these draft requirements were written for meteorologists (vice Air Navigation Service Providers), and as a result they would not be able to validate these requirements from an operational perspective—*the real need*.

3.2 *Writing Mid-Term Requirements in TFM Specific Terminology*

To be able to rewrite the MOC requirements in terms common to TFM specialists, the NWPRT used a set of Near-Term (2013-2014) weather requirements from the TRWG that had been drafted earlier using TFM-specific terminology. The NWPRT adopted TFM terminology from the Near-Term requirements to reframe the TFM requirements for the Mid-Term.

The TRWG definitions of metrics are:

- *Lead-time to Onset*: the time between issuance of a forecast and the forecast start-time of the weather phenomenon

- *Lead-time to Cessation:* the time between issuance of a forecast and the forecast end-time of the weather phenomenon

- *Timing Error:* the maximum allowable difference between forecast and actual time of onset and cessation in determining if a weather phenomenon verifies

- *Location Error:* the maximum allowable horizontal and vertical tolerance in determining if an observation or forecast of a weather phenomenon verifies

- *Probability of Detection/False Alarm Rate (Verification Skill):* the statistical reliability of the forecast in terms of location and timing

The NWPRT also made judgments as to whether the requirements for the Mid-Term should be the same as the Near-Term or considerably more stringent, that is, closer to Far-Term performance requirement values. The terminology for TFM weather elements was different from those of the Far-Term requirements. For example, TFM specialist guidance to the NWPRT was very specific about the size of thunderstorms that matter for their decision-making. Their particular Near-Term and Mid-Term convective requirements focus on thunderstorms with maximum cloud tops over 30,000 feet and whose diameter is over 20 nautical miles in flow-constrained areas. Only observations and forecasts of storms of that size will trigger strategic TFM decision-making. Another criterion was that the thunderstorm forecast had to have a probability of 50 percent or greater for TFM decision-making. The assumption is that a thunderstorm forecast with a lower percent probability of occurrence would not warrant concrete action by TFM. Other Near-Term TFM definitions of ‘Thunderstorms in Flow Constrained Areas’ and ‘Thunderstorms for the Core Airports’ will be used with similar performance requirements for the Mid-Term.

With TRWG guidance, the NWPRT also modified the performance requirement language by rewriting them with more operationally relevant language. For example, the Far-Term delineation of ‘begin time’ and ‘end time’ was changed to ‘onset’ and ‘cessation’ for Mid-Term TFM use. However for the Far-Term, definitions of ‘begin time’ and ‘end time’ are operationally equivalent and will remain.

The NWS developed current forecast performance values using the TFM metrics above for convection, ceiling, visibility and surface winds. The TRWG will use these values for the Near-Term requirements and after validation of those requirements, have a baseline from which they can perform a gap analysis for Mid-Term requirements for TFM. Once that analysis is completed, the TRWG will promulgate a plan for progressing forward. The TRWG intends to publish an implementation plan specifying how to achieve improved weather information along with an implementation schedule in the fall of 2011. Actual implementation of Near-Term requirements is expected to begin in the fall of 2012. By then, the TRWG will have completed the gap analysis between the Near-Term and the Mid-Term and begun the planning for the later transition.

4. METHODOLOGY TO TRANSITION FROM TODAY TO THE MID-TERM

4.1 *Requirements Validation*

After identification of the needed weather information is accomplished, the next step in the validation process is to identify characteristics or attributes of the weather information. These pertain to the "goodness" of the weather information, as specified by the decision-maker or operational user who perceives “goodness” in terms of accuracy. This includes how precise the observation is measured or how well the forecast matched the observation, as well the latency, the spatial and temporal resolutions, and the magnitude accuracies of the various weather elements. Once the decision-makers have validated the required accuracy values, the associated performance requirements are developed. The selection of solutions developed as part of the FAA’s Acquisition Management System for the various capabilities of the NAS weather architecture, that is, observing, forecasting, and dissemination, will be based on these performance requirements.

The NWPRT recognized that these requirements must be validated by the operational community to be credible. More importantly, this validation would establish a baseline of TFM weather requirements. Then, and only then, can a shortfall (or gap) analysis be conducted to determine what weather gaps exist and how best to address those gaps in future weather services. The NWPRT is working with the TRWG and other TFM personnel to validate the functional and performance weather requirements for the Mid-Term.

The validation process began with TFM personnel reviewing draft performance requirements provided by the NWPRT. With each requirement, the user will want to validate the following important aspects:

- Validate the actual need and use for the information (quantify user need and relative value)

- Validate that the information is accessible in a timely manner (quantify that the receipt of, or access to, weather information is consistent with inputs to decision tools)

An important aspect of the validation process is to determine TFM decisions that are impacted by weather. Earlier research from Mission Need Statement # 339, the JPDO ConOps and the Weather ConOps provided the NWPRT with sufficient knowledge of weather-impacted decisions. However, as part of the requirements validation process, TFM members of the TRWG and other TFM specialists confirmed those decisions.

In Table 1 TFM decisions are listed down the left-hand side and corresponding impacting weather events or parameters are on the right. An analysis of this matrix reveals that several weather events or parameters impact multiple TFM decisions:

- Thunderstorms disrupt NAS operations the most as they impact all six TFM decisions
- Volcanic Ash is also significant as it impacts four of six TFM decisions
- Non-Convective Turbulence impacts three of the six TFM decisions
- In-Flight Icing, Low Ceilings/Visibility and Slant Range Visibility each impact two of six TFM decisions
- Precipitation on the surface impacts TFM decisions differently; all forms (liquid, freezing, frozen) impact AAR Determination while freezing precipitation can result in Ground Delays
- Low-Level Wind Shear/Microburst, Surface Icing, and Surface Winds each impact TFM decisions the least with one of six decisions

TFM Decision	Impacting Event/Weather
Severe Weather Avoidance Plan (SWAP) Implementation	Thunderstorms
Metering/Spacing	Thunderstorms
	Volcanic Ash
	Non-Convective Turbulence
Airspace Flow Programs	Thunderstorms
	In-Flight Icing
	Non-Convective Turbulence
	Volcanic Ash
Airport Arrival Rate (AAR) Determination	Thunderstorms
	Low-Level Wind Shear/Microburst
	All Precipitation
	Surface icing
	Volcanic Ash
	Low Ceilings/Visibility, Slant Range Visibility
	Surface Winds
	Winds & Temps Aloft, Clouds
Ground Stops/Delay	Thunderstorms
	Freezing Precipitation
	Low Ceilings/Visibility, Slant Range Visibility
	Surface Winds
	Volcanic Ash
Route Change	Thunderstorms
	In-Flight Icing
	Non-Convective Turbulence
	Volcanic Ash

Table 1 TFM Decisions vs. Impacting Weather

While Volcanic Ash (VA) is recognized as a non-weather event, per se, improved weather observations and forecasts can mitigate its impact on NAS operations. High-resolution observations and forecasts of Winds Aloft enable TFM to collaborate with airline dispatchers and route/re-route aircraft around any VA-impacted airspace.

4.2 *Scenarios for Selecting Mid-Term Performance Values*

A logical path between Near-Term, Mid-Term and Far-Term depends on a clear vision and the answers to the right questions from the perspective of the requirements writer. Close study of concept of operations philosophy for the future and coordination with users who can visualize these concepts will lead to a starting point for mid- and end-point metrics. Occasionally, Mid-Term needs may be an easy interpolation backwards from the end-state (Far-Term) or forward from the Near-Term, but it is not often that simple.

There are a number of scenarios that exist for choosing the right performance values along the Near-Term to Mid-Term to NextGen path. The easiest scenario is where performance values for observing and forecasting do not have to change. Occasionally, a value sufficient for today will suffice for the Far-Term, for example, performance criteria for winds aloft are consistent from today through Far-Term. Determining a Mid-Term metric for accuracy in that case is easier—no change.

The second scenario is where the level of performance needed in the future doesn't exist today. This forces us to evaluate the future requirement to see when it appropriately needs to be introduced. For example, in the Far-Term, there is a requirement for a more precise picture of what we call a "thunderstorm" today. The concept is labeled as a "Convective

Hazardous Volume" (CHV) and includes the need for phenomena not necessarily included in what is defined today as "thunderstorm" as detected by radar, for example, composite reflectivity or vertically integrated liquid (Souders, 2011).

In the future, however, observations and forecasts of both turbulence and icing areas will more descriptively fill in the CHV to identify attributes other than reflectivity that pose aviation hazards. This will enable safer and more efficient operations in the vicinity of "thunderstorms," increasing the amount of usable airspace, especially critical in NextGen trajectory-based operations. The CHV concept is not required for Mid-Term, though, so this is an example of a future need that is not necessary until the NextGen era. In this case, Near-Term requirements for thunderstorms will be adjusted as appropriate for Mid-Term, with the transition from thunderstorm to CHV happening between Mid-Term and Far-Term.

The third scenario is where the level of the performance of observing or forecasting needs to increase in accuracy through the Mid-Term and into the Far-Term to support the development of TFM algorithms or DSTs. In Table 2 the highlighted areas show an example of a requirement accuracy becoming finer with time from the Mid-Term to the Far-Term. Note the increase in wind direction accuracy from plus or minus five degrees to plus or minus one-half degree. The rationale is that in the Far-Term, terminal airspaces, such as the Core airports with high-tempo operations and/or those with closely spaced parallel runways, will require greater accuracy in wind direction observations and forecasts to support operations.

An underlying consideration affecting all weather performance requirements is spatial and temporal resolution, latency, and accuracy. Generally, latency requirements specify the minimum time required for the delivery of information to the user. Spatial resolution gets finer and the need for denser data increases as we proceed toward NextGen, especially in the airspaces where density of data will allow a capacity payoff in the future. The aggregation of spatial and temporal resolution, and accuracy requirements is once again reviewed and adjusted based upon the central question "How is this information used?"

4.3 *Baseline*

The special case of "baseline" as it relates to Near-Term requirements must be highlighted. The NWS will establish a "baseline" for their current forecast capability for the weather elements included in the Near-Term requirements. Using the NWS forecast performance values; the TRWG will perform a gap analysis between the current capability and the Near-Term requirements. Then Near-Term requirements will be used as a starting point to determine shortfalls (or gaps) in attaining Mid-Term requirements. The differences between the forecast verification statistics for present criteria (including desired lead time) and the actual verification goals of TFM will clearly define the gaps. Shortfall analyses will justify funding for implementation or for research and development to be conducted if no current solution appears viable.

5.0 TRANSITION CHALLENGES

After the FAA operational decision-makers have validated the requirements, they need to be allocated to solutions. These solutions will be implemented in accordance with the FAA NAS weather enterprise architecture.

The next few years are crucial for several reasons. First, successfully transitioning from the current weather enterprise architecture to that of NextGen requires not only implementing the new infrastructure but also maintaining the legacy infrastructure until it can be replaced. This requires funding both the maintenance of the existing legacy infrastructure and the acquisition of the new infrastructure. Therefore, it is common to have an inflated budget for several years while replacing a function or capability as the legacy capability must be maintained until the replacement can be fully implemented.

Secondly, during the next couple of years the FAA will be operating under an austere fiscal budget environment. New program starts important to NextGen will undergo both budget and schedule scrutiny. All programs must progress through each of the FAA acquisition phases efficiently in order to reduce the risk of not reaching their final investment decision 'on time' and 'on budget.' Weather programs associated with NextGen are not exempt from such risk and could lose funding necessary for implementation if untenable

Surface Observation Accuracy Sample	
Time Frame of Surface Meteorological Element	**NAS Terminal Airspace**
Near-Term Wind Direction	± 5°
Mid-Term Wind Direction	± 5°
Far-Term Wind Direction	± 0.5°
For Near-Term and Mid-Term, "NAS Terminal Airspace" refers to two airspace categories for weather support: High-Density Terminal Airspace and Designated En Route Terminal Airspace. For Far-Term, it refers to three airspace categories for weather support: High-Density Terminal Airspace, Designated En Route Terminal Airspace, and Designated Global Terminal Airspace.	

Table 2 Surface Observation Accuracy Sample

delays are encountered in reaching their final investment milestone.

The FAA NAS weather enterprise architecture transition is exacerbated by several factors, both external and internal. Externally, the NAS weather architecture is impossible to disentangle from that of the NWS. The NWS will be responsible for a major component of NextGen required by the NAS—the 4-D Weather Data Cube (4-D Wx Data Cube) and, by extension, the 4-D Weather Single Authoritative Source. As TFM will access weather information from the 4-D Wx Data Cube, any NWS implementation delays preclude improvements to the weather services essential for the collaboration necessary to reduce or mitigate the impacts of weather on NAS operations. Internally, not all components of NextGen will be in place by the Mid-Term. The FAA will continue to receive weather information from the NWS in a variety of formats, some legacy and some net-enabled. While the FAA has prepared for this, that 'mix' precludes attaining a total net-enabled weather architecture which is essential for access to all weather information. Lastly, it is presently unknown what TFM automation systems will be available for integrating weather information by the Mid-Term.

6.0 SUMMARY

The challenges the FAA faces in determining aviation weather needs for TFM in the Mid-Term are being addressed by the TFM TRWG, a joint agency team of both information users and providers. The TRWG determined what weather events or elements impacted NAS operations the most. Using this information, the NWPRT developed a set of weather elements needed by the TFM decision-makers. This set was validated and the NWPRT developed a draft set of Mid-Term requirements specifying spatial and temporal resolution, and accuracy. The TRWG requested that the NWPRT modify the Mid-Term weather performance requirements to include more operationally relevant language. Accordingly, the NWPRT has begun the modification of the Mid-Term requirements.

After the weather information needed in the Mid-Term is identified and the performance requirements are written, the TFM specialists must validate the Mid-Term requirements. Validation of weather performance requirements requires an iterative process consisting of questions, answers, and adjustments as specified previously. Post validation efforts include performing gap analysis, gap mitigation strategies, and documenting this information, as well as agency allocation in an implementation plan. Requirements that cannot be met in the Mid-Term with current state of the science will be allocated to weather research and development.

7.0 REFERENCES

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