9B.2 THE NEXT GENERATION AIR TRANSPORTATION SYSTEM WEATHER CONCEPT OF OPERATIONS

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1.0 Introduction

1.1 Background

During the past year, the Joint Planning and Development Office (JPDO) has published two key documents that define the vision and concepts for the Next Generation Air Transportation System (NGATS). The JPDO released the initial version of the Concept of Operations for the NGATS (Version 0.2) as well as the NGATS Weather Concept of Operations (Version 1.0). The NGATS Weather concept compliments the overall NGATS concept by providing detailed definition of the weather elements of that document. Both of these documents are available for public review and comment through the Tech Hanger section on the JPDO website: (http://www.jpdo.aero/concepts.html).

The overall philosophy driving the delivery of services within the NGATS is to accommodate user preferences to the maximum extent possible. Achieving many of the NGATS objectives relies on transforming the roles and capabilities of the aircraft and flight crew, along with changes in the air traffic management (ATM) capabilities and decision-making authority. For example, automation assumes a far more significant role in the management of real-time operations; and four-dimensional trajectories (4DTs) will become the basis for planning and executing all flight operations supported by the air navigation service provider (ANSP)*. In many situations, ATM decision support systems present alternatives for collaborative decision making between the ANSP and the flight operator (to include the flight crew and dispatch as appropriate).

Assimilating weather into ATM decision making is one of the NGATS foundational, underpinning capabilities. Today, weather impacts are responsible for nearly 70% of all NAS delays over 15 minutes (Aviation Capability Enhancement Plan 2003). To meet the projected 3x air traffic demand in 2025, revolutionary efforts to mitigate weather impacts must be implemented. To help define this revolution in aviation weather support, the JPDO Weather Integrated Product Team (IPT) developed the NGATS Weather Concept of Operations (CONOPS).

*NOTE: For reference purposes, the ANSP for the United States is the Federal Aviation Administration (FAA).

1.2 NGATS Weather Concepts – Key Components

This paper outlines the NGATS weather concepts for 2025 and presents the core elements and direction of the NGATS Weather CONOPS. A key purpose of the NGATS Weather CONOPS is to facilitate the integration of NGATS-relevant weather information with NGATS Decision Oriented Tools (NDOTs). The NGATS weather support concept needs to be flexible enough to support multiple potential futures. Specifically, the NGATS Weather CONOPS provides:

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a. Guiding principles of operation for weather support and the manner in which they relate to NGATS principles of operations
b. Major concepts and features of future weather support
c. Descriptions of the major functionalities of weather support

2.0 NGATS Weather Support Concepts

The Weather CONOPS analyzes the eight key NGATS capabilities to identify the weather support implications. This analysis resulted in 19 guiding principles for NGATS weather support that are organized into five categories: Policy and Organizational; Data Collection and Access; Products and Decision Assistance Tools; Integration and Procedures, and Enhanced Aircraft Capabilities. The 19 operating principles represent either firm statements of weather support capabilities that are envisioned for 2025 or those that are projected but less certain and imply an element of risk in the NGATS Weather CONOPS. The NGATS 2025 Weather Operating Principles are included as an appendix to this paper.

It is important to note that the NGATS Weather CONOPS is a living document. The document will continue to evolve as the NGATS 2025 Concepts are further defined and as the JPDO IPTs work toward a better understanding of what capabilities will be possible in the next 20 years. It also needs to be emphasized that the NGATS Weather CONOPS does not address the evolution or transition roadmap from the current NAS to the future NGATS weather support systems and procedures; they will be addressed in a separate document.

2.1 Decision Support

The NGATS Weather CONOPS establishes that the primary role of weather information is to enable the identification of where and when aircraft can or cannot fly due to weather impacts. 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 NGATS decision-oriented automation capabilities and human decision-making processes. Future NGATS decision making will migrate from mostly human to mostly automated machine to machine (M2M) applications as automated decision making proves its value.

The NGATS Weather CONOPS also defines the NGATS users (or decision makers), the relationship of weather with the anticipated NDOTs, the weather information needed by the decision-makers, and the sources of aviation weather information. The primary decision-makers addressed in the CONOPS are the NGATS Automation (machine to machine), the Air Traffic Service Community (i.e., the ANSP), the Flight Community (i.e., pilots and dispatchers), Homeland Security (DHS) /Department of Defense (DoD) and other users (e.g., airports).

2.2 Decision Weather Access: 4-D Weather

To achieve this transition and weather integration, the NGATS Weather CONOPS identifies a single authoritative source for current and forecast weather information, including probabilistic forecasts. This source is designed the Aviation Weather 4-D Designated Data Sources (4-D Weather).

Today, weather information is drawn from numerous sources through point-to-point communications. Under NGATS, the numerous weather information sources will continue to be available but the access will be through network enabled operations. The 4-D Weather will be a subset of the Network Enabled Weather Information Sharing (NEWIS) “virtual database” and it will be the official source for weather information used to support the NGATS Air Traffic Service (i.e., ANSP) decisions, both human and automated. The use of a single authoritative weather data source supports collaborative NGATS decision-making (e.g., flow planning).

> *Note: NGATS users may incorporate alternative sources of weather analyses and forecasts (e.g., vendor provided) in their internally focused decision making. Such alternative weather sources, however, are not formally part of the NGATS system and joint decision making processes.*

Figure 1 illustrates the network enabled access to both public and private weather data sources. Figure 2 illustrates 4-D Weather, the single authoritative source for weather information for ATM / ANSP decisions.

The 4-D Weather fuses multiple weather observations and draws upon climatology for long rang planning and unusual situations. The 4-D Weather includes probability (confidence factor) as an element of forecast products. Data from automated gridded products, models, and human forecasts are distilled into a single official forecast that is stored in the 4-D Weather. The concept of routinely issuing weather products becomes outdated since the 4-D Weather observations and forecasts are constantly changing.

The meaning of 'a single official forecast' is that there is only one forecast for a specific point in time and space from which all government provided decision tools, decision support tools, or tactical decision aids will retrieve needed weather information. That single forecast, however, can be expressed in many ways. For example, at a single point in time and space, the following forecasts can exist simultaneously:

a. Moderate icing (deterministic)
b. A 10% chance of heavy icing
c. A 40% chance of moderate icing
d. A 70% chance of light icing
e. An AIRMET ZULU flag turned 'on'
f. Icing SIGMET flag turned 'off'

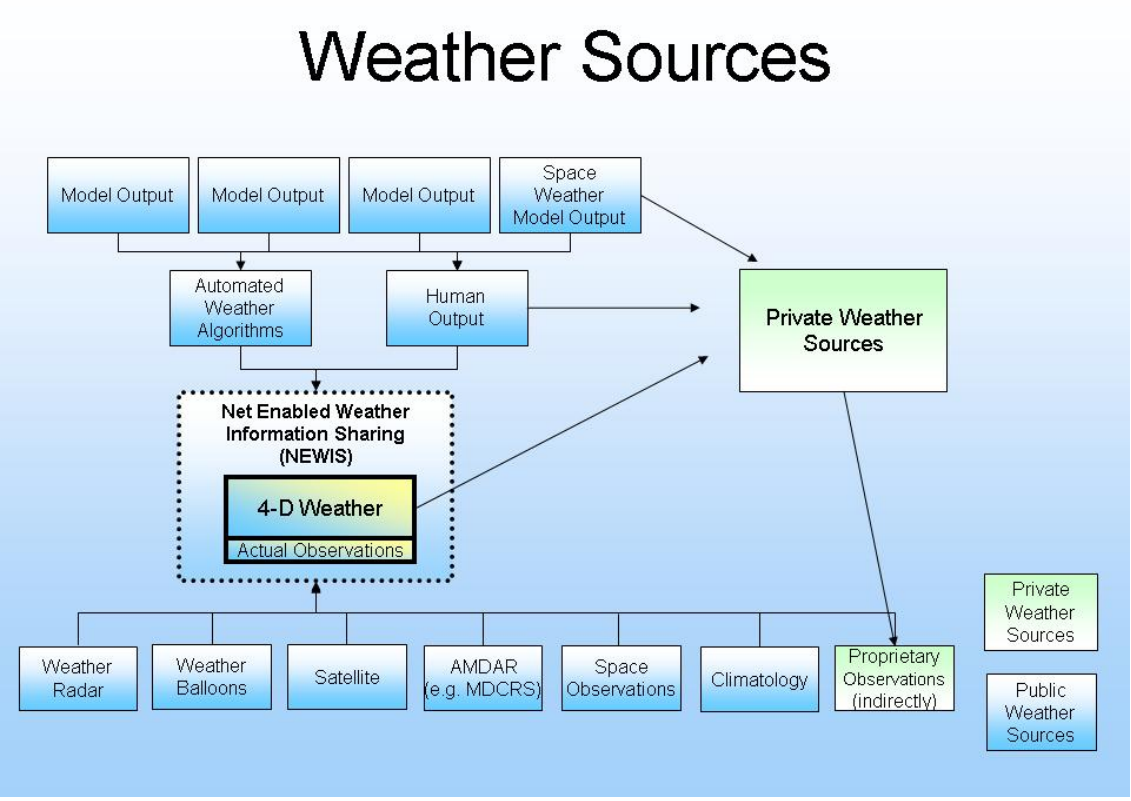

Figure 1. Aviation Weather Information Sources

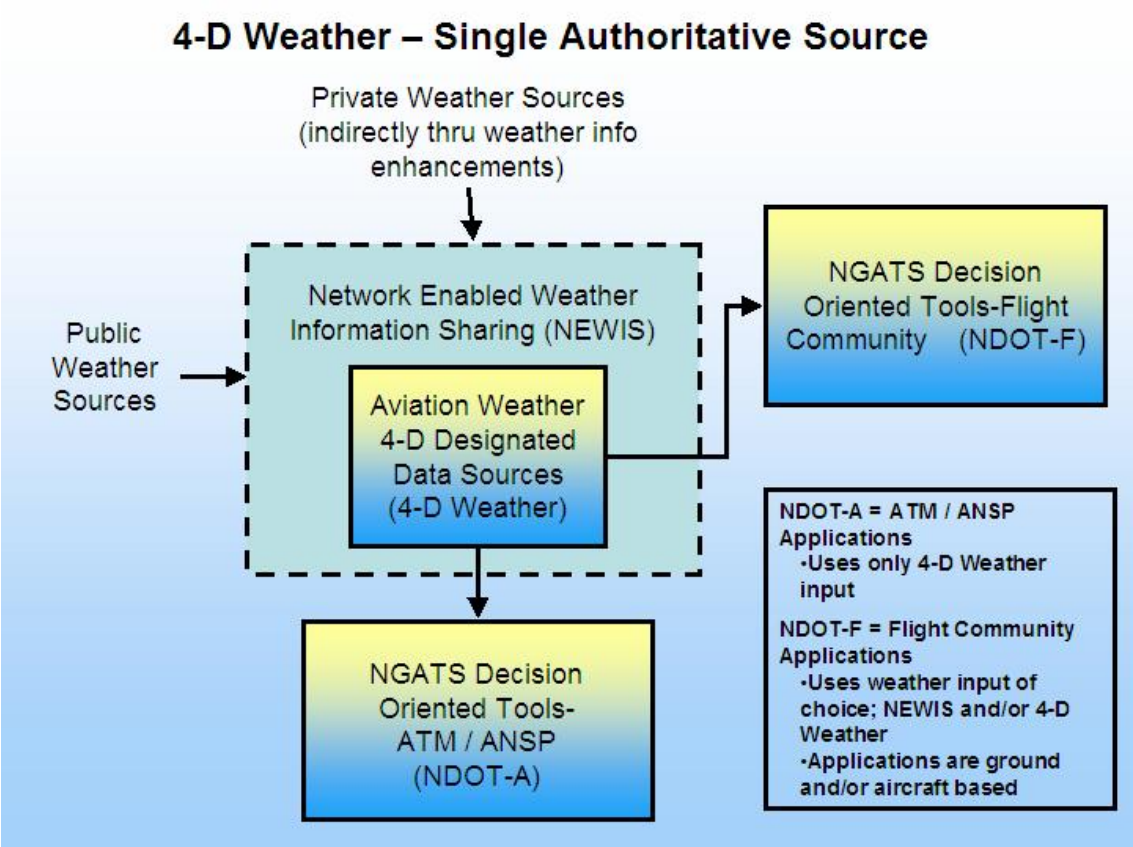

Figure 2. 4-D Designated Data Sources (4-D Weather)

The 4-D Weather forecasts will include probability information and methods will be developed to use weather probability information in establishing and assessing risk in NGATS decision making. This probabilistic information will enable decision-makers and supporting decision tools to better identify and use available weather-favorable airspace and employ risk-based techniques in flight planning and operations, as well as in airspace management.

Observations are also integrated into the 4-D Weather observational analysis. The real-time atmosphere presented to the NDOTs and product formatters is analyzed from both observational data and model data. Source observations such as Meteorological Aviation Reports (METARs) are also available, but most decision algorithms and aids use the 4-D Weather observational analysis.

The 4-D Weather is the weather source for ATM / ANSP algorithms and for displays useful to human decision-makers. Private weather sources can also provide displayable information to human decision-makers, but not for ATM / ANSP decision-makers, unless that service is purchased by the government and is publicly available to all.

2.3 NGATS Weather Information Types

The Weather CONOPS also describes how NGATS weather information must be designed to fit the overall decision framework. There are two primary types of weather information, basic weather information files and weather products.

a. Basic weather information files:

These files reside in the commonly accessible NEWIS / 4-D Weather and also include information which cannot be described or extracted from grids (e.g., fronts). Basic weather information files are very useful for the NDOTs' algorithms and are not intended for direct human decision-maker application. Human decision-makers

require weather products to include decision aids as described below.

Basic weather information can be constructed or improved using weather information from non-government sources (including proprietary). An example includes the current use of proprietary lightning data to improve the quality of the National Convective Weather Forecast (NCWF). Typically, the government has data processing agreements with the owners of such proprietary data.

b. Weather Products:

Weather products are derived from the 4-D Weather and created into a format (by a product formatter) specifically designed to help human decision-makers make better decisions. Product formatters are designed and provided by both government and private sectors. There are many types of weather products:

i. Decision Assistance Tools. These products integrate weather information from the 4-D Weather with other variables and criteria that are important to the decision, and provide recommendations to the decision maker.

ii. Binary Package of Basic Weather Information. These files are in digital formats (i.e., GIS, XML GRIB or BUFR), which communicate the basic weather information files to product formatters to be integrated into the users' display or process. For example, the National Convective Weather Forecast (NCWF) is converted from a binary package to a blue polygon display; and a significant weather forecast for turbulence is packaged in BUFR format and sent through the World Area Forecast System and integrated with a weather briefing workstation.

iii. Graphics (such as a jpeg, gif, or java display). For example, in today's Aviation Digital Data Service (ADDS), hundreds of Forecast Icing Potential (FIP) graphics are made for each forecast cycle from the gridded data. An interface in ADDS allows users to choose the graphics to display. The graphics are formatted by software, which determines the type of graphic, colors, fonts, contour lines, legends, etc. The ADDS Flight Path tool creates these graphics on the fly using java technology and interactive requests from the user.

iv. Text. These products are constructed to meet Federal Aviation Administration (FAA) or International Civil Aviation Organization (ICAO) requirements.

2.4 ATM / ANSP Weather Applications

ATM / ANSP will not treat weather as "one-size-fits-all;" especially with regard to hazardous weather conditions. Key inputs to the 4DT processing are individual flight limitations and preferences, which may be dynamically updated by users. In NGATS, these operator/user inputs are incorporated into decision-making along with a set of pre-collaborated rules for efficient flight. With this knowledge, the ANSP can provide 4DTs that are tailored to individual flights (See Figure 3 below). Examples of individual weather-related flight limitations and preferences are listed below.

a. Limitations

i. Pilot or flight crew certification and rating

ii. Aircraft type and capabilities to include Performance Based weather capabilities such as airborne weather radar, weather data link, weather sensors, and weather mitigation capabilities (e.g. synthetic vision to overcome low visibility)

b. Preferences

i. Avoid all moderate-to-extreme precipitation areas (i.e., >30 decibels (dBZ) by at least 20 nautical miles (NM);

ii. Avoid all areas with greater than 10% probability of moderate-to-severe turbulence by at least 40 NM (lateral) or 2000 feet (vertical)

iii. Avoid all areas with greater than 70% chance of light icing by at least 10 NM (lateral) or 1000 feet (vertical)

NGATS weather capabilities allow rapid notification (machine-to-machine) of changing weather situations to NGATS decision makers and users. Decision-oriented automation capabilities are continuously updated with weather, commensurate with the need to react to unanticipated, rapidly changing circumstances. Hazardous weather is disseminated in real-time. For example, aircraft may periodically request ("pull") weather information impacting their route of flight, while broad area weather advisories and warnings are issued ("pushed') in real time to all affected aircraft when safety-critical changes occur.

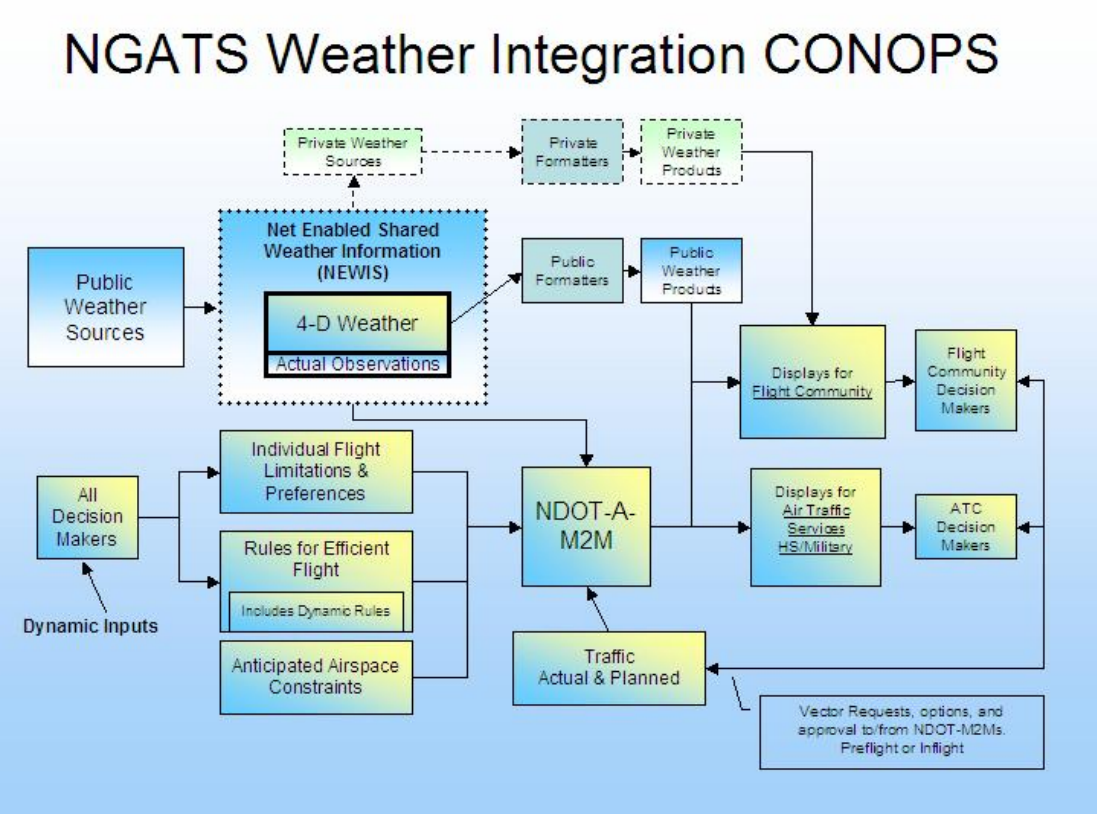

Figure 3. ATM / ANSP Support

In the NGATS time frame, ANSP shares in the responsibility with the pilot for strategically directing aircraft in avoiding hazardous weather conditions. Any 4DT routing or individual aircraft penetration through hazardous weather areas will be based on coordinated decisions that include at least the individual aircraft and the ANSP. This ANSP assistance is especially important to aircraft with limited or no equipment for weather avoidance.

2.5 Aircraft Systems

Aircraft systems are also important components of the NGATS Weather CONOPS. Advanced aircraft systems, such as synthetic vision, gust alleviation, wake vortex suppression, and in-flight icing support weather mitigation, thereby reducing the impact of weather on aircraft safety and airspace utilization. Further, weather information both to and from the aircraft via data link communications are essential. Aircraft weather observations are transmitted to

ground-based systems for integration with other NEWIS weather sources, and even to other aircraft. Conversely, ground-based 4-D Weather information is provided to the cockpit in response to specific aircraft requests or as a broadcast of weather information updates including weather advisories and warnings.

3.0 NGATS Air Traffic Support – Scenario Example

Now, let's walk through the steps related to NGATS weather support for an IFR flight plan flight from Los Angeles (LAX) to Chicago O'Hare (ORD) as illustrated in Figure 4 below.

Note: For this example, the route choices are based on the Risk of Delay expressed as the probability of weather or traffic deviations causing a 30 minute delay. This is a notional example for illustration purposes only. The NGATS ATM processes and procedures are an area for research to determine how best to meet the needs of all users.

Figure 4. Example Flight Scenario from LAX to ORD

Step A - The pilot (or dispatcher) files a flight plan request which includes the Individual Flight Limitations and Preferences with the following weather criteria:

1. Aircraft weather performance capabilities:
   a. Weather mitigation: de-icing capability; no other weather mitigation capabilities
   b. Weather sensing: airborne weather radar; also routine barometric pressure, temperature and flight level wind sensing
   c. Weather data link: Weather data link – broadcast receive only (text

and graphic); also routinely transmits AMDAR reports (MDCRS and/or TAMDAR)

2. Flight weather preferences:
   a. Only light turbulence; avoid all forecast areas of moderate or greater turbulence with 60% probability by at least 50 NM (or 2000 feet in altitude)
   b. Avoid all forecast areas of convection with greater than 40% probability of 30 dBz intensity or greater by at least 20 NM

Step B - The NGATS ATM / ANSP automation (NDOT-A) processes the LAX-ORD flight plan request; accessing the 4-D Weather and provides choices based on:

1. planned traffic and known airspace restrictions
2. aircraft and pilot/crew capabilities
3. weather
4. user preferences (see Step A above)

Step C - Pilot and/or Dispatch chooses the flight plan route based on:

1. their own cost information and risk tolerance
2. possible alternate weather sources beyond 4-D Weather

Step D - Flight plan is accepted and ATM / ANSP automation (NDOT-A) logs and subsequently tracks (monitors) the flight profile:

1. providing alerts (pushed to the cockpit)
2. recommending re-routes as changing weather and/or traffic conditions occur

This is a continuous, dynamic process – even in flight:

1. the pilot (or dispatcher) may also change the Individual Flight Limitations and Preferences (Step A)
2. they may request (from ATM / ANSP automation) changes to the flight plan when deemed necessary

4.0 NGATS Functions – Weather Support Analysis

The final section in the NGATS Weather CONOPS describes the overall concepts for weather support to specific NGATS functional areas. Eight functional areas are described: Flight Planning, Airspace Management, Traffic Management, Air Traffic Control, Oceanic /International Support, Space Weather Impacts to NGATS, Airport Management Support, and Unmanned Aircraft Systems (UAS) Support. Unique needs per user class (e.g., pilot, dispatch, ATC, DoD, and DHS) are also highlighted as appropriate.

5.0 Summary

The NGATS Weather CONOPS is based on the NGATS 2025 Concepts. It includes the following key concepts:

a. Weather is integrated as a key input to NGATS decision oriented tools (NDOTs); weather is not a stand-alone separate display
   i. NGATS decision making is primarily through automated machine to machine (M2M) applications
   ii. Network Enabled Operations (NEO) provides the basis for information access and sharing necessary to support ATM / ANSP decision making

b. Weather forecast inputs include probability information (confidence factor)
   i. Methods are developed to use weather probability information in establishing and assessing risk in NGATS decision making
   ii. Application of weather probability information significantly increases NGATS effective use of weather information, independent of any increased fidelity and/or accuracy of weather forecasts

c. 4-D Weather files are established as the authoritative source for NGATS support of ATM / ANSP decisions

i. 4-D Weather files are a subset of NEO accessible aviation weather information (NEWIS)

d. Weather information to/from aircraft, and aircraft weather mitigation capabilities are included as performance-based service components

The NGATS Weather CONOPS has been developed to describe the weather support required to meet the vision for 2025 and provide flexibility in being able to support multiple potential futures. It also provides insight into the mitigation capabilities to be implemented in NGATS to reduce the loss of airspace due to weather uncertainty. The CONOPS defines the JPDO Weather IPT's consensus on how weather will support the continuum of users from the most NGATS performance capable aircraft to the least and especially, how weather information will be integrated in the multiple NGATS decision oriented tools.

This CONOPS will be used to facilitate understanding of how the NAS weather architecture must be transformed to support the NGATS vision, while mitigating the impact of weather on the NAS. Even when coordination is completed, much work remains to be done. The next steps include developing requirements and determining the research and development needed to define the capabilities and attributes of the NGATS 4-D weather database; developing the application of probabilities in aviation weather support; and coordinating the integration of NGATS ATM/ANSP Weather concepts.

In summary, the NGATS Weather CONOPS poses a new way of looking at the role of weather information. It is not about the weather products themselves; rather, it is about enabling better air transportation decision making through direct integration of weather information into NGATS decision-oriented automation capabilities and human decision-making processes. The JPDO vision for NGATS weather capabilities is a key enabler for achieving the NGATS goals and objectives.

6.0 Acronyms

ADDS	Aviation Digital Data Service
AMDAR	Aircraft Meteorological Data Relay
ANSP	Air Navigation Service Provider (ANSP in the United States is the FAA)
AIRMET	Airmens Meteorological Information
ATC	Air Traffic Control
ATM	Air Traffic Management
BUFR	Binary Universal Form for Representation of Meteorological Data
CONOPS	Concept of Operations
DHS	Department of Homeland Security
dBZ	Decibels
DoD	Department of Defense
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FIP	Forecast Icing Potential
GIF	Graphics Interchange Format
GIS	Geographic Information System
GRIB	Gridded Binary
ICAO	International Civil Aviation Organization
IPT	Integrated Product Team
JPDO	Joint Planning and Development Office
JPEG	Joint Photographic Experts Group
M2M	Machine to Machine
METAR	Meteorological Aviation Report
MDCRS	Meteorological Data Collection and Reporting System
NAS	National Airspace System
NEWIS	Network Enabled Weather Information Sharing
NDOT	NGATS Decision-Oriented Tool
NDOT-A	NDOT-ATM / ANSP
NDOT-F	NDOT Flight Community
NEO	Network Enabled Operations
NGATS	Next Generation Air Transportation System
NWS	National Weather Service
SIGMET	Significant Meteorological Information
TAF	Terminal Aerodrome Forecast
TAMDAR	Tropospheric Airborne Meteorological Data Reporting

UAS	Unmanned Aircraft Systems
VFR	Visual Flight Rules
WAAS	Wide Area Augmentation System
XML	Extensible Markup Language
4-D	Four Dimensional
4DT	Four Dimensional Trajectories

7.0 References

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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, the National Oceanic and Atmospheric Administration or any other component of the Federal Government.

Appendix: NGATS 2025 Weather Operating Principles

The operating principles for NGATS weather support represent either firm statements of weather support capabilities that are envisioned for 2025 or those NGATS weather support capabilities that are projected but less certain and imply an element of risk in the NGATS Weather CONOPS. The operating principles are listed in five categories: Policy and Organizational; Data Collection and Access; Products and Decision Assistance Tools; Integration and Procedures, and Enhanced Aircraft Capabilities.

Note: The NGATS Weather CONOPS is a living document and will continue to evolve as the NGATS 2025 Concepts are further defined and as the JPDO IPTs work toward a better understanding of what capabilities will be possible in the next 20 years. As necessary, these operating principles will be revised to support the evolving NGATS concepts.

Policy and Organizational Principles

Three key principles are identified:

a. NGATS weather support is a joint agency responsibility and requires revisions to existing weather policies and regulations.

b. NGATS weather support concepts are globally harmonized and consistent with ICAO guidance.

c. ATC will share the responsibility of aircraft separation from weather, especially aircraft with limited or no equipment for weather avoidance.

Data Collection and Access Principles.

Five key principles are identified:

a. All NGATS users are able to receive required weather information.

b. The NGATS 4-D Weather is the single, authoritative government supported source of data. It fuses multiple weather observations [and forecasts], and draws upon climatology for long range planning and unusual situations. It includes probability (confidence factor) as an element of the forecast products.

Note: NGATS 4-D Weather is a subset of weather information from a variety of sources that are accessible as part of Network Enabled Weather Information Sharing (NEWIS) described in Section 2.2 of this paper.

c. NGATS weather provides increased coverage in airport observations and forecasts for non-towered and virtual towered airports to support increased Instrument Flight Rules (IFR) operations using Broad-Area Precision Navigation (e.g., WAAS approaches).

d. Aircraft 'Performance-Based Service' includes data link capability for:

   i. accessing and processing in-flight updates to NGATS weather products
   ii. transmitting and receiving aircraft weather observations generated through on-board sensors and automation (i.e., the Meteorological Data Collection and Reporting System (MDCRS) or Tropospheric Airborne Meteorological Data Reporting (TAMDAR) type systems.

   Note: UAS platforms are used to gather such in flight data.

e. Pilots/flight crew are provided a full weather self-briefing for both preflight planning and in-flight updates reducing the need for Flight Service Station support.

Products and Decision Assistance Tools Principles.

Four key principles are identified:

a. NDOT fully automated and integrated machine to machine (M2M) applications are the primary method for NGATS weather exploitation.

b. Legacy text products are targeted for elimination.

c. NGATS weather provides increased resolution of weather information, both observations and forecasts, to support:

   i. Identification of hazardous weather in real-time
   ii. Super density operations with reduced aircraft spacing and separation (terminal and en route) to include new weather support capabilities for wake vortex/turbulence avoidance
   iii. New requirements in space weather support and weather information for chemical/biological/nuclear security incidents

d. NGATS weather impact decisions are based on:

   i. Pilot and aircraft capabilities to include pilot/flight crew imposed currency limitations, personal weather minimums, and Federal Aviation Regulations (FAR) requirements such as IFR vs. Visual Flight Rules, Part 121, Part 135, Part 91, etc.)
   ii. Weather avoidance (adverse and/or hazardous)
   iii. Flight efficiency (favorable winds and temperatures)
   iv. Flight quality and preference (pilot/flight crew and passenger stress and/or comfort)

Integration and Procedures Principles.

Five key principles are identified:

a. Weather information is an end in itself, but is fully integrated into the NGATS government and user community systems that support air transportation operations, thus becoming transparent to the users.

b. NGATS operations evolve toward more collaborative flight management and flight control based on Net Centric Information sharing (e.g., NEWIS and 4-D Weather).

c. NGATS weather products are consistent across all flight domains with continuity from pre-flight to post-flight operations, including oceanic and international.

   Note: Vendor provided alternative sources of weather analyses and forecasts (whether based on the NGATS 4-D Weather in whole or part) are utilized by NGATS users in their own internally focused decision making, but are not formally part of the NGATS system and joint decision making processes.

d. NGATS weather system procedures and concepts are designed for efficient user integration and application in NDOTs, requiring minimal user action for dissemination or interpretation.

e. Dynamic in-flight rerouting capabilities are based on the NDOTs capability using timely updates of NGATS weather information provided to all users including pilots/flight crews.

Enhanced Aircraft Capabilities Principles.

Two key principles are identified:

a. Aircraft systems can mitigate the impact of weather on aircraft operations.
b. Aircraft weather mitigation systems reduce the associated airspace restrictions that hinder capacity.