J4.1 NEXT GENERATION AIR TRANSPORTATION SYSTEM (NEXTGEN) WEATHER REQUIREMENTS: AN UPDATE

Cheryl Souders*
Thomas Kays
Susanne Spincic
Frances Bayne
Federal Aviation Administration, Washington, DC

Cecilia Miner
Steve Abelman
National Weather Service, Silver Spring, MD

Robert Showalter
James Tauss
Lorraine Leonard
CSSI, Inc., Washington, DC

Ernie Dash
Jack May
AvMet Applications, Inc., Reston, VA

1.0 Introduction

While the National Airspace System (NAS) of today is the safest in the world, it is under significant stress. Aircraft operations are expected to grow significantly through 2025, with super-density operations hubs emerging along with the shift to increased numbers of smaller aircraft, which require more flight operations to move equal numbers of people. There are well-founded concerns that the increased demand will exceed the ability of the current air transportation system to accommodate even moderate growth. Not all major metropolitan airports can expand operations by simply building more runways. The current National Airspace (NAS) processes and procedures do not have the flexibility needed to meet the growing demand. Through Next Generation Air Transportation System (NextGen), new air traffic management (ATM) technologies and processes must be implemented to accommodate the higher volumes of air traffic in a safe, efficient, and environmentally sound manner.

Because of the profound impact adverse that weather has on transportation, NextGen is focusing on a major new direction in aviation weather information capabilities that enables stakeholders at all levels to make better operational decisions during impacting weather situations. For NextGen, weather information has a core function—identify where and when weather will impact NAS operations.

According to the Joint Program Development Office (JPDO) NextGen Concept of Operations (ConOps) [V2.0, June 2007], the primary role of weather information is about enabling better air transportation decisionmaking. Weather information is not just an end product to be viewed in a stand-alone display. Rather, weather information is designed to integrate with and support NextGen decision-oriented automation capabilities and human decisionmaking processes.

In the NextGen era, safe and efficient NAS operations will depend on enhanced aviation weather capabilities that are based on three major tenants of the NextGen ConOps [V2.0, 2007]

- A common picture of the weather for all transportation decisionmakers and aviation system users
- Weather directly integrated into sophisticated decision support tool capabilities to assist decisionmakers
- Utilization of Internet-like information dissemination capabilities to realize flexible and cost-efficient access to all necessary weather information

NextGen sets forth a new way of looking at how weather information will be integrated into decisionmaking, enabling proactive support to the air transportation system of the future. It is not just about new or 'better' weather products; but more importantly it is about the availability of consistent and optimum weather information to enable better collaborative decisionmaking by operational stakeholders (e.g., air traffic controllers, traffic management specialists, flight service station specialists, flight crews and dispatchers). This paper focuses on the NextGen user needs and the analysis approaches that led to a set of functional and

* *Corresponding author address:* Cheryl Souders, FAA
800 Independence Ave., SW Washington, DC 20591
Cheryl.Souders@faa.gov *202) 385-7235*

performance weather requirements necessary to support NAS operations in 2025.

2.0 CHANGING DEFINITIONS AND SHIFTING PARADIGMS

The NextGen Weather ConOps [Ver 1.0, 2006] sets forth the premise that NAS operations are improved if all participants in the aviation system to use the same weather information for their decisions rather than to use multiple and possibly conflicting sources. The prevailing FAA weather service model today encourages optimized weather information solutions for decisionmakers but has no requirement for national scale consistency. Therefore, the ability to make weather-related decisions on a national scale are often difficult, since users are not provided with the same information, except in the limited context of the collaborative decisionmaking (CDM) process associated with the Collaborative Convective Forecast Product (CCFP).

It is easy to see how today's users, trying to work together, find it difficult to collaborate as each may have a different picture or reference of the current weather situation and that of the future as well. More consistent information *increases confidence* among different users in what is happening or expected (e.g., predicted) to happen, which enables them to collaborate more effectively. Thus, the ConOps argues, if everyone had the same depiction of weather, or a "common weather reference," they could better determine and proactively implement the best national approach to operate safely and efficiently while accounting for the weather. Proactively managing weather uncertainties is more effective than reactively trying to manage the achievement of ATM performance goals. Thus, weather predictability requires three important capabilities to support air traffic management in the presence of impacting weather: 1) provide a single, unique (optimal) prediction for weather at a given point in space and time, 2) provide consistent predictions, and 3) facilitate the determination of ATM impacts.

In addition to consistent weather information, another important NextGen capability is access to network-enabled information that will ensure information is available, securable, and usable in real-time for different communities of interest across the NAS. Sensors, processors, and collection servers containing weather information from Government and Industry suppliers will exist in a distributed and networked environment across multiple locations. These servers and virtual data sources are known collectively as the Four Dimensional Weather Data Cube (4-D Wx Cube).

Depicted in Figure 1, the 4-D Wx Data Cube will contain public domain, unclassified, domestic weather information relevant to aviation decisionmaking including human and machine-derived observations (ground, air or space-based), analyses, and forecast products (text, graphic, gridded, machine readable), model information, and climatological data. Foreign and proprietary information as well as privately sourced products are also included. A multi-agency domain authority will be defined and will provide authorized access to proprietary or sensitive data as appropriate. The contents, access and utilization of the 4-D Wx Data Cube by NAS users' operational applications through network-enabled constructs are a foundational NextGen Weather capability.

Since the 4-D Wx Data Cube encompasses all relevant aviation weather information from multiple sources, it may also provide information that occasionally conflicts or will have variable performance attributes including accuracy, availability, statistical reliability, consistency, update rates, and resolution in time and space. Therefore, a means is needed to de-conflict and fuse 4-D Wx Data Cube information into a "common weather reference" on which all stakeholders can rely. [JPDO NextGen ConOps Ver2.0]

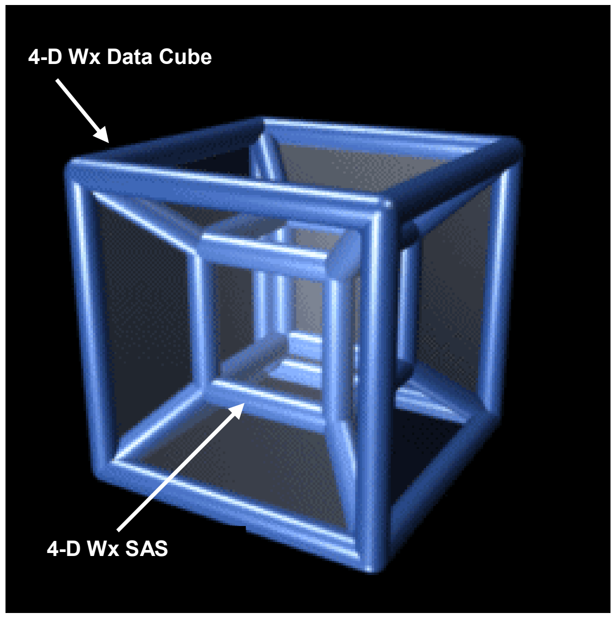

Figure 1. 4-D Wx Cube/SAS

2.1 Four Dimensional Weather Single Authoritative Source (4-D Wx SAS) Definition

The 4-D WX SAS is a subset of the 4-D Wx Data Cube (see Figure 1) that contains gridded data fields of current and forecast aviation weather parameters. It supports the civil Air Navigation Service Provider's (ANSP), or FAA's ATM decisions. The 4-D WX SAS provides users access to common weather information for CDM and ATM decisions, and it facilitates automated processing by decision support tools (DST) with its tailored, machine-compatible output.

The 4-D WX SAS is currently defined (as approved by the NextGen Executive Weather Panel (NEWP)) as *an optimal representation of all ANSP-used weather* *information and is consistent in time, space, and among weather elements. The 4-D WX SAS is specified by the ANSP and is accessible to all. The 4-D WX SAS is the source of weather information for ANSPs' ATM decisions and is supported by the same network services as the 4-D Wx Data Cube. The ANSP will specify characteristics of the weather information needed to support its ATM decisionmaking and decision support tools. As NextGen capabilities mature, the ANSP requirements will evolve. The National Weather Service (NWS) will determine what information best meets the 4-D WX SAS requirements specified by the ANSP; information from any source, including commercial sources, can be used to meet 4-D WX SAS requirements as long as the 4-D WX SAS information can be freely distributed to all.*

With rare exceptions, the 4-D WX SAS will be the only source of weather information for the ANSPs' ATM decisions; however, it will not necessarily be the only source for other decision makers, such as pilots and dispatchers. Making the 4-D WX SAS both a support tool for the ANSPs' ATM decisions and NextGen resource provides both transparency and predictability in these decisions, as well as shared situational awareness for all NextGen participants.

The 4-D WX SAS contains time-sensitive, seamless, consistent, de-conflicted, and gridded weather information.

- "Time-sensitive" means the 4-D WX SAS will include data elements with short latency constraints needed to support tactical decisions (e.g., lightning strokes, microbursts, and wind shear)
- "Seamless" means user transparency regarding all of the infrastructure and interfaces 'built in' to access the 4-D WX SAS information and tailoring of the output
- "Consistent" means the same weather element values for a given time and location are made available simultaneously to users
- "De-conflicted" means that when more than one observation or forecast model product exists for a location at a specified time, a set of business rules determines the most accurate and optimal representation of that observation or forecast

Over the next 10-15 years, the 4-D WX SAS will evolve and grow in capability. Early iterations will have limited data content, scope, and functionality; however, with spiral development and iterative fielding of new/emerging capabilities, the 4-D WX SAS will meet the needs of the NextGen user community.

However limited in content, scope, and functionality early iterations of the 4-D WX SAS may be, it will be similar to the 4-D Wx Data Cube: network-enabled and machine-readable with its contents geo- and time-referenced. Spiral development of the 4-D WX SAS provides increasingly organized and complex computer-based representations (e.g., 4-D grids) along with increasingly robust functionality that allows systematic access, automated retrieval, and tailored output.

The 4-D WX SAS will be federated, meaning that the 4-D WX SAS will be derived from a collection of data sources or databases, as in a virtual database that is treated as one entity and viewed through a single user interface. Figure 1 illustrates the 4-D Wx Data Cube/SAS relationship.

In NextGen, it is not necessarily only about the weather products; rather it is about enabling better air transportation decisionmaking. The common weather reference (sometimes referred to as the 'common weather picture'), enabled by the 4-D WX SAS capability, facilitates common situation awareness and reduces the need for stakeholders to decide between potentially competing or conflicting sources.

2.2 The 4-D Wx Data Cube/SAS

The dynamic nature of weather poses a problem for aviation decisionmakers because they need to know, with a very high level of confidence, the location of impacting weather. In addition, decisionmakers need to know well in advance when and where the weather will be and the degree of its operational impact. The availability of consistent weather impact forecasts facilitates proactive decisions – meaning operations are adjusted ahead of time so that any potential impacts are minimized to the greatest extent possible. Conversely, inconsistent and varied weather guidance leads aviation decisionmakers to interpret different weather impacts on their operations. The common weather reference (i.e., SAS) reduces these conflicts and again leads to better decision coordination and management.

Traditionally, decision guidance tools have been designed for use in 'good' weather conditions only. This has been done on purpose due to historically poor confidence that potential impacting weather will actually occur with any consistency and poor understanding of what the impacts may be. The determination of 'weather impact' has been left up to the individual decisionmaker. Thus, when 'bad' weather occurs or is forecast, meaning the weather 'may' impact the success of a safe operation, most decisionmakers have to make a subjective interpretation of what specifically that effect (or impact) will be on their operation. The decisionmaking between users is not coordinated and leads to inefficiencies that affect operational performance of the NAS. Further, because weather can also compromise safety, very conservative decisionmaking results – meaning large margins for error are 'built into' an operation. This frequently leads to additional operating inefficiencies.

2.3 The 4-D Wx SAS Facilitates Consistent Impact Assessments

In NextGen, consistent, probabilistic weather information in a digital format will be assimilated directly into automation platforms and DSTs to support improved decisionmaking and risk management. DSTs will be used to plan safe and efficient routes around emerging weather hazards and may propose routing alternatives taking into account user preferences or aircraft operational thresholds.

The common weather reference (4-D Wx SAS) facilitates a more effective integration capability. It enables replacement of the subjectivity of manual interpretation with that of objectivity—meaning there are defined sets of translation rules or translation techniques that determine the users' operational impacts. Objective weather translation facilitates a common understanding of impacts among all users. The most optimum translation techniques are used based on rules and constructs that are directly tied to defined NextGen operations. They include the risk of having the operation compromised due to weather.

3.0 FORMULATING WEATHER REQUIREMENTS

A functional analysis was an essential first step in developing the functional and performance requirements necessary for JPDO agencies to plan and implement NextGen. Functional analysis determines those activities (or functions) that must be accomplished to meet stakeholder needs and results in a complete set of functional requirements that satisfy those needs. [SEM] It facilitates improved integration, discourages predefined solutions, and enables the incorporation of new and innovative designs and solutions.

Functional analysis determines those activities (or functions) that must be accomplished by the stakeholder to perform their mission, which in turn helps determine a complete set

To document these NextGen weather requirements, the JPDO established a Weather Functional Requirements Study Team and published the *Four-Dimensional Weather Functional Requirements for Next Generation Air Transportation System (NextGen) Air Traffic Management, Version 0.1 of January 18, 2008*. Participants on the team included FAA representatives from the Air Traffic Organization (terminal, en route, system operations, and NextGen and operations planning), four general aviation pilots (two with multiple engine ratings), two air traffic control specialists with en route, terminal, and flight service experience, a DoD meteorologist, as well as two NWS meteorologists.

The study team first extracted operational needs from the NextGen ConOps (V2.0). Ten functional areas were identified in *Providing Weather Services* in supporting NextGen concepts as shown in Figure 2. These high-level functions were iteratively decomposed until sufficient detail existed to determine the high-level NextGen weather functions. The study team translated the resultant functions into limited functional and performance requirements, including data attributes (e.g., spatial and temporal resolution, data latency and update rates, reliability, integrity, and information content). The study team focus for this initial effort only addressed the SAS functional and related performance requirements for Observe Atmospheric and Space

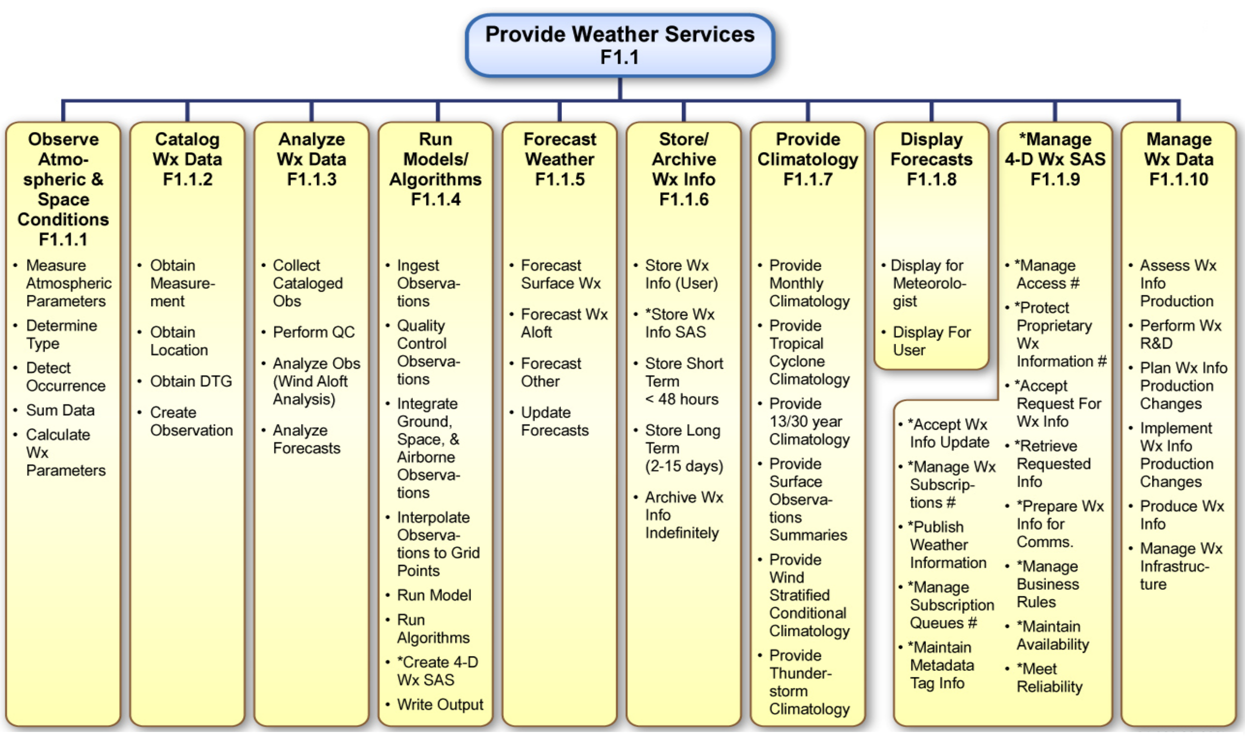

Figure 2. NextGen Provide Weather Services Functions

Conditions (F1.1.1) and Forecast Weather (F1.1.5) in Figure 2.

The NextGen Weather Performance Requirements (NWPRT) team defined five airspaces:

- **Super-Density Terminal Airspace** – a volume of airspace centered over super-density airports with a base at the surface, a radius of 180 km [Mid-Term ConOps], and an upper boundary at the top of the airport terminal airspace. This category includes domestic airports that each account for at least one percent of total U.S. enplanements.
- **Designated En Route Terminal Airspace** – a volume of airspace centered over selected en route airports with a base at the surface, a radius of 40 km, and an upper boundary at the top of each airport's terminal airspace. This category may include medium and small hub airports not included in the area covered by Super-density Terminal Airspace.
- **En Route Airspace – all domestic airs**pace outside Super-Density Terminal Airspace and Designated En Route Terminal Airspace, with a base at the surface and an upper boundary at the top of the NAS. This category includes all domestic airports not included in the area covered by Super-Density Terminal Airspace and Designated En Route Terminal Airspace.
- **Designated Global Terminal Airspace** – a volume of airspace centered over selected global airports with a base at the surface, a radius of 50 km, and an upper boundary at the top of each airport's terminal airspace.
- **Global Airspace** – all non-domestic airspace outside Designated Global Terminal Airspace with a base at the surface and an upper boundary at the top of controlled airspace

NOTE: Today, the top of Class A airspace is flight level 60,000 ft (FL600), but this is expected to change in NextGen), as will the defined top of terminal airspace with integrated departure/arrival operations. Thus, the following terms will be used when in the weather performance requirements: for top of Global Airspace, use "top of controlled airspace"; for top of terminal airspace of all airports, use "top of the terminal airspace"; for all else, use "top of the NAS".

With regard to these airspace definitions, the following are a few examples of SAS functional requirements developed by the team.

The SAS shall provide:

- 10 km horizontal resolution for forecast elements in designated global terminal and global airspace
- 500 ft vertical resolution from the surface to the top of the NAS for forecast elements in designated en route terminal and en route airspace
- 0.5 km horizontal resolution for observations of all required weather elements (convection and non-convective) above the surface in super-density terminal airspace
- 1 km horizontal resolution for observations above the surface for convection in designated en route terminal and en route airspace
- 100 ft vertical resolution from the surface to 4,900 ft for all required observed weather elements (convective and non-convective) in super-density terminal, designated en route terminal, and designated global terminal airspace
- 18 hours of observation and analyses storage including the last two scheduled forecast issuances, including all corrections and amendments

Some selected examples of functional-level conclusions include:

- Climatological data will be in the 4-D Wx Data Cube, not in the SAS
- While Long Range Outlooks of 90 days are consistent with that of the NOAA Climate Prediction Center, the operational value of SAS information beyond seven days for aviation planning decisions, etc., is not warranted
- The SAS will most likely contain the mean or average of ensemble model outputs as a viable operational solution
- All weather information below 18,000 ft will be expressed in feet above mean sea level (MSL); 18,000 ft and above will be expressed in terms of flight level (FL). Weather information required in feet above ground level (AGL) will be converted through DSTs;
- "Calm wind" will not be in the SAS as an Observational Element, because "calm wind" is an operational phrase that applies to more than one value (i.e. 'calm' is reported by ATC at terminals when the wind is less than 3 knots [FAA Order 7110.65, 2-6-5]; Flight Service denotes 00000KT as "calm" [FAA Order 7110.10, 13-1-8]). The value of 'calm' varies between operational users;
- Freezing precipitation occurs at the surface (i.e., on the ground, on structures, or on aircraft on the ground), while Icing occurrence above ground level and up to the top of the NAS is called *in-flight icing*. Only types of *in-flight icing* will be observed. The forecast presence of any type of *in-flight icing* is *sufficient for* decisionmaking.
- *Intensity of* tornados, waterspouts, and funnel clouds will not be mea*sured. In aviati*on, the intensity of tornado is not significant. The presence of a tornado in the NAS has a significant and immediate impact no matter what the intensity.

- Various space weather elements will be observed and forecast such as the magnitude of geomagnetic storms, radio blackouts and scintillation

The reader is directed to the referenced Functional Requirements Document [3] for more detail and further defined functional requirements.

3.1 Performance Requirements Development Process

The FAA subsequently convened a multi-disciplinary NextGen Weather Performance Requirement Team (NWPRT) to develop the associated weather performance requirements. The NWPRT used the JPDO-developed functional weather requirements as the initial baseline to develop the NextGen weather performance requirements. The draft weather performance requirements that will be contained in the document, the 'JPDO Wx Functional and Performance Requirements for NextGen ATM Jan 2010, pPR', just underwent agency review [5] and comments are due back in February. During the performance review process, some new functions were added while others were deleted and the functional requirements were re-baselined. NAS level performance requirements for all airspaces were then developed for the functional requirements. The resulting weather requirements are intended to meet all weather service needs for both terrestrial and space operations circa 2025.

Before developing the weather performance requirements, the NWPRT reviewed the spatial and temporal resolutions for the surface and aloft within each air traffic domain (i.e., super-density terminals, en route, and global). Appropriate performance and accuracy values plus tolerances were determined for each functional requirement by airspace domain. During that review process, it became obvious that there were many common functional/performance criteria that applied equally to the SAS information across any given air traffic domain. As a consequence, a table was created to include groups of common Observation Performance Requirements and another table was developed to illustrate common Forecast Performance Criteria.

Forecast Valid Period	Air Traffic Domain			
	Terminal	En Route		Global
		Convective	Other Wx	
0-2 hrs	1/4 km	1/2 km	2 km	5 km
2-4 hrs		1 km		
4-10 hrs	1/2 km	2 km		
10-24 hrs				
24-60 hrs	1 km			
60 hrs-7 days	2 km	4 km	4 km	10 km

Table 1 – Forecast Horizontal (Location) Accuracy

3.2 Preliminary SAS Performance Requirements

Table 1 and Table 2 are examples that correspond to the weather functional requirements in Figure 2. An overall example plus a specific (highlighted) example is provided for each Table. Table 1 details the horizontal forecast accuracy for the location of a weather element.

Forecast Valid Period	Air Traffic Domain		
	Terminal	En Route	Global
0-2 hrs			
5,000 ft - Top of NAS	250 ft	250 ft	250 ft
AGL to 4,900 ft	50 ft		
2-4 hrs			
5,000 ft - Top of NAS	250 ft	250 ft	250 ft
AGL to 4,900 ft	50 ft		
4-10 hrs			
5,000 ft - Top of NAS	500 ft	500 ft	500 ft
AGL to 4,900 ft	100 ft		
10-24 hrs			
5,000 ft - Top of NAS	500 ft	500 ft	500 ft
AGL to 4,900 ft	100 ft		
24-60 hrs			
5,000 ft - Top of NAS	1,000 ft	1,000 ft	1,000 ft
AGL to 4,900 ft	150 ft		

Table 2 – Forecast Vertical (Base/Tops) Accuracy

- Overall: The NextGen forecast horizontal accuracy shall be plus or minus the values specified in Table 1 below for each respective time period and domain
- Specific: The NextGen forecast horizontal accuracy shall be plus or minus 1/4 km in latitude and longitude location for 0-2 hour forecasts in the Terminal Air Traffic Domain
- Table 2 details the forecast vertical accuracy for the bottom and top of a weather element.
- The NextGen Forecast vertical accuracy shall be plus or minus values specified in Table 2 for each respective time period, domain, and altitude stratum
- The NextGen Forecast vertical accuracy shall be plus or minus 50 ft for all 0-2 hour forecasts for conditions between AGL to 4900 ft in the Terminal Air Traffic Domain

Approximately 9,000 performance requirements were developed (2,500 observing requirements and 6,500 forecasting requirements).

3.2.1 Forecast Uncertainty Requirements

Forecasts of weather informational elements may be deterministic or probabilistic but, in nearly all cases, will be probabilistic to maintain 4-D Wx SAS consistency and to allow users to apply their own risk thresholds to operational decisions. Probabilistic forecasts will quantify the uncertainty of operationally significant weather (e.g., convection and turbulence). Many of the efficiencies and capacity improvements in the NextGen concepts such as Trajectory Based Operations (TBO) and Collaborative Air Traffic Management (C-ATM) will not be fully realized without reducing the impact of weather uncertainties. Since the initial JPDO functional weather requirements did not include the probability forecast requirements, a Forecast subteam was formed to address probability. Their task was to tackle the challenge of risk management in a statistical framework underlying predictive products that users could understand and that their DST algorithms could process, as well as to develop the probabilistic forecast functional and performance requirements. The probabilistic forecast performance requirements should be completed by the end of the year.

Containing 4-D (x, y, z, and time) probabilities, the 4-D Wx SAS enables ANSPs' automation and flight operations DSTs to aid decisionmakers in managing operational risk due to adverse weather (e.g., in-flight icing and reduced visibility). These probabilities will be provided for all time periods ranging from the near-immediate to the long-term.

The purpose of probabilistic forecasts is to provide decisionmakers and DSTs with assessments of all the likelihoods (or risks) of occurrence and magnitude of a weather parameter. Adverse weather intensity will be quantitative (i.e., in numerical values) rather than qualitative (e.g., "moderate," and "severe") to enable integration into DSTs. The integration of weather information into DSTs will complement the limitations of human cognitive processes. Probabilistic weather information will enable multiple decisionmakers to use the same weather information, applying their own operational filters (or thresholds) to determine the overall risk to their operation.

In NextGen, trajectory planning and in-flight navigation tools will use probabilistic forecasts to assess the risk of trajectory deviation and determine the most efficient trajectory that meets individual flight tolerances for adverse or non-preferred weather conditions. Probabilistic forecasts support various ANSP functions as ANSPs will use probabilistic forecasts to minimize airspace capacity limitations by reducing the likelihood of overly-conservative actions:

- In trajectory-based airspace, ANSPs will use DSTs to assess weather constraint potential in the NAS
- Capacity managers will use probabilistic weather through DSTs to identify available NAS airspace
- Flow control managers will use probabilistic weather through DSTs to address large demand/capacity imbalances
- Trajectory managers will use near-term forecast improvements and observation trend analysis through DSTs to safely resolve aircraft conflicts in a complex and tactical environment

The quality of the probabilistic weather forecasts will meet minimum measures of acceptability and be provided in the form best suited for the DST application or weather phenomena:

- Straight probability for yes/no forecasts
- Probability Distribution Functions (PDF**)** for continuous phenomena (e.g.., temperature, pressure and eddy dissipation rate)
- Probability Mass Functions (PMF) for discrete phenomena (e.g., type of precipitation, prevailing wind direction within one of 36 categories representing 36 directions, and ceiling categories)
- Cumulative Distribution Functions (CDF) of individual PDF or PMF curves as a natural reporting format intended for use in relating aviation bias tolerance curves originating outside the 4-D Wx SAS to forecast weather hazards – This is how DSTs are envisioned to apply and control their own rules of behavior to the analysis results of 4-D Wx SAS common weather

An additional 2,500 probability requirements were added to the 9,000 observational and forecast requirements that were identified. The FAA anticipates the 4-D Wx SAS probabilistic forecast performance requirements to be completed in 2010.

4.0 WEATHER ENTERPRISE DECISION SUPPORT SERVICE (WEDSS) FUNCTIONS

The NWPRT determined that additional functions were necessary to provide the information required by users that will not be directly measured or forecast. Some of the weather information the user requires cannot be directly extracted from the SAS grid point data; information such as density altitude, maximum daily temperature over the last 24 hours, or altimeter settings. For example, the requirement for specifying when a weather phenomenon impacts operations (e.g., time when a runway crosswind component exceeding 20 knots will begin or end) depends on the users' operational needs. The most appropriate and efficient method for supporting such a large range of operational requirements is to establish a weather enterprise decision support service (WEDSS) that can examine the 4-D Wx SAS grid values and provide tailored information to the user.

To support such NextGen weather requirements, the action verb "forecast" of some of the functional and performance requirements became "determine" or "calculate" and a WEDSS capability beyond the 4-D Wx Data Cube and 4-D Wx SAS will be needed to perform that function. In general, the "determine" functions are those that were deemed not needed at every point in the NAS, but rather are needed only occasionally or for specific applications (e.g., determine occurrence of ceiling). Users or a function within the weather enterprise would be required to extract the needed information from the SAS via the WEDSS. Other examples of functions, which are to be "determined" include: vertical extent, horizontal extent, layer thickness, beginning time, ending time, and duration of weather elements.

Other functions provided by the WEDSS are those that require derivation. A derived weather element is one that is not explicitly contained in the 4-D WX SAS, but is produced by the WEDSS using 4-D WX SAS information. An example of this may be the time when the probability of rain at a point (location, altitude) in the NAS is forecast to first exceed 80% within the next two hours. This information is not explicitly contained in the 4-D WX SAS. The explicit 4-D WX SAS information used to derive this information is the probabilistic rain forecast information at that point (location, altitude) in the NAS.

Another example of a derivation may be the highest probability (most likely time) of when the wind direction is forecast to change such that it meets the definition of wind shift at a defined grid point (location, surface) during the time interval of interest. The probability of wind shift time is not explicitly forecast in the 4-D WX SAS. The explicit 4-D WX SAS information used to derive this information is the probabilistic wind direction and the probabilistic wind speed information (10 knots or more is required to meet wind shift criteria during the period of the shift) for a point (location, surface) during the selected time interval.

Constructions will also to be performed by the WEDSS. A construction is defined as a 2-D or 3-D object in the NAS that collectively describes a weather feature combining weather elements from many points at an instant or over a period of time. Examples of constructions include:

- Freezing level -- a construction which describes an irregular, typically horizontal but sometimes folding surface, which separates above freezing temperatures from below freezing temperatures
- Fronts (including cold and warm) – a construction that represents the interface or transition zone between two air masses of different density
- A Convective Hazard Volume (CHV) -- a construction that depicts the volume of the NAS containing aviation weather hazards caused by convection which always includes lightning. Hazards within the CHV **(Figure 3)** may or may not include turbulence, icing, hail, low-level wind shear, rapidly ascending and/or descending air (not necessarily very turbulent), mesocyclones, tornadoes, waterspouts, or funnel clouds.

4.1 DEFINING THE CONVECTIVE WEATHER HAZARD VOLUME

Historically, the term thunderstorm is defined as a local storm invariably produced by a cumulonimbus cloud and always accompanied by lightning and thunder, usually with strong wind gusts, heavy rain and sometimes hail. For aviation, thunderstorms also imply moderate to heavy turbulence and icing. However, some of the hazards to aviation extend beyond the thunderstorm cloud. To account for these additional hazards, convective SIGMETS include the following as

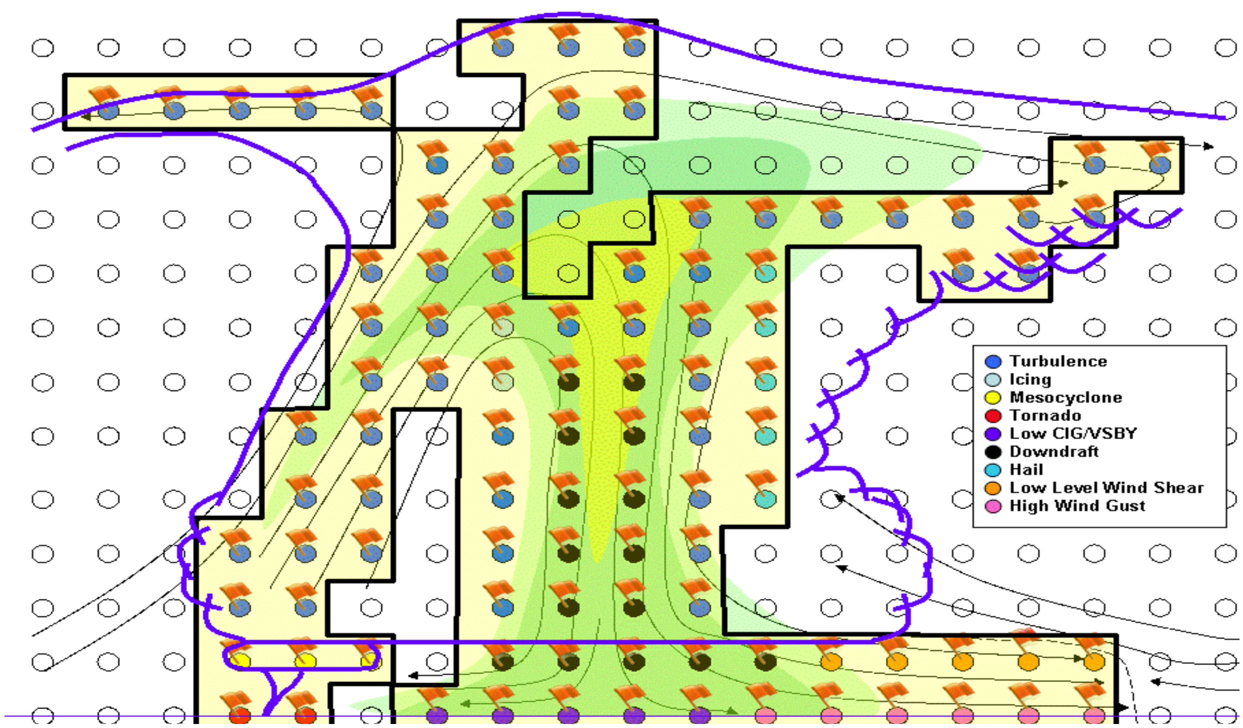

Figure 3. Convective Hazard Volume Depiction

convective hazards:

- Moderate or greater turbulence and areas of widespread vertical motion
- Moderate or greater turbulence and areas of widespread vertical motion
- Low-level wind shear and gusty surface winds
- Large hail
- Moderate or greater in-flight icing
- Mesocyclones, tornadoes, funnel clouds, and waterspouts
- Heavy precipitation
- Lightning

In the NextGen era, identifying the precise criteria needed to define a volume of airspace that meets the condition of having a thunderstorm was found by the NWPRT to be difficult. This more precise way to describe the traditional 'thunderstorm,' as well as the weather requirements to support it, could illustrate potential airspace usage (e.g., clearer depiction of 'holes' or layers with non-impacting weather). Such a description would provide a 3-D composite of all thunderstorm hazards rather than today's surrogate, which is a vertical column bounded by high radar reflectivity. The CHV is designed to be an independent, more comprehensive way of representing convective hazards.

Instead of using the term thunderstorm to describe the hazards associated with convection, Figure 3 depicts in 2-D the volume of airspace in a CHV containing thunderstorm-related phenomena hazardous to aviation associated with convective characteristics of cumulonimbus clouds. This CHV definition would also include phenomena that may not occur within a volume defined only by high values of VIL or composite reflectivity phenomena such as:

- Turbulence in the anvil portion of a cumulonimbus cloud far away from lightning flashes
- Moderate to strong low-level wind shear caused by outflow boundaries many miles away from lightning flashes
- Tornado on the ground 30 miles from the heavy precipitation area of a thunderstorm (Lawrence, Kansas, 2006)
- Tropical storm convection with little lightning.

5.0 NEXT STEPS

The FAA anticipates that the probabilistic forecast performance requirements will be completed by the end of 2010 or after the JPDO agencies agree to a common framework for this type of performance requirement. The completed NAS-level functional and performance requirements for super-density airports have been distributed for user and meteorological community review. Additional functional and performance requirements for all remaining defined airspace categories will be distributed for review in spring 2010. Once all reviews have been completed and comments resolved, the FAA will use modeling and simulations with service providers (e.g., traffic flow management specialists) and users to validate, refine and finalize these weather requirements. At that time, the complete set of FAA weather performance requirements will be allocated to specific weather systems within the NAS Enterprise Architecture Weather Roadmap and to weather research and development, as necessary. The NWPRT will also develop performance requirements for the other weather functions such as analyze weather, run models and algorithms, and create climatologies.

6.0 REFERENCES

[1] Joint Planning and Development Office, *Concept of Operations for the Next Generation Air Transportation System*, Version 2.0, 13 June 2007, executive summary and section 5.3.

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[3] Joint Planning and Development Office Weather Working Group Policy Team 2, *Definition of the 4-D Weather Single Authoritative Source (SAS)*, NextGen Weather Executive Panel, July 17, 2009

[4] Joint Planning and Development Office, JPDO Weather Functional Requirements Study Team, *Four-Dimensional Weather Functional Requirements for NextGen Air Traffic Management,* Version 0.1, 2008.

[5] Draft 'JPDO Wx Functional and Performance Requirements for NextGen ATM' Jan 2010, pPR.

[6] Federal Aviation Administration NextGen Mid-Term Concept of Operation for the NAS, Initial Coordination Draft, Version 1.0, June 20, 2009.

[7] FAA System Engineering Manual (SEM), Section 4.4, June 6, 2006.

NOTE: The views expressed herein reflect the personal views of the author(s) and do not purport the views or position of the Federal Aviation Administration or any other component of the Federal Government.