WEATHER CONCEPT OF OPERATIONS

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 FORWARD

This document reflects the work of nearly 150 dedicated individuals who have supported the Joint Planning and Development Office’s (JPDO) Weather Integrated Product Team (IPT), which began late in 2003. These individuals have represented the JPDO Government Agencies, supporting contractors, academia, research organizations, and private industry.

In reviewing this document, the reader should be aware of the following points:

• This document is subordinate to the overarching JPDO NGATS Concept of Operations, scheduled for public release in the summer of 2006. Significant effort was made to ensure the weather concept of operations is consistent with the NGATS Concept of Operations. If, however, inconsistencies are identified the NGATS document remains primary. As the NGATS program matures this concept of operations will also evolve. At a minimum, the Weather IPT plans on updating this concept of operations on an annual basis.

• Many of the concepts described in this document draw upon the experience(s) of the membership of the Weather IPT, and therefore are built upon a framework of subject matter expertise. The Weather IPT fully intends to align agency research over the next few years to explore, refine (and if necessary, replace) concepts presented here.

• Consistent with the philosophy employed in the NGATS Concept of Operations, some of the concepts in this document could be considered aggressive, but are consistent with the idea of “transformation”.

• Embedded inside several of these main concepts are significant policy issues which will require further study and work to resolve over the next few years, if necessary. The upcoming NGATS Concept of Operations document will additionally highlight several weather-related policy issues when released.
Executive Summary

The Next Generation Air Transportation System (NGATS) is intended to meet the air transportation needs of the U.S. in the 21st century – in particular, a significant growth in demand for air traffic services, possibly on the order of three times today’s demand levels. Since weather conditions can seriously restrict aircraft operations and levels of service available to system users, the manner by which weather-related information is collected, managed, disseminated, and utilized in decision-making is of paramount importance.

The Joint Planning and Development Office (JPDO) has the responsibility for the formation of the NGATS vision and principle concepts. The Weather Integrated Product Team (Wx IPT) of the JPDO considers how enhanced weather information can enable accomplishment of NGATS goals and objectives. In support of JPDO planning, this document provides the envisioned NGATS Weather Concept of Operations (ConOps), as developed by the Wx IPT. It is intended to spark discussion among NGATS stakeholders on needed future weather information capabilities and their use, and to provide supporting details to the evolving, overall NGATS Concept of Operations. Specifically, this document provides:

- Guiding principles of operation for weather support and the manner in which they relate to NGATS principles of operation;
- Major concepts and features of future weather support; and
- A description of the major functionalities of weather support.

This executive summary emphasizes basic principles of the NGATS Weather ConOps and how it differs from today.

Role of Weather Information

Under this ConOps, the primary role of weather information is to enable the identification of where and when aircraft can/cannot fly. 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. Weather information supports trajectory-based planning and decision-making. The NGATS weather and automation capabilities work as an integrated system during preflight (including weeks to months prior to departure) to catalog and analyze all flight plans and provide recommended routes to pilots and/or dispatchers with route recommendations based on weather and other constraints. A combination of NGATS user and service provider decision-making processes takes into account flight limitations and preferences (e.g., certification and ratings of pilot/crew), aircraft weather-related capabilities (e.g., weather sensors, weather data link, weather mitigation), and aircraft operator (e.g., airline) preferences for routing and delay tradeoffs.

As today, estimation of airspace and airport capacity poses a huge challenge for 2025 planning. Weather information in the form of meteorological variables that are observed or forecasted (e.g., storm intensity, echo tops, etc.) must be translated into
information that is directly relevant to NGATS users and service providers, such as the likelihood of a flight deviation, airspace permeability, and capacity. Uncertainty in meteorological phenomena that have significant impact on system capacity is managed through the use of probabilistic forecasts. These forecasts are in a quantitative format, covering location (three-dimensional space), timing, intensity, and the probability of all possible outcomes, each with an associated likelihood of occurrence.

In addition to probabilistic weather information, update frequency is commensurate with the need to react to unanticipated, rapidly changing circumstances. For instance, airspace structural changes are better customized in response to changing weather conditions (e.g., realign sectors to conform to a line of thunderstorms). Also, the NGATS weather capabilities allow rapid notification (automation-to-automation) of changing weather situations to strategic and tactical NGATS decision makers.

As with enhanced communication of weather information to ground-based automation systems and human users, weather data communications to the cockpit involves both “push” and “pull” dissemination of critical information. Aircraft may request (“pull”) specific weather information impacting their route of flight, while broad area weather advisories and warnings are issued (“pushed’) to all affected aircraft when safety-critical changes occur. Advanced aircraft systems, such as synthetic vision, gust alleviation, wake vortex suppression, and in-flight icing play a vital role in weather mitigation, further reducing the impact of weather on aircraft safety and airspace utilization.

Under NGATS, aircraft also become active participants in collection and transmission of weather information; observations are transmitted to ground-based systems for integration with other weather sources, and even to other aircraft. Aircraft act as fully enabled nodes on the information access network. Aircraft may process information to produce localized forecasts/nowcasts, as well as provide and consume data from in situ and forward-looking sensors via bi-directional data-links to ground stations and nearby aircraft. Unmanned Aircraft Systems (UAS) are used for: making in situ observations; performing weather reconnaissance missions such as scouting for favorable routes and collecting critical observations where and when needed; and collecting radiation activity originating from space weather.

_Serving the Needs of the Users_

The NGATS vision calls for varying levels of service, delivered in accordance with user requests and user performance capabilities. Required weather performance is a prerequisite for aircraft acceptance into busy airports and airspace severely impacted by weather. The ability of aircraft to detect weather hazards varies enormously with equipage and flight crew training. For many aircraft, on-board information enables the air crew to better avoid safety-critical conditions. Strategic separation of aircraft from weather by service providers is proactively provided for those aircraft operators seeking such service or due to lack of on-board capabilities.
Weather information is tailored to user needs and flight-specific situations. Higher spatial resolution is used for shorter-term forecasts while lower resolution is used for longer horizon forecasts. In addition to standard flight planning and Air Traffic Management (ATM) decision-making information, weather information supports the following wide range of weather-related circumstances and needs:

- More precise forecasting of the timing and location of weather that present hazards blocking arrival and departure routes or that temporarily shutdown airports, or constraints that impact traffic flows and NGATS throughput.
- Rapidly updated weather forecasts (e.g., surface winds, convective weather) to predict the need for reconfiguration of terminal airspace or an airport.
- Availability of ceiling and visibility information for improved airport arrival flow decisions (especially for aircraft not fully performance capable).
- Airport operations support information for ramp operations, runway snow removal, aircraft de-icing, and treatments for off-nominal weather (e.g., freezing rain).
- 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.
- Automated message generation sent to UAS when mission-dependent weather condition parameters are exceeded.
- Real-time weather hazard reporting in support of equivalent visual operations and super density operations.
- Observation and forecasts of cosmic radiation levels on polar routes and potential interruption of communication and satellite navigation services.
- Weather observations and forecasts for tracking chemical/biological/nuclear releases within the atmosphere to support homeland defense needs.

A Unified Weather Information Source

The above NGATS roles and needs for weather information are facilitated by transitioning to a single authoritative source for NGATS weather information. Today, weather information is drawn from numerous sources. At times, air transportation decision-making has suffered from referral to uncoordinated, if not conflicting, weather sources. To ensure consistency and continuity in the weather information supplied to NGATS decisions, government-provided weather information is collected, fused, managed as a single authoritative source, and distributed by the Network Enabled Weather Information Sharing (NEWIS) “virtual database” capability. The single authoritative source concept means, for example, that information on convection for a geographic area, developed by different forecast models, are arbitrated or merged into a single forecast that all requesting users receive. These NEWIS observation and forecast information are the primary source of weather utilized in joint government/user NGATS decision making processes, in keeping with the Network Enabled Operations (NEO) vision for NGATS information sharing. Today’s complex and costly architecture of point-to-point connections to
weather sources is replaced by a single access approach for all users (e.g., “give me all current information for Chicago”).

At the core of the NEWIS capability are four dimensional (4-D) weather sources formed from the merger of automated gridded products, models, climatology, and human forecasters. For example, measured and forecasted winds, temperatures, convection, volcanic ash, icing, and turbulence forecasts, as well as satellite images of cloud tops or satellite-derived products are available and formatted for generation of displays, and for direct integration into automated systems (e.g., systems for planning potential flight routes). Observations from ground and ocean surface sources, manned aircraft, UAS, and atmospheric-sensing satellites, along with forecast data are also incorporated into NEWIS.

In addition to weather information made available via NEWIS, users, such as pilots and flight operations centers, may choose to utilize weather information from private providers to support their internal decision-making processes. These alternative sources are not directly a part of NEWIS-enabled decision-making processes (e.g., collaboration of flow strategy development), unless they are purchased by the government and made available to all NEWIS subscribers as part of the single authoritative source. Pilots can also use on-board processing and display of in situ weather observations to enhance their tactical planning/safety decision-making; such observations are part of NEWIS as well.

Assimilation and Integration

Because today’s weather information is not well integrated with automated decision assistance tools, it frequently requires interpretation and manual integration by users. NGATS weather system procedures and concepts are designed for efficient user integration and application in automated decision tools, requiring minimal user action for dissemination or interpretation. As automation matures, some decision-making migrates from human-based to automation-assisted and fully automated. NGATS weather products are consistent across all flight domains, including oceanic and international, with continuity from pre-flight to post-flight operations. NGATS weather support concepts are globally harmonized and consistent with International Civil Aviation Organization (ICAO) guidance.

Summary

This 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. The single authoritative source for weather information facilitates common situational awareness and relieves stakeholders of the need for deciding between potentially competing or conflicting sources. This streamlined architecture for information access also reduces operations and maintenance costs for both the government and users, since today’s complex maze of point-to-point interfaces is a thing of the past. Direct integration of weather information and decision support tools ensure that NGATS is supported by both
NGATS-relevant weather information and Weather-Savvy decision support automation. This powerful combination better informs decision makers of options, assists in the identification of potential decision risks, and poses suggested solutions along with projections of NGATS impacts. This national vision for NGATS weather capability is a key enabler for the achievement of NGATS’ goals and objectives.
NEXT GENERATION AIR TRANSPORTATION SYSTEM (NGATS)
WEATHER CONCEPT OF OPERATIONS

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Next Generation Air Transportation System (NGATS)  
Weather Concept of Operations

1. Background/Purpose

This document provides an outline of the principle concepts for providing weather support to the Next Generation Air Transportation System (NGATS). It serves as the basis for planning by the Joint Program Development Office (JPDO), Weather Integrated Product Team (IPT).

1.1. Scope (2025 Concept)

This NGATS Weather Concept of Operations (ConOps) represents the future vision for weather support concepts in the year 2025. The evolution or transition roadmap from the current National Airspace System (NAS) weather support systems and procedures is addressed in a separate document and are not part of the NGATS Weather ConOps.

1.2. Approach

The JPDO NGATS 2025 Concept, Version 4.8, August 31, 2005 is the baseline for this NGATS Weather ConOps. In this NGATS Weather ConOps, some assumptions are made with regard to the NGATS 2025 Concept. As new versions of the NGATS 2025 Concept are published and/or further collaboration occurs with other JPDO IPTs, this document will be updated accordingly.

In Section 2 (NGATS 2025 Concept), the NGATS Operating Principles and each of the eight NGATS key capabilities are briefly described and carefully examined to identify their respective weather support impacts or implications for consideration by the JPDO Weather IPT.

In Section 3 (Weather Concept Operating Principles), guiding principles for providing NGATS weather support are identified. These guiding principles represent the major attributes and components of the NGATS Weather ConOps necessary to meet the weather support impacts and implications from Section 2.

In Section 4 (Weather Support Concepts), the concepts for providing NGATS weather support in 2025 are described. These concepts are based on providing weather support for Air Traffic Management (ATM) decisions made by automated NGATS systems, and for those made by human users including air traffic managers as well as pilots, dispatchers and others.

In Section 5 (NGATS Functions – Weather Support Analysis), the NGATS Weather ConOps is described for multiple NGATS users by functional NGATS capabilities.
2. **NGATS 2025 Concept – Weather Support Impacts and Implications**

The JPDO NGATS 2025 Concept, as currently published (Version 4.8, August 31, 2005), includes five basic NGATS operating principles and eight key capabilities. Section 2.1 reviews the NGATS operating principles. Sections 2.2 through 2.9 provide summaries of these eight key NGATS capabilities, followed by the impacts and implications for the Weather ConOps.

2.1. **NGATS 2025 Operating Principles**

The NGATS 2025 Concept is based on five operating principles:

a. “It’s about the users …” [it’s not about the weather]

b. System-wide transformation

c. Prognostic approach to safety assessment

d. Globally harmonized

e. Environmentally compatible to enable continued growth

Under the NGATS 2025 concept, the focus is on the “user” rather than the current system that is focused on the NAS physical/technical infrastructure and the capabilities of the service providers. Access to today’s system is accomplished in the context of constraint – constraint from ground-based infrastructure, from equipage capabilities of particular aircraft, and perhaps most notably, from lack of information sharing. NGATS moves this focus from the service provider or supplier to the system user – and in doing so, removes many of the constraints inherent in the current system. Users have access to information that they are able to assimilate into operating parameters designed around their specific needs and desires – thereby enabling them to make better, faster decisions. The new system is also globally harmonized allowing the U.S. user to operate internationally, and the international user to operate in the U.S. without unnecessary constraint.

The 2025 NGATS requires innovation across all lines of development. The implementation of technology innovation causes major changes in the way Air Traffic Services (ATS) are provided in 2025 including providing environmental protection compatible with aviation growth and implementing a “Prognostic Approach to Safety through Risk Based Management” to support the Safety Management System (SMS) standard. These changes encompass more than system technology and procedures; they also require policy changes, organizational innovations, and cultural acceptance. One key change is the shift from providing weather information to human users to primarily providing weather information
directly to decision support tools such as NGATS Decision-Oriented Tools (NDOT) as described in Section 2.7.1.

2.1.1. **Required Weather Information Available To Users**

Weather information required for decisions are provided in a format compatible with the users needs. The weather information may be provided in established formats. This implies a standard set of weather information available worldwide. All users have assured access to the weather information, including back-up for safety critical weather information that allows them to make faster, better decisions. Weather alerts and amendments to safety critical weather information are pushed to known or identified users, or notifications are broadcast to unknown or unidentified users.

Weather information sources, which are used to populate the official weather information system, are certified to be valid current information. The weather information is monitored with a set of tools and processes to allow for continuous forecast and data quality improvement.

2.1.2. **Weather Support Policies and Regulations Are Revised**

Regulatory and guidance documents are revised, as necessary, to reflect the NGATS weather support concepts outlined in this document. Those revisions are coordinated to be globally harmonized and consistent with International Civil Aviation Organization (ICAO) guidance.

2.2. **Network-Enabled Information Access**

Network-Enabled Information Access is a key capability of the NGATS 2025. This access facilitates shared situational awareness through global secure access and information handing according to communities of interest. This NGATS 2025 capability provides real-time free-flow of public domain information from government, private and commercial sources with aircraft serving as additional nodes in the network. Aircraft, with some exceptions including low-end General Aviation (GA), are able to distribute data such as flight trajectories and weather information to the ground, as well as other aircraft. Through this NGATS 2025 capability, weather, surveillance, and intent information become integrated across the government and user communities of interest.

The current NAS system is labor intensive and requires multiple information inputs to provide users the weather information they require. In NGATS, beyond information sharing, automation sorts the mounds of weather data and makes it comprehensible for each community of interest; “weather data” becomes “weather information”. Weather information needed for decisions is provided in a form easily extracted and specifically formatted to the task or decision. Everyone involved in managing a situation is able to call upon more information to share the context and understanding of the intent and present needs. Network Enable Operations (NEO) achieves communications using a network that is not fixed solely on the ground. NGATS
information is provided to known users (pushed) or available for retrieval by unknown but authorized users (pulled). While some NGATS information may be restricted depending on their content, weather information from the Aviation Weather 4-Dimensional designated data sources (referred to throughout the remainder of this document as ‘4-D Weather’) are openly available.

2.2.1. **Aviation Weather 4-D Designated Data Sources (4-D Weather) Are the Single Authoritative Government Supported Source of Weather Information**

Through Network Enabled Weather Information Sharing (NEWIS), a multitude of aviation weather information sources are accessible to users through NEO. Specific subsets of the NEWIS are designated as the 4-D Weather. NGATS ATM weather support is based on this 4-D Weather. This ensures consistency and continuity in the weather information inputs to NGATS ATM decisions. Sections 4.5 and 4.6 provided further detail on the 4-D Weather concept.

2.2.2. **Alternative Sources of Weather Analysis and Forecast Information May Be Provided By Vendors but Are Not Part of the NGATS System**

Users, such as pilots and/or dispatchers, may acquire weather support from private or commercial vendors. The vendor-provided alternative sources are not part of the 4-D Weather (unless they are purchased by the government and made available to all NEWIS subscribers as part of the single authoritative source) and are not integrated into NGATS traffic management processes or decisions. This concept requires a major policy decision.

2.2.3. **User Interfaces to Use Products Based On the 4-D Weather Can Also Integrate Weather Information from Alternative Sources Including Air-to-Air (Aircraft) Data**

A user (e.g., pilot and/or dispatcher) tool (e.g., display, cockpit decision assist application) can use weather information from both the 4-D Weather and alternative vendor weather sources. Pilots can also use on-board processing and displays as well as automation to incorporate in situ (i.e., ambient) weather observations with weather products based on the 4-D Weather.

2.2.4. **Parity of Information (Intended Information Content Is the Same) Is Maintained Regardless Of What Node You Are On**

All processing of NGATS weather information, to include automation applications, and communications and/or display formatting, must maintain the integrity of the original weather information. For example, when the resolution of weather radar data (e.g., Next generation Radar [NEXRAD]) is reduced for cockpit display, the intensity of the most hazardous areas on a ground display must be provided to and displayed on cockpit displays.
2.2.5. Weather Support Involves both Broadcast and Addressed-Enabled Communications

Weather information communications to the cockpit involves both push and pull data communications concepts. Aircraft may request specific weather information while broad area weather advisories and warnings are broadcast to all aircraft in the vicinity.

2.3. Performance-Based Services

Performance-based services are determined through a risk-based assessment of the NGATS safety, security, and environment performance needs. NGATS services such as advanced approach procedures or airspace access are defined by user performance capabilities. The NGATS service guarantees (i.e., Required Total System Performance [RTSP]) are clear so users can plan their investments in performance capabilities. Temporal flexibility in the service guarantees allow adjustments in service levels based on the current situation.

Performance-based service capability enables a definition of service tiers and allows the government to move from equipment-based regulations to performance-based regulations. Service is flexible according to the situation and consolidated needs of the users, and can equate to time-varying access. As an example, the busiest airspace would have the highest air traffic service level. This would require the highest level of user avionics performance, and users who do not equip to this level of performance could find themselves temporarily unable to enter that airspace during the busiest times of the day.

2.3.1. Aircraft Are Capable Of Receiving and Transmitting Weather Information

Fully capable aircraft have the appropriate communications systems to receive weather information from the ground and to transmit sensor data to the ground, as well as send alerts of hazardous weather to other aircraft.

2.3.2. Weather Sensors Included In Performance-Based Services

Fully capable aircraft have a standardized set of weather sensors/algorithms to provide weather data to other users directly and via the 4-D Weather. Weather data from aircraft are valuable inputs to the 4-D Weather for providing advice and warning to nearby aircraft, and for providing input and verification for weather forecast products. At a minimum, in addition to accurately providing its 4-D geospatial position, aircraft provide in situ winds, temperature, relative humidity, turbulence and icing information. Aircraft may also measure non-weather parameters (e.g., volcanic ash), utilize forward or down looking remote weather sensors, and carry dosimeters to measure the radiation environment which is affected by space weather activity.
2.3.3. **Unmanned Aircraft Systems (UAS) Used For Weather Reconnaissance**

Some UASs are equipped to collect and report in-flight weather data. Specialized UASs are also used for weather reconnaissance to scout potential flight routes and trajectories to identify available “weather-favorable” airspace. UASs may also carry dosimeters to measure the radiation environment which is affected by space weather activity.

2.3.4. **Weather Impacts Are Mitigated Through Technology**

Aircraft systems (e.g., airframe, propulsion, and avionics) suppress the effects of weather such as icing, turbulence, and ceiling and visibility. Candidate weather mitigation or suppression systems include synthetic and enhanced vision, gust alleviation, wake vortex suppression, and in-flight icing mitigation systems. Such systems significantly reduce the impact of weather on the aircraft as well as the associated airspace restrictions that hinder capacity.

2.4. **Weather Assimilated Into Decisions**

NGATS weather support provides a common weather picture across NGATS with a fused set of 4-D global weather observation and forecast data sources. These Aviation Weather 4-D Designated Data Sources (i.e., 4-D Weather) are dynamically updated as needed and identify hazardous weather in real-time.

The time scales for NGATS decision systems work across all time horizons from days/weeks/months prior to flight up to separation management (20 minutes or less). Weather is assimilated into NGATS ‘decision loops’, so there is total integration via machine-to-machine, using both probabilistic and deterministic weather information. Weather assimilation is optimized to maximize identification of available “weather-favorable” airspace. The purview of “weather” is expanded, in the 2025 era, to include the space weather that impacts radiation exposure, communications, and navigation. These issues further define the “weather favorable” airspace.

2.4.1. **Weather Assimilated Into NGATS “Decision Loops”**

Weather information is not an end in itself, but is fully integrated into NGATS systems supporting aircraft operations. Weather information becomes “invisible” in that the NGATS systems include all the weather information needed to keep the system safe and maximize capacity. The assimilation (or integration) of NGATS weather support is imbedded in the ground and cockpit systems and becomes transparent to the user.

The accuracy and resolution of forecasts of key aviation parameters (e.g., convection, turbulence and icing) are improved, as is forecasting capabilities for new categories of weather information, especially space weather and weather forecasts for homeland security applications, such as bio hazard dispersion. Although forecast accuracy is improved, making more airspace available and useable, the remaining uncertainty in
forecasts is managed though the use of probabilistic forecasts. Also, weather capabilities enable expanded operations at small and medium sized airports, as currently unavailable observations and forecasts become available to all users.

2.4.2. Multiple Weather Observations Fused Into the 4-D Weather

Weather data (observations, forecast, model/algorithm data, and climatology) is integrated into the 4-D Weather (the authoritative source of all weather used in NGATS), which covers the NAS from the surface to low Earth orbit. Weather observations are contained in the 4-D Weather and used by forecasting toolsets to produce forecasts (both routine and aviation impacting) for all users, which are also integrated in the 4-D Weather.

Users retrieve weather information needed for decision-making in real-time from this 4-D Weather. Vendors use information from the 4-D Weather to produce tailored, value-added products. Some weather information such as turbulence and icing are also tailored to the airframe, as well as the route. This capability depends on the ‘Network Enabled Information Access’ capability to provide a common picture used to support NGATS decision-making.

Weather information is also used to help in understanding environmental impacts from increased aircraft operations such as increased noise and exhaust emissions in and near airports and contrail creation in en route airspace.

2.4.3. Hazardous Weather Identified In Real-Time

Improved information from ground sensors (e.g., NEXRAD dual Polarization), new sensors on satellites, as well as increased weather observations by ground and aircraft sensors (e.g., commercial, GA, UASs) identify hazards, which are disseminated to aircraft in real-time.

2.4.4. Weather Support Provided For Space Operations

NGATS weather support includes real-time observations, alerts and warnings of space weather events, and predictions of environmental impacts on space-based operations. Space-based operations include shuttle and Recoverable Orbital Vehicle (ROV) operations, as well as, weather communications and navigation satellites.

2.4.5. Weather Assimilated Into Aircraft Mitigation Systems

Flight crews, with appropriate mitigation equipage, are alerted of the weather ahead, as well as the level of mitigation that may be achieved by the on-board systems, and the optimal path for hazard avoidance or flying through the hazard region within the authority of the advanced mitigation designs.
2.5. **Layered, Adaptive Security**

The ‘Layered, Adaptive Security’ capability integrates security functions into NGATS operations in a manner that increases security while moving more people and requiring proportionally fewer resources to do it. Responses to anomalies and incidents are proportional to the assessed risk involving individuals, cargo, airports and/or aircraft.

2.5.1. **Weather Information Provided For Chemical/Biological/Nuclear (Radiation) Security Incidents**

Improved sensors and number of sensors, both on the ground and aloft, provide crucial weather information (e.g., winds, temperatures, and stability) to determine and forecast the potential impact area of chemical/biological/nuclear releases within the NAS.

2.6. **Broad-Area Precision Navigation**

Broad-Area Precision Navigation provides “instrument landing” navigation precision with no ground-based navigation aids. This enables precision approaches at any “air portal” and reduces or eliminates legacy systems and procedures.

2.6.1. **Observation and Forecast Provided For Non-Towered and Virtual Towered Airports**

Current and forecast weather information (using observations, forecasts, model/algorithm data, and climatology) is available for non-towered and virtual towered airports at the required spatial and temporal resolution. Hazardous weather in the terminal area impacting departures and arrivals is also detected in real-time and forecasted.

2.6.2. **Space Weather Information Provided For Satellite Navigation Systems**

Satellite based navigation systems are affected by space weather. The scintillations of the total electron content in the ionosphere can cause satellite navigation signals to be unavailable at times. Space weather information and forecasts of these conditions in the NGATS are provided.

2.7. **Aircraft Trajectory-Based Operations**

Aircraft trajectory-based operations allow airspace configuration adjustments to meet user needs. The current NAS is geographically based and allocation of airspace is rigid, maximizes capacity across a range of airspace conditions, but is suboptimal for most conditions, and thus limits the overall capacity of the system. NGATS incorporates dynamic airspace operations with airspace configuration driven by user needs, national security, safety, environment, and the overall efficiency of operations. There is a single mechanism for implementing special requirements such as military,
homeland security, and emergencies. NGATS is built to deal with the uncertainty in weather and its uncertainties are accounted for in airspace allocation decisions.

4-D trajectories are the basis for planning and execution of user negotiating agreements for airspace access and service. Trajectory analysis and separation assurance are machine-based, and the airspace is reconfigurable during the day of operation. NGATS resources are matched to demand and adjusted as required. Key functions in the NGATS “management by trajectory” involve allocation of decisions between automation and humans, and between the air (aircraft operators) and the ground (service providers).

2.7.1. 4-D Weather Supports NGATS Decision Oriented Tools

The NGATS includes ground and aircraft systems that facilitate rapid, timely decision-making. For this document, an application which facilitates decisions within NGATS is referred to as a notional NGATS Decision Oriented Tool (NDOT). The NDOTs range from fully automated machine-to-machine decision support (NDOT-M2M) to automation assistance for human decisions, and include both those that support ATM applications (NDOT-A) and those that support Flight Community applications (NDOT-F), i.e., pilot and dispatch. The 4-D Weather supports the full range of NDOT applications:

a. Machine to machine algorithm which automates decision-making

b. Machine to human display, which recommends decisions (options or advisory)

c. Machine to human display which organizes information for human decision

NDOT development geared toward items b and c above follows a user-centric design approach ensuring information is properly tailored for each set of users. NDOT is a functional system description and is not a specific allocation of requirements to systems for investment.

2.7.2. 4-D Weather Provides the NDOTs with Trajectory-Based Weather

The 4-D Weather provides the NDOTs with trajectory-based weather information (observations, forecasts, model/algorithm data, and climatology including surface observations and weather aloft) to allow for full integration of weather into decision-making. Weather information from the 4-D Weather allows the NDOTs to identify weather impacted airspace (both real-time and forecasted) as reduced capacity as well as no fly airspace. The 4-D Weather provides the NDOTs with climatology (to permit up to at least 3 month pre-flight planning window) and provides probabilistic forecasts to allow for multiple preplanned trajectories and airspace configuration scenarios.
2.7.3. **4-D Weather Draws Upon Climatology for Long Range Planning and Unusual Situations**

Climatology information (including surface observations and weather aloft) is integrated with the 4-D Weather to provide the NDOTs with information for long-range planning. For example, through conditional climatology methods, the probability of unusual weather situations such as widespread freezing rain is forecast.

2.7.4. **New Aircraft Weather Mitigation Capabilities Influence the NDOTs**

Advancement in aircraft weather mitigation designs and operations are factored into the NDOTs, allowing aircraft trajectories to be less heavily influenced by weather.

2.7.5. **ATC Separates Aircraft from Weather, Especially For Limited or Non Equipped Aircraft**

ATM service providers share in the responsibility with the pilot for strategically directing aircraft in avoiding hazardous weather conditions.

2.8. **“Equivalent Visual” Operations**

Equivalent Visual Operations (EVO) allow more predictable operations, especially at busy airports. ATM service providers delegate “maintain separation” function to properly equipped aircraft within established traffic flow conditions or rules. Through information sharing, the cockpit has the same picture of the situation (e.g., nearby aircraft and weather) as the controller. Precision navigation ensures the accuracy of this picture. Most routine operations (such as passing maneuvers or parallel landings) are managed by the pilot on board or the remote pilot for UAS operations. Air portal capacity loss or reductions due to severe thunderstorms or wind shifts still occur.

2.8.1. **4-D Weather Provides Timely, High Fidelity Hazardous Weather Information**

Improved, rapidly updated weather data (ground sensors, aircraft sensors, model/algorithm data, and other sources) is integrated into the 4-D Weather. Low-altitude hazardous weather information particularly in the arrival and departure areas is disseminated in real-time to departing and arriving aircraft as well as to the NDOTs.

2.8.2. **Synthetic and Enhanced Vision Aircraft Capability Enables Clear Day Operations**

The synthetic and enhanced vision system optimizes aircrew situation awareness of aircraft state, geo-location, and surrounding environments in all weather conditions. For aircraft with this performance-based capability, visibility and ceiling are removed as factors in air operations.
2.9. “Super Density” Operations

Super density operations allow peak performance at the busiest airports. More runways at more airports are used at near full capacity. Maximized runway capacity, reduced runway occupancy time, and simultaneous operations on a single runway are components of super density operations. Performance-based services, EVO, and new wake vortex procedures are used to safely reduce separation distances between aircraft on arrival and departure. The airport “landside” capabilities (including security) are sized accordingly to support Super Density Operations.

2.9.1. Wake Vortex Impacts Provided Across All Required Domains

Wake vortex detection, tracking, dissipation, and prediction information is provided to arriving and departing aircraft in the terminal area as well as to en route flight operations. New wake procedures are enabled by this information, thereby increasing airport capacity.

2.9.2. Aircraft Wake Vortex Suppression System Enables Closer Aircraft Operations

Aircraft with this Performance-Based capability have advanced wing designs and gust alleviation systems. These on-board aircraft systems dampen the effects of aircraft generated wake vortices as well as suppress the effect of gusts whether naturally or artificially generated.
3. **Weather Concept Operating Principles**

This section provides the guiding principles that should be followed in order for the Weather ConOps to fulfill the weather support requirements outlined in Section 2. These principles provide the baseline for the NGATS Weather Support Concepts described in Sections 4 and 5. The principles are listed in five categories: Policy and Organizational; Data Collection and Access; Products and Decision Support Tools; Integration and Procedures, and Enhanced Aircraft Capabilities.

### 3.1. Policy and Organizational Principles

Three key principles are identified:

a. NGATS weather support is a joint agency (i.e., Department of Transportation/Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), Department of Defense (DOD), Department of Homeland Security (DHS), and Department of Commerce (DOC)) responsibility and requires revisions to existing weather policies and regulations.

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

c. Air Traffic Control (ATC) strategically separates aircraft from weather, especially aircraft with limited or no equipment for weather avoidance.

### 3.2. Data Collection and Access Principles

Five key principles are identified:

a. Required weather information is made available to all NGATS users.

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

c. NGATS weather provides increased coverage of 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., Wide Area Augmentation System [WAAS] approaches).

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

   1) Accessing and processing in-flight updates to NGATS weather products.

   2) Transmitting and receiving aircraft weather data generated through on-board automation such as 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 pre-flight planning and in-flight updates reducing the need for Flight Service Station (FSS) service provider support.

3.3. **Product and Decision Assistance Tool 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 weather products are targeted for elimination.

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

   1) Identification of hazardous weather in real-time

   2) Super density operations with reduced aircraft spacing and separation (terminal and en route) to include new weather support capabilities for wake vortex avoidance

   3) New requirements in space weather support and weather information for chemical/biological/nuclear security incidents

d. NGATS weather impact decisions are based on:

   1) Pilot and aircraft capabilities to include pilot/flight crew imposed currency limitations and personal weather minimums and Federal Aviation Regulations (FAR) requirements such as IFR vs. Visual Flight Rules [VFR], Part 121, Part 135, Part 91, etc.

   2) Weather avoidance (adverse and/or hazardous)

   Note: Weather impacts may be mitigated through aircraft/avionics technology such as icing detection and elimination, or turbulence detection and mitigation.

   3) Flight efficiency (favorable winds and temperatures)

   4) Flight quality and preference (pilot/flight crew and passenger stress and/or comfort)
3.4. **Integration and Procedures Principles**

Five key principles are identified:

a. Rather than be an end in itself, weather information 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 NEWIS.

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 NDOT's capability using timely updates of NGATS weather information provided to all users including pilots/flight crews.

3.5. **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.
4. Weather Support Concepts (2025 Concept)

Decisions which ensure the safest, most efficient and most reliable movement of large numbers of people and goods throughout the air transportation system require reliable, accurate, and pertinent weather information integrated with other NGATS information describing NAS variables. The NGATS includes ground and aircraft automation systems that facilitate rapid, timely decision-making.

4.1. Decision Makers

All of the activities within this weather concept of operations are grouped by five primary decision-making roles.


To allow the NAS to triple its capacity, heavy reliance is placed on the NDOTs’ role to quickly and effectively make decisions. Without automation, human decision-makers and the safety margins required in anticipation of human error do not allow this goal to be achieved by 2025. The NDOTs include a system of automated decision tools which work together to produce safe and efficient flight from a myriad of variables relevant to NAS operation. Collaboration among stakeholders is needed to pre-determine the factors and user preferences for safe and efficient flight upon which the NDOTs depend.

b. ATS Community. Decisions made by the ATS community (e.g., decisions illustrated by those made by today’s ground, tower, Terminal Radar Approach Control [TRACON], Traffic Management Unit [TMU], Air Traffic Control System Command System [ATCSCC], including collaborative decision making).

Decisions of this type involve human intervention when automation is perceived inadequate or immature. In such instances the updates to weather and congestion databases do not necessarily reflect the current or “tactical” situation. The actual situation may trump the NDOTs’ picture of weather and congestion in circumstances when: the 4-D Weather is not refreshed quickly enough; the observational data does not contain enough information to accurately analyze information between the observations; or the forecast data is not reliable enough to make tactical decisions.

c. Flight Community. Decisions made by the pilot and organizational functions designed to facilitate pilot decisions (e.g., dispatch), referred to as the ‘flight community’.

Flight community decisions are made to improve the safety and efficiency of the individual flight within the constraints determined by the NDOTs and the
decisions of air traffic managers. In many cases, decision support is provided to the Flight community by the NDOTs and private industry to facilitate the selection of flight options given the NDOTs knowledge of the individual aircraft capability, individual pilot preference, together with known and estimated constraints due to traffic and weather (see Section 4.13 for a simplified scenario).

Choices provided by the NDOTs also contain a calculated decision risk factor which the pilots consider before making a choice among provided alternatives or requesting a decision of their own design through NDOT-F applications. Choices provided by the NDOTs are not solely weather driven, but result from weather integrated with other factors that affect flight. NDOTs provide choices that integrate information on weather constraints and congestion constraints, as well as decision risk assessments that integrate weather and congestion.


Under normal circumstances the military and homeland security users of the NAS are integrated into the normal operations of the NAS with necessary modifications to meet special military needs. However, with proper authority, the NAS must be prepared to respond to orders from Homeland Security or the Military in an emergency.

e. NGATS – Other. Decisions made by other NGATS participants.

Decision makers in this category include the customers of air traffic such as passengers and those that further facilitate the transportation of people and goods through the NAS. Included in this category are those that operate airports, maintain runways, deice aircraft, plow snow off terminal parking lots, prepare gates for aircraft departure and arrival, etc.

4.2. NDOT Categories

Table 4-1 illustrates the three basic types of NDOTS (reference Section 2.7.1) relative to the five basic communities of NGATS decision makers described above in Section 4.1. The table provides a short hand method to quickly describe the type of NDOT and the community for which it is intended.

The fully automated NDOT M2M applications are the primary method for providing NGATS weather support. The machine to human NDOT applications are used when automation support may not be available or when NDOT M2M applications are unable to replicate the actual situation in near real-time.
a. The “M2M” applications are essentially algorithms which take information from weather and other sources and make decisions based on a predetermined set of rules.

b. The “Alts” applications are tools which present human decision makers with alternatives from which to choose. They may include a recommended alternative along with information regarding each choice to assist in evaluating each choice.

c. The “Info” applications are tools which present human decision makers with information organized to facilitate decision-making.

Table 4-1 NDOT Categories

<table>
<thead>
<tr>
<th>NGATS Community</th>
<th>Type of NDOTs</th>
<th>Machine to Machine</th>
<th>Machine to Human with Decision Alternatives</th>
<th>Machine to Human with Organized Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Community (F)</td>
<td>NDOT-F-M2M</td>
<td>NDOT-F-Alts</td>
<td>NDOT-F-Info</td>
<td></td>
</tr>
<tr>
<td>Homeland Security / Military Community (HSM)</td>
<td>NDOT-HSM-M2M</td>
<td>NDOT-HSM-Alts</td>
<td>NDOT-HSM-Info</td>
<td></td>
</tr>
<tr>
<td>Other Communities (Other)</td>
<td>NDOT-Other-M2M</td>
<td>NDOT-Other-Alts</td>
<td>NDOT-Other-Info</td>
<td></td>
</tr>
</tbody>
</table>

4.3. Decision Weather Information

Weather information tailored for the NGATS automation is digital, gridded, and mostly probabilistic (especially after one hour). It is expressed in units required by the NDOTs decision algorithms. For example, decision tools within the NDOTs require probability information for each weather feature forecast category (e.g., icing potential or intensity that is severe, heavy, moderate, light, and no icing, or their numeric equivalent). In this way the information needed by the NDOTs and the preferences of the flight community are considered together, and the appropriate decision risk assigned to each alternative offered by the NDOTs to the pilot.

Weather information for all human decision makers is either integrated into decision assistance tools which are displayed to help decision-makers make better decisions, or is displayed as a weather graphic designed to facilitate decisions, or is displayed as text. Some NGATS automation contains graphical weather presentations constructed upon request from the latest information in the 4-D Weather to help human understanding. Constantly updated NDOTs are needed for most human decisions.
because the 4-D Weather is constantly changing. The concept of routinely issuing weather products becomes outdated.

The evolution of decision-making in the NAS shows a migration from human to automated decision-making as automated decision-making proves its value. The first migrations are in the strategic planning category (e.g., automating strategic playbook design). Figure 4-1 illustrates that migration among the three major groups of decision makers.

The following sections describe the integral parts of weather support to the NAS and their relationship with each other. These are shown schematically with accompanying diagrams.

4.4. Weather Information Framework

Weather information must be designed to fit this overall decision framework. There are two primary types of weather information, basic weather information sources and weather products.

a. Basic weather information sources.

This information resides in the commonly accessible 4-D Weather (i.e., grids) and also includes information which cannot be described or extracted from these grids (e.g., fronts). Basic weather information sources are very useful for NDOT algorithms and are not intended for direct human decision maker application. Human decision makers require weather products to include decision aids as described below.

b. Weather Products

Weather products are derived from the 4-D Weather and specifically designed to help human decision makers make better decisions. Formatters are designed and provided to both the government and private sectors to assist in easily obtaining required weather information from the 4-D Weather. There are many types of weather products:

1). Decision Support 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

Figure 4-2. Example: Decision Assist Tool Used Today
maker. For example, Figure 4-2 is a current decision support tool which integrates terminal forecast information with runway use criteria at several hours into the future.

2). A binary package of the basic weather information sources. These products are encoded in digital formats (i.e., Geographical Information System [GIS], Extensible Markup Language [XML], GRIdded Binary [GRIB] or Binary Universal Form for the Representation of Meteorological Data [BUFR]) which communicate the basic weather information sources to formatters to be integrated into the users display or process. An example from today is the National Convective Weather Forecast (NCWF) shown as a blue polygon and a significant weather forecast for turbulence packaged in BUFR format and sent through the World Area Forecast System and integrated with a weather briefing workstation.

3). Graphics (such as a Joint Photographic Experts Group [JPEG], Graphics Interchange Format [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.

4). Text. These products are constructed to meet ICAO or FAA format requirements.

4.5. Aviation Weather Information Access

a. Weather information from a variety of sources is network accessible and serves as a source for automated and human decisions regarding NAS decisions. See Figure 4-3.

1. NEWIS provides access to the multitude of aviation weather information sources through NEO.

2. NGATS ATM weather support is based on specific subsets of the NEWIS that are designated as the Aviation Weather 4-D Designated Data Sources (i.e., 4-D Weather).

b. As stated above, basic weather information sources in 4-D Weather enable the automated portion of NGATS management. Packaged weather information in the form of products (graphics, decision aids, and information for decision assistance tools) is produced through user interfaces.
c. Weather information from non-government sources are used for human decision-making and to feed applications developed by non-government organizations to aid decision-making.

d. Weather information from non-government sources is not a part of 4-D Weather, nor used by the NDOT-A applications for ATC decision makers, unless that service is purchased by the government and is publicly available.

![Aviation Weather Information Access](image)

**Figure 4-3 Aviation Weather Information Access**

### 4.6. Aviation Weather 4-D Designated Data Sources (4-D Weather)

a. The 4-D Weather is the official source of weather information in 4-D space and time. It is the weather source for NDOT-A algorithms and a source for displays useful to human decision makers. Private weather sources can also provide displayable information to human decision makers, but not the NDOT-A or ATC decision makers, unless that service is purchased by the government and publicly available to all.

b. Data from automated gridded products, models, and human forecasts are distilled into a single official forecast stored in the 4-D Weather (Figure 4.4). 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 can retrieve
needed weather information. That single forecast, however, is expressed in many ways. For example, at a single point in time and space the following forecasts can exist simultaneously:

1). Moderate icing (deterministic)
2). A 10% chance of heavy icing
3). A 40% chance of moderate icing
4). A 70% chance of light icing
5). An AIRMET ZULU flag turned ‘on’
6). Icing Significant Meteorological Information (SIGMET) flag turned ‘off’

What is not allowed is a variety of algorithms and models to provide more than one ‘official’ forecast for a single point in time and space such that, for example, there is more than one probability of heavy icing from which the NDOT-A or products being produced from the 4-D Weather must choose.

c. Observations are integrated into the 4-D Weather observational analysis.

1). The real-time atmosphere presented to the NDOTs and product formatters is analyzed from both observational data and model data.

2). Source observations such as Meteorological Aviation Reports (METARs) are also available, but most decision algorithms and aids use the 4-D observational analysis.
4.7. Weather ‘Products (Graphics, Sources, Decision Aids)

Weather products are constructed from the 4-D Weather

a. Humans peer into the 4-D Weather through ‘products’.

b. Products are created through formatters. The formatters are able to “slice and dice” the 4-D Weather based on user provided criteria.

c. Weather products are viewed by the user through a user interface, preferably not a stand-alone weather interface, but within an ATS or flight navigation interface.

d. Decision assistance tools use weather information from the 4-D Weather and/or private meteorological services.

4.8. Private Weather Information Providers

a. Private weather information providers (i.e., vendors) have access to all NEWIS information including the 4-D Weather (Figure 4.5).

b. Users may choose to augment the 4-D Weather with weather information provided by private vendors, at their own expense.
c. Weather information provided by private (non-government) vendors is integrated into the 4-D Weather only if it is purchased with public funds and made available to the public as part of the single authoritative source.

**Private Weather Sources**

![Diagram of Private Weather Sources and Relation to Public Weather and User Interfaces](image)

**Figure 4-5. Private Weather Sources and Relation to Public Weather and User Interfaces**

### 4.9. Air Traffic Services (ATS)

ATS is primarily automated using the NDOT-A-M2M applications, which include the notional Factors and User Preferences for Efficient Flight that include the Individual Flight Limitations and Preferences which are described in the following Sections 4.10 and 4.11 respectively. These notional air traffic functions are used to illustrate the NGATS weather support concept and do not represent specific NGATS functions that are currently recognized or defined by the JPDO.

a. NDOT-A-M2M applications keep track of weather, pilot preferences and limitations, aircraft limitations, planned and actual traffic (Figure 4-6). Using the factors and user preferences for efficient flight, the NDOT-A-M2M applications enable almost all strategic requests and some tactical requests because they can do so better than human planners. The NDOT-A-M2M applications provide the constraints outside of which the ATC and flight communities operate and make decisions assigned to their discretion.

b. ATC decisions not done by the NDOT-A-M2M applications are mostly tactical because there are limits to the NDOT-A-M2M abilities to replicate the actual situation in near real-time, especially weather.
c. Flight deck decisions (and flight community) are confined to those not done by the NDOT-A applications or ATC. The flight community makes requests to the NDOT-A applications or ATC. The NDOT-A applications normally provide options to the flight deck, each with a degree of decision risk of interruption due to weather and/or traffic associated with it.

d. Almost all pre-flight planning is handled by the NDOT-A applications. In response to requested routes, the NDOT-A applications analyze potential traffic and weather constraints and offer the flight planner alternatives with an estimate of interruption probability so the planner can manage the decision risk. If flight planners want to see images of the 4-D Weather, they do so through their flight planning interface, which is more than a stand-alone weather machine. They also interrogate decision assistance tools through these interfaces.

Figure 4-6. Weather Information Integrated into Automated (NDOTs) and Human Directed Traffic Management

4.10. Factors and User Preferences for Efficient Flight

a. The NDOT-A-M2M algorithms determine how best to strategically and (to the extent possible) tactically manage traffic flow. They do not include procedures which humans perform better.

b. Factors and User Preferences for Efficient Flight consider items such as:
1. The time of day, day of year.
2. Historic flow patterns without weather.
3. System Rules
   a. Static Rules and Policies
   b. Daily Operational System Preferences
4. Algorithms used to de-conflict constrained airspace.
5. The interests of neighboring airspace (e.g., Canada, Mexico).

**Figure 4-7 Factors and User Preferences for Efficient Flight Which Use Real Time Traffic and Weather Information within the NDOTs**

4.11. Individual Flight Limitations and Preferences

The NDOT-A algorithms must be aware of each flight’s limitations and preferences

a. Examples of flight limitations include:
   1). Certifications and ratings of the pilot and/or flight crew
2). Certifications and ratings of the aircraft to include performance-based weather capabilities (e.g., weather sensors, weather data link, weather mitigation)

b. Examples of flight preferences include:

1). Route my flight around areas with greater than 10% chance of moderate icing by at least 40 miles.

2). Route my flight around forecast areas of icing with greater than 70% chance of light icing occurrence by at least 10 miles.

4.12. NGATS Weather Integration

Figure 4-8 provides an overview of the overall NGATS integration of weather information.

![NGATS Weather Integration CONOPS](image)

Figure 4-8 Overall Integration of Weather Information with NAS

4.13. Summary Scenario

The following scenario illustrates a typical use of weather information under the NGATS Weather ConOps:

a. An airline (flight community) proposes to the NDOTs a flight from Los Angeles (LAX) to Chicago (ORD) leaving at 11:30 a.m.
b. The NDOT-A applications provide choices given what is known about the weather, planned traffic, the factors and user preferences for efficient flight, and what the airline has provided to the NDOT-A about the certifications of the aircraft and crew, as well as the airline weather preferences and tolerances. The NDOT-A applications provide routes from which the flight community chooses, each with an estimated time of flight and the 'risk' of delay due to weather and/or traffic congestion. In the Figure 4-9, risk of delay is expressed as the probability of deviations causing a 30 minute delay. There are certainly other criteria upon which the decision risk is based.

c. Flight community chooses based on their own cost information, risk tolerance, or possibly weather products or decision tools which use weather information provided by alternative weather sources. The NDOT-A applications are unaware of alternative sources of weather information.

d. The choice is logged by the NDOT-A applications.

e. The process is continuous, even in flight, until near the end of the flight.

f. Direct human management of flight occurs only for near-term decisions such as direct weather avoidance. In this case weather/traffic 'model' accuracy is not reliable enough to be automated.

![Route Planning in 2025](image)

NDOTs Flight Planning Alternatives are provided to the Flight Community showing projected time of flight and probability of 30 minute delay. Flight Community would insert their own cost information and choose route.

**Figure 4-9** Illustration of NDOT-A Response to Request from Dispatcher for flight from LAX to ORD
5. **NGATS Functions – Weather Support Analysis**

NGATS functions that must be supported by the 2025 weather capabilities span NAS ATS, homeland security, military operations, and commerce. For this version of the weather concept of operations, the emphasis is on NAS ATS. Other functions will be added in the future based on coordination with appropriate stakeholders.

The FAA organizes the current NAS services (or functions) into five service groups as illustrated in Figure 5-1. Weather information supports critical decision-making within the current NAS; especially in the ATS and Airport Management Services. The weather information today, however, is not routinely integrated into automated decision assistance tools and frequently requires interpretation and manual integration by the NAS users.

![Figure 5-1. Current NAS Services](image)

This section provides descriptions of weather support to decision-making for NGATS flight operations in 2025. The section is organized by notional NGATS functions (see Figure 5-2). For each function, the NGATS weather support concepts are described along with any unique needs for specific users (pilot, dispatcher, ATC, DOD, DHS, etc).

The weather support concepts presented here are based on the current understanding and interpretation of the JPDO NGATS 2025 concept, Version 4.8, August 31, 2005. These concepts will be revised and updated as the JPDO NGATS 2025 concept matures and the NGATS ConOps is developed. Further, in some cases, the weather
support concepts may include alternative approaches that require research and concept demonstrations to determine the best approach.

5-2. NGATS ATS Functions (Notional)

5.1. Flight Planning

Flight planning support provides NAS users with essential weather and aeronautical information. This service offers preparation to conduct a flight within the NAS and allows changes to flight profiles while operating within the NAS.

5.1.1. Flight Planning - Preflight

In the NGATS era, all observations, forecasts, and climatology are provided to the 4-D Weather component within the NEWIS for flight planning. The NDOTs are linked to the 4-D Weather and this weather information is used to prepare and de-conflict flight plans from weather impacts and other known constraints. Private industry develops the decision support tools for pilots and dispatch centers to mitigate the impact of hazardous weather.

The 4-D Weather and the NDOTs work as an integrated system during preflight to catalog and analyze all flight plans and provide recommended routes to pilots and/or dispatchers with route recommendations based on weather and Traffic Flow Management (TFM) constraints. Using a combination of anticipated traffic, weather forecasts and observations, aircraft capability and air crew certifications; the NDOTs
provide routing recommendations that are both safe and system efficient. Each recommendation includes a decision risk assessment.

In order to meet the needs of users and the NDOTs, weather information is described in four dimensions (X, Y, Z and time) and in terms of intensity and probability. Weather information for all services including flight planning has several levels of resolution:

a. Local Airport (landing, takeoff, taxi) with required airport resolution classified by traffic (from major hub to grass strip)

b. Transition (from/to altitude from/to approach/departure)

c. En Route

Weather information (observations and forecasts) are developed to populate the 4-D Weather at the required resolution. Airport domain weather information for flight planning includes:

a. Observations such as minute-by-minute Automated Surface Observing System (ASOS) observations and graphical representations of these observations

b. Forecast information represented as 4-D digital information from which various graphics and text forecasts are extracted in formats prescribed by the Meteorological Authority

c. More airport observations and forecasts (e.g., Terminal Aerodrome Forecast [TAFS]) that include non-towered airports to support increased IFR operations using Broad-Area Precision Navigation (e.g., WAAS approaches)

The primary use of weather information as extracted from the 4-D Weather for the purpose of flight planning includes:

a. Flight planning programs

b. Graphical representations of the 4-D Weather created in real-time

c. Any text products still required by ICAO

Flight planning decisions continue to be based on safety, comfort, and efficiency, which directly relate to flight quality. However, improved weather for NDOTs offers flight planners better tools to make more intelligent planning decisions which lead to more efficient, comfortable and safer flights. These include:

a. Improved forecast reliability, quantification and probability of in-flight weather hazards such as turbulence, icing, and thunderstorms
b. Better pairing of flight crew and aircraft capabilities with predicted weather conditions 

c. Improved severe weather airborne and ground-based avoidance tools, leading to enhanced safety, more efficient routes around severe weather, and more efficient use of resources 

In order to support these abovementioned planning decisions, 4-D Weather information are extracted by the NDOTs which, together with expected constraints in air traffic due to congestion, provide a variety of recommended route alternatives. Each route contains an assessment of risk associated with weather and congestion, which is used to determine the route of flight that best meets that flight’s need for safety, delay tolerance, etc. Supplemental to flight recommendations is a display of requested weather information tailored to the specific route. 

In NGATS, decision-makers rely primarily on sophisticated self-briefing systems for both pre-flight planning and in-flight updates although current briefing methods may continue in some cases (e.g., in-flight support to VFR pilots). Self-briefing relies on airspace evaluation tools which incorporate anticipated congestion forecasts and weather impact assessments from increased resolution in weather forecasts and observations. Simplified, accurate, and consistent weather products and NDOTs allow users to assess expected NAS events and safely perform flight planning tasks while also considering passenger comfort and flight efficiency. The NGATS also provides more flexibility when and where users perform pre-flight planning and provides users with immediate feedback on possible weather impacts to a submitted flight plan. In addition, NGATS provides users with a “what-if” capability where users can submit multiple flight plans and compare the schedules, distances, and weather impacts of those plans. 

Some users may choose not to make use of NGATS pre-flight planning services and in-flight updates. However, self-briefing is anticipated by most users because NGATS makes access to and applicability of weather information simple. 

5.1.2. Flight Planning – In-Flight 

The dynamic nature of both aircraft operations and NAS operational constraints often result in a need to change a 4-D trajectory plan while the aircraft is en route. Users (i.e., flight deck, Airline Operations Center [AOC]) receive current and predicted airspace constraint information (e.g., delays, flow initiatives, and special use airspace status) via net-centric dissemination, which allows advantageous preferred plan/re-plan trajectories within the dynamic constraints of the NAS. Additionally, users receive information tailored to the specific needs of the flight, including aircraft capabilities and pilot/operator preferences from the NGATS 4-D Weather. The NDOTs, located on board the aircraft and at the AOC, enable combined 4-D Weather information and trajectory prediction analysis, showing the impact of weather on the flight and aiding in more effectively planning of various flight operations. As with pre-flight planning, ground-based NDOTs are used to alleviate conflicts with traffic.
flow constraints, conflicts with other flight plans, and (based on flight crew preferences) strategic conflicts with adverse weather conditions. Fully performance capable aircraft accept the responsibility to maintain separation from other aircraft or to fly through potentially hazardous phenomena for which the aircraft has mitigation technologies. They also exercise the authority to freely maneuver in en route airspace while establishing a new user-preferred trajectory that conforms to any active local traffic flow management constraints. These user-preferred trajectory modifications may be generated by the flight deck’s NDOT or by the pilot (with AOC input), as well as generated entirely by the AOC and transmitted to the flight deck. The flight deck then transmits its modified flight plan to ground-based NDOTs immediately before initiation of a trajectory modification. The ground-based NDOTs double check the flight deck’s de-confliction and sends an appropriate acknowledgement response back to the flight deck.

5.2. Airspace Management

Airspace management ensures the safe and efficient organization and use of the national airspace resource. Airspace management includes two aspects: design, and organization and implementation. Airspace design establishes the guidelines for airspace structures in order to accommodate the different types of air activity, volume of traffic, and differing levels of service. Airspace organization and implementation is the process by which the airspace design options are selected and applied to meet the needs of the ATM community.

Maximum safety and efficiency in using airspace result from coordinating airspace user needs and available capacity. Effective airspace management in the NGATS timeframe is enabled by the integration of airspace design with the enhanced management of weather and/or traffic constraints. As traffic grows, becomes more operationally diverse, and less predictable; flexibly structured, dynamically managed airspace, routes, and airports help provide the required system capacity, as well as address temporary constraints to that capacity such as those due to weather.

5.2.1. En Route

Evolution toward the strategic ability to reconfigure airspace in real or near-real time is a capability currently referred to as dynamic sectorization. In the current system, dynamic sectorization is applied in a limited manner. Specific configuration of the airspace is parsed into a discrete set of options, with the option selected based on operational conditions (e.g., en route airspace adjusts based on the runway configuration at a given airport). The NGATS concept includes both changes in the structure of the en route airspace, as well as the services provided. In combination with improved probabilistic weather forecasts; integration of weather into NDOTs; advances in performance based navigation; development of net-centric shared situational awareness; and introduction of aircraft self-separation, NGATS is able to make greater use of congested/constrained en route airspace. Where congestion is predicted due to high demand and weather constraints (e.g., lines of convective weather), sectors are strategically adjusted to facilitate efficient provision of new services (e.g., streaming) and reduce impacts on users. Where this differs from the
current limited dynamic sectorization operations, is that the structure changes are not limited to a select set of options, but are better customized to emerging operational changes. These customized changes are implemented quickly and effectively to address fast-paced weather changes.

Increased weather information accuracy (i.e., greater forecast skill), which is both anticipated and desired, and increased weather information relevance (i.e., information tailored to decision-making and including probabilistic forecasts) enable more efficient airspace change decisions. And, rapid updates to the weather situation enable effective and pro-active adaptations of the airspace plan. Greater efficiency is gained due to less conservative decisions.

For example, a north-south line of thunderstorms stretching from Chicago to Houston significantly restricts the flow of west-east (and east-west) traffic. However, improved weather forecasts enable flow managers to have high confidence that two sectors along this line, will allow east-west flow of traffic for the next several hours. The rapid update of weather forecasts allows for a strategic decision to be made to dynamically resectorize, creating three (more-elongated) sectors, where there were previously only two sectors (Figure 5-3). Additionally, two of these sectors (A & B) will be restricted to those aircraft equipped to operate in streaming airspace, while the third sector (C) is designated for all other traffic.

Figure 5-3. Dynamic Resectorization and Streaming Concept
The two streaming A&B sectors are activated using previously defined closely parallel east-west routes (i.e., separated by 4 nautical miles) across. Performance-based, time-coordinated, 4-D trajectories “organize” the converging flow into a manageable sequence. Aircraft entering these routes are equipped and responsible for self-separation. They are aided by on-board NGATS decision oriented tools and 4-D trajectory operations. The controllers assigned to these sectors manage the flow and address exceptions to self-separation, if they should develop. These streaming sectors provide higher levels of capacity and lower user impact for aircraft transiting beyond the impact of the convective weather.

In the third C sector, active control of separation would remain with ground controllers and the services provided would remain much the same as they are today. In this third C sector, only a more limited flow of aircraft is accommodated, leading to delays, if the demand by non-streaming equipped aircraft is high. It is also possible, during peak times that all three sectors could be designated for streaming aircraft, resulting in alternate reroutes for non-equipped aircraft (i.e. equip-for-service).

5.2.2. Terminal

In the terminal area, dynamic terminal airspace configuration is enabled by improved weather observations and short-term terminal weather forecasts; integration of weather into NGATS decision oriented tools; advances in performance based navigation; and development of net-centric shared situational awareness. Today, when an airport is reconfigured due to weather, it is often a reaction to a change in the weather, rather than an organized plan employed in anticipation to a weather change. This reaction is often characterized by a significant period of traffic holding that persists until traffic streams are reestablished. With NGATS, improved and more rapidly updated weather forecasts (e.g., surface winds, convective weather initiation/decay forecasts), which are available both on the ground and the flight deck identify in advance any change in weather pattern that would require a change in terminal airspace. This allows for planned and more orderly terminal airspace reconfigurations that helps maintain higher airport capacity and increased safety, which is especially important at peak times and/or in poor weather conditions.

5.2.3. Airport

The increase in the number of aircraft privately operated either as corporate, fractional ownership, or charter tends to increase the number of flights to satellite (i.e., secondary) airports in or near major metropolitan areas. These flights tend to focus on the final destination of the traveler (e.g., airport closest to the business meeting, vacation home, etc.). Because of their smaller size, these aircraft are also able to use smaller airports rather than compete for space at the large commercial airports. Improved weather support at those airports enables their utilization (e.g., automated weather observation and dissemination systems). Since the future Communication, Navigation and Surveillance (CNS) technologies enable precision
approaches to almost all runways, these airports are able to provide service in most weather conditions (i.e., EVO).

RWP (Required Weather Performance) is a prerequisite for acceptance into busy facilities. New weather-dependant wake procedures reduce arrival/departure separation and increase airport capacity. These procedures require wind and wake observations and forecasts on the glide slope, at the threshold, and along departure paths. Better wake predictions enable more proactive vs. reactive planning. Improved lightning detection and prediction make ramp operations (e.g., refueling) safer and increase airport efficiency. New and improved weather observation information make snow removal and deicing operations more efficient, leading to improved airport operations during winter weather events.

5.3. Traffic Management

The TFM function supports the air traffic control mission by adjusting and smoothing traffic flow. By managing the flow to provide for a more efficient use of the available airspace, ATC handle additional aircraft while reducing delays and overall system demands are balanced with that of system capacity. Subsequently, daily operations run more smoothly as collaborative decision making (CDM) information is exchanged. This allows enhanced efficiency of airspace use and results in a safe, orderly, and expeditious flow of traffic with minimal delays. The availability of applicable, meaningful tailored weather information plays a key role in this decision-making process.

5.3.1. Weather Impacts on TFM Decision-Making

In general, weather impacts many TFM operational decisions. The effectiveness of these operational decisions determines the relative success toward continual enhancement of capacity and safety of flight. From the traffic manager’s perspective, this generally refers to any weather condition that disrupts the flow of air traffic and/or causes a reduction in the capacity of a jet route, sector or terminal area.

The traffic flow decision makers translate the weather information (observations, forecasts, tailored products) into its impact on the NAS. For example, forecasted inclement weather may reduce the expected airspace capacity in certain regions. System capacities are therefore, in general, uncertain. NDOTs use such probabilistic information to provide consistent, accurate, timely, and comprehensible TFM to manage NAS safety, capacity, and efficiency.

The NGATS net centric communications system significantly improves the availability of additional, more aviation-focused weather information that enhances operational decision-making. For example, the weather needs of transition traffic flow decision-makers are met by integrating local weather information into a traffic management subset of the NDOTs. Improved longer-term forecasts of various convective phenomena (e.g., storm cells, gust front) enhance advance planning, making NGATS traffic management proactive vs. reactive. In addition, the
availability of ceiling and visibility information—especially along final approach and in terms of aviation operational thresholds for parallel runways and for those aircraft not full performance capable—improves Airport Acceptance Rate (AAR) decisions.

5.3.2. Operational Environments

TFM decisions are driven by the operational environments as well as the associated rules and regulations in which air traffic are operating. Operationally significant airspace is defined for three distinct areas: the terminal area, the transition area or arrival/departure gate, and en route. The terminal area is defined as the area within 20 nautical miles (nm) of the center of the runway complex. The arrival gate is defined as the airspace and routes existing from the top of the descent to the terminal area boundary including the approach gates (i.e., posts). The en route area is defined as an area having predetermined traffic patterns within specified area boundaries that allows for the safe and efficient transit of air traffic through that airspace. The definitions may change as NGATS airspace configuration is formulated.

Operationally significant time is described in terms of tactical or strategic importance—this means current, up to five minutes, up to 1 hour, from 1 to 2 hours, and from 2 to 8 hours.

5.3.3. TFM Decisions Affected by Aviation-Impacting Weather

The air traffic management problem has a broad dynamic range, both spatially and temporally. For traffic flow strategic planning, flight plans and traffic flows are planned several hours in advance and over a range of thousands of miles. At the tactical end, delay maneuvers and conflict resolutions occur over a matter of a few minutes and a few nautical miles.

Strategic planning in TFM sets up a smooth flow for tactical decision-making. The strategic planning does not plan out the details of those tactical decisions, such as deciding which flights will have to be de-conflicted. A key objective of strategic planning is to ensure that airspace and terminal areas are fully utilized but not overloaded. Therefore, while the particular tactical actions in those sectors and terminal areas are not known in advance, those tactical actions are set up for success.

Probabilistic TFM is used as there is uncertainty in forecasting of both airspace and terminal area weather impacts on capacity. Also, capacity forecast uncertainties, in turn, lead to uncertainties in the longer-term forecasts of user demand. For instance, terminal area capacity influences user demand, in later time periods, in nearby en route airspace.

Trajectory-based, rather than limited flow-based, methods are used so that traffic is better managed for the particular NAS-wide scenario. Managing traffic at the trajectory, rather than static flow, level allows for substantial improvement over today's methods. And probabilistic traffic management reduces risk as it is more robust to forecasting uncertainty because it adjusts itself to the forecast uncertainty.
For instance, in cases of greater forecast uncertainty the strategic decision-making is more conservative. In general, the decision-making is tuned to the forecast uncertainty level.

The TFM decision-making has the following meteorological information requirements. The long range forecasts which are used are not required at high spatial resolution. Lower spatial resolution, on the order of tens of nautical miles is required for the strategic TFM decision-making.

Trajectory-based, probabilistic TFM by no means removes the requirement for improved meteorological forecasting. It is robust to forecasting uncertainty but its performance is influenced by forecasting accuracy. Improved forecast accuracy is desirable, for high accuracy forecasts improve performance.

The meteorological information is used in forecasting system capacities. These capacities include the airport, terminal area and en route airspace. Although probabilistic traffic management decisions are often made preflight, strategic decisions may also occur in flight. Also, many flights are of relatively short duration (i.e., less than two hours). Therefore, probabilistic traffic management decisions sometimes occur over short time horizons, say in the 30 – 60 minute look ahead time horizon. Therefore, meteorological forecasts ranging from 30 minutes to 6 hours are required.

These forecasts are not of uniform format. Higher resolution is used for shorter term forecasts, while lower resolution is used for longer term forecasts. The forecasts are in a quantitative format, amenable for use in predicting capacity impact. Forecasts provide the probability of all possible outcomes (i.e., forecasts merely stating that a particular weather phenomenon has a particular probability of occurring are not useful). For example, a forecast stating that there is a 30% chance of a 1,000 foot ceiling is not useful. The other 70% chance is assigned as well. Probabilistic descriptions describe the full spectrum of outcomes and probability of each.

Such probabilistic descriptions may include both temporal and spatial correlations, though such correlations are minimized with prudent grid design (temporal and spatial).

Probabilistic descriptions inherently provide forecast users with a measure of the forecast uncertainty. For instance, there may be low uncertainty, such that a single event with a high probability. On the other hand, when the uncertainty is higher no single event has a high probability.

Probabilistic forecasts are required for all meteorological phenomena that have significant impact on system capacity. At the airport, key phenomena are thunderstorms, ceiling, visibility, and winds. Ceiling and visibility are important parameters in determining airport arrival and departure capacity when equivalent visual operations are not possible. And in equivalent visual operations, thunderstorms moving over an airport cannot be ignored. Winds also affect airport
capacity via their influence on final approach ground speed (which influences runway throughput) and a temporary but significant effect in their causing airport configuration shifts. Additionally, snow, ice and lightning significantly affect ground operations. Accurate and reliable probabilistic forecasts would help optimize efficiency and minimize associated costs.

In the terminal area and en route, convective weather is important. In the terminal area, the general level of convective activity is used to gauge capacity reduction. More precise timing and location information is used in determining arrival and departure route blockage, and temporary airport shutdown.

In the en route airspace the general level of convective activity is used to gauge airspace capacity reduction. The general type of storm is also used in gauging the impact on airspace capacity. More precise timing and location information is used to refine the capacity reduction estimate. For instance, more detailed convective information is used to gauge specific route blockages. These include storm geometry (e.g., a north-south line may block more east-west routes than north-south routes), specific cell locations, and storm height.

5.4. Air Traffic Control

5.4.1. Separation Assurance

As the planning horizon is reduced from that of TFM, predictability is increased, and the focus shifts from probabilistic congestion management, including consideration of weather factors, to a combination of probabilistic and deterministic analysis of specific aircraft-to-aircraft conflicts or other conflicts that may affect safety of flight. The Separation Assurance function has a look-ahead time that extends out (from current-time) from several minutes to roughly 30 minutes. The separation criteria applied may include a combination of temporal or distance-based factors, depending on the trajectories of the affected aircraft, the underlying surveillance and navigation accuracy, aircraft performance parameters, and needed intervention time to maintain a required level of safety performance.

In the NGATS timeframe, the responsibility for separation assurance is likely shared by the air navigation service provider (hereafter denoted “service provider”) and the flight crew/pilot. The allocation in terms of airspace or situations cannot be specified exactly, but from a weather standpoint, the NGATS aviation weather system must support a range of concepts. This includes providing a single authoritative weather source (4-D Weather) that is directly integrated into ground-based and/or aircraft based automation systems and display capabilities, thereby realizing a common operational picture of the weather.

From the service provider point of view, monitoring of aircraft conformance with their trajectories is largely performed by the automation support (i.e., NDOTs including the Evaluator). When a potential separation violation is detected by the NDOTs and the service provider is responsible for separation, the NDOTs
automatically generate, negotiate, and clear specific maneuvers for the appropriate aircraft. In contrast to TFM reroutes, Separation Assurance maneuvers are usually small route changes (e.g., a 5 mile deviation from route) to resolve a problem with a high probability of loss of spatial separation, while maintaining the ability to meet a down-stream metered arrival time or other objective. In generating these maneuvers, the automation is constantly informed with up-to-date information on the weather situation so that inadvertent routing into severe weather is avoided.

The NGATS weather system design allows rapid “push” notifications of changes to the weather situation to those impacted by the change (both to humans and automation). This monitoring and resolution capability also supports the service provider in proactively and routinely (not just as workload allows) assisting aircraft in dealing with weather situations. The service provider is notified, via the NDOTs, of the weather avoidance capabilities of the aircraft. For aircraft equipped with weather access and display capabilities (expected to be most), tactical separation from weather is the responsibility of the pilot; the NDOTs need to be notified (through the service provider via voice or data link) of maneuvers being taken to avoid the weather. Both the pilot and the service provider have access to the same ‘authoritative’ weather information, thereby realizing a common weather picture. For those few aircraft not capable of tactical weather avoidance, the service provider is notified in advance (e.g., at least 10 minutes out) of the impending situation to enable timely development of a tactical weather avoidance reroute for the impacted aircraft. This proactive approach to weather situations thus becomes a new dimension of the separation assurance function as executed by service providers. In some weather situations, the NDOTs maneuvering solution may be complex, for example when navigating through numerous individual weather cells. Air/ground data link is crucial for delivering such clearances to the aircrew in an efficient manner.

In airspace that supports delegated separation to the cockpit, the responsibility for resolving an aircraft, severe weather, or flow restriction (e.g., military airspace) conflict is also delegated to the cockpit; this scenario requires the involved aircraft to have full performance (e.g., with weather access via data link). For a conflict situation that is highly complex involving multiple aircraft, the responsibility likely remains with the service provider and the supporting automation. The pilot utilizes aircraft-based automation to develop a revised trajectory that resolves the problem without creating new ones. To accomplish this, the up-to-date weather information available from the NGATS 4-D Weather is automatically input into the aircraft based resolution algorithms to ensure that the resolutions are safe from a weather avoidance standpoint. The aircraft automation communicates directly with the NDOTs, via data link, to ensure that the aircraft-generated resolution is known and may be monitored. These aircraft automation/weather capabilities also support pilot requests for more strategic route changes to deal with anticipated, downstream weather. The workload of both the pilot and service provider are reduced because the request is more likely to be acceptable as made, and thus automatically processed and implemented directly by the automation (NDOTs). Service provider intervention may be necessary, if the request is not acceptable. The common weather picture helps streamline negotiations
regarding the requested reroute, whether carried out by the service provider or via the NDOTs directly.

5.4.2 Emergency & Alerting

Emergency alerting monitors the NAS for distress ‘calls’ or urgent situations, evaluates the nature of the distress, and provides an appropriate response to the emergency. Applicable situations include those that occur on the ground or in-flight.

The NGATS weather capability provides more timely and accurate information to assist in helping the VFR pilot get out of a hazardous situation, as well as the planning for rescue missions targeted at locating aircraft that have encountered an emergency.

5.4.3 Advisory

General Service Delivery and other facilities provide advice and information to assist pilots in the safe conduct of flight and surface aircraft movement. These advisories include providing weather information, traffic, and NAS status information to pilots, flight planners, and the general public. These advisories and information are either directed to a specific user or broadcast to any user in the area.

The NGATS, net-enabled weather capability (with enhanced observations and forecasts) significantly improve the quality and timeliness of weather advisories to all users, in all phases of flight. The single authoritative source (4-D Weather) enables users to get directly tailored “information”, without having to access and manually integrate several data sources. The weather information is highly tailored to a particular flight situation, thus increasing the utility of the information and reducing the chance of misinterpretation.

During preflight, pilots, flight planners, and service providers more readily come to agreement on the weather situation, with the resulting improved traffic flow and flight safety. Especially in the case of GA pilots, better “go-no go” decisions are possible, reducing the chance of encountering unexpected weather situations. While in-flight, the weather capability automatically notifies all affected parties when an unanticipated weather change has occurred. This includes direct broadcasts of weather alerts to in-flight aircraft in or near a weather impacted area or flight path.

5.5. Oceanic/International Support

A seamless transition of information and weather products is provided when moving from the national airspace to oceanic or international airspace. Information exchange and cooperative decision-making continue to be primarily automation-to-automation, but an increased human role in the decision-making process may be required due to the potentially lower levels of infrastructure. All information is delivered through the NGATS’ hybrid ground/satellite communications links. The communications system automatically switches to satellite-based communications over regions without ground links.
Net-enabled information access and NDOTs provide access to vital timely and accurate weather information from the 4-D Weather. Measured and predicted winds, temperatures, convection, volcanic ash, icing, and turbulence forecasts, as well as satellite images of cloud tops or satellite-derived products formatted for use by automated systems are available for potential flight routes. Data from ground and ocean surface sources, manned aircraft, UASs, and atmospheric-sensing satellites, along with forecasts data are incorporated into 4-D Weather. Information, including probability and severity estimates suitable for automation systems’ use, is available from this database. Aircraft flight deck and ATC NDOTs may use the information directly or use it to create custom products for humans. On polar routes, space weather information is of particular importance in order to minimize crew and passenger exposure to dangerous radiation. Fuel freeze is also of particular concern on northern routes. Ground-based and satellite weather information, including composite radar images and satellite products, is accessible to the aircraft as it becomes available, as are forecasts of relevant parameters (e.g., flight level temperatures). NDOTs plan a safe and efficient flight route using all available pre-flight information, and continuously monitors for changing weather conditions and tactical hazards including significant convection, hail, volcanic ash clouds, and en-route wake, convection, and clear air turbulence.

Automated systems control the aircraft’s onboard radar and other forward-looking sensors (e.g., Lidar and passive Infrared [IR]) monitoring the development of thunderstorms and enabling aircraft to maintain safe separation from rapidly developing cells. The automated airborne surveillance system identifies other potential hazards including icing, hail, volcanic ash, and all classes of turbulence. Flight deck NDOTs continuously scan both in situ observations and 4-D Weather and report aircraft-specific hazards to the flight crew, while the route optimization system helps re-plan the flight route as necessary while airborne.

Aircraft act as fully enabled nodes on the information access network and may process information to produce localized forecasts/nowcasts, as well as providing and consuming data from in situ and forward-looking sensors via broadband bi-directional data-links to satellites, ground stations, and nearby aircraft. Observations from the aircraft, such as forward-looking sensor-derived products, detected lightning, flight level winds, and in situ measurements of temperature, humidity, icing, and turbulence are continuously broadcast to provide updates for use by nearby aircraft and the 4-D Weather. Aircraft-based forecast/nowcast products, if sufficiently validated, are incorporated into this 4-D Weather for all users and provided to nearby aircraft.

5.5.1 Oceanic

Oceanic operations depend heavily on the net-enabled infrastructure to integrate satellite data, ship and buoy observations, and aircraft forward-looking and in situ sensor information. Accurate flight-level wind information derived from forecast products incorporating these observations enables routing decisions that maximize efficiency. Sensor information from manned and UAS aircraft are fully exploited in the weather information processing infrastructure and made accessible through net-
enabled communications. Weather and atmospheric information is integrated by this infrastructure for strategic traffic management and to produce hazard alerts, and by aircraft automation systems producing aircraft-specific hazard alerts and supporting decision-making.

5.5.2 International

International operations in developed areas, such as Europe, rely on the local weather information management infrastructure, which is harmonized worldwide and provides weather hazard detection and forecasting capabilities to ground and airborne users for collaborative decision making. This information supports ground and airborne decisions, including those made by automated decision-support systems, air traffic managers, and pilots. Operations in underdeveloped areas depend heavily on NGATS communications infrastructure for 4-D forecast/nowcast products and net-enabled information access among manned aircraft and UASs to augment sparse local observations. Forward-looking and in situ airborne sensors provide critical weather information and alerts for wind shear, turbulence, icing, altitude density, and other hazards, on-board, air-to-air, and to the 4-D Weather.

5.6. Space Weather Impacts to NGATS

5.6.1. Aircraft and Spacecraft Vehicle Radiation Support

As the number of aircraft using polar routes increases, more passengers and crew are exposed to cosmic radiation for longer periods of time. The amount of exposure to cosmic radiation (CR), which consists of energetic particles of both galactic and solar origin, depends on the duration of flight, as well as, altitude, latitude, and solar activity. Vehicles operating in the high latitudes (north and south poles) are more exposed to radiation hazards than vehicles operating in the mid-latitudes. Similarly, vehicles operating at orbital altitudes are more exposed to radiation hazards than vehicles flying at typical en route flight levels. To alert vehicles to radiation hazards, NGATS ingests both current and forecast radiation levels based on a vehicle’s position and flight level. Solar radiation levels from the surface to upper atmospheric regions are measured in real time and displayed on a global map using color schemes depending on the alert levels. CR levels are constantly monitored along the vehicle’s trajectory, taking into effect the projected flight duration. Cockpit graphical displays map the CR levels based on trajectory information. When CR levels exceed the threshold values, the NDOTs send a message to the crew with a recommended flight altitude, or other mitigation measures.

5.6.2. Satellite Navigation

NGATS takes advantage of real-time and forecast space weather information to alert the crew to hazards of timing signal errors on satellite based navigation aids. Since timing delays from the satellite to the navigation system depend largely on conditions in the ionosphere (total electron content (TEC)), the NDOTs (i.e., evaluator) obtain
current and forecast TEC levels. Based on these levels, the projected Global Positioning Satellite (GPS) errors are sent to the satellite-based navigation provider, for inclusion into their error monitoring systems and also shown on graphic displays in the cockpit. The current and forecast GPS errors are highlighted in color, depending on the level of severity and tracked based on the vehicles trajectory. A warning message is sent from the NDOTS to the crew if the current or projected trajectory intersects regions of large errors. Due to rapid changes in the TEC, scintillations of the propagated signal results in times when the transmitted signals are unavailable to the receiver. The NGATS alerts aircrew and traffic management when these conditions occur.

5.6.3. HF, Satellite, & UHF Communication

NGATS seeks to minimize communication errors by making available to the pilot and crew, current and forecast space weather conditions that may affect operations. Knowledge of this information helps maintain communication during all phases of flight. The NDOTs receive current and forecast space weather indices for geomagnetic and solar radiation storms, and radio blackouts and determine a best-frequency solution given the vehicle’s flight plan. A warning message is sent from the NDOTs to the crew when interruptions to the voice/data communication services are imminent, or forecast to occur in the near future.

5.7. Airport Management Support

Airport, air carrier, and GA management includes activities to enable passenger, flight and cargo operations to be conducted within airport considerations of safety, efficiency, resource limitations and local environmental issues.

For NGATS, the airport system in 2025 provides sufficient infrastructure to accommodate user demand. To attract travelers and operators, increased competition among major commercial, secondary, and reliever airports is expected. Airports respond with measures to stay cost effective, while remaining convenient for travelers and shippers alike. To maintain positive community relationships, multiple airports in a geographic region coordinate planning to provide a range of facilities that balance transportation needs with environmental standards for noise and emissions. The NGATS meets users needs from maximizing overall metropolitan area capacity to servicing smaller communities as well as airport access alternatives and associated transportation, security, and information systems requirements such as regional airports, and city check-in by specific location.

NDOTs integrated with improved weather forecasts (e.g., probabilistic) and observations make decisions or provide users with alternatives involving:

a. Runway snow removal due to off-nominal weather (e.g., snowfall rate and type). More efficient snow removal management results in increased availability of runways, taxiways, gates, and other airport facilities during winter weather events, positively impacting airport arrival and departure rates.
b. Aircraft de-icing schedules, chemical mixtures, and the need for additional treatments due to off-nominal weather (e.g., snow, freezing rain). More efficient de-icing management results in improved levels of safety and efficiency.

c. Changes to runway configuration due to nominal (e.g., wind shift) and off-nominal (e.g., convective) weather. More efficient airport surface management positively impacts airport arrival and departure rates.

d. Forecasted changes to wake departure separation procedures due to nominal (e.g., winds, turbulence, ceiling, visibility) and off-nominal (e.g., convective) weather, as well as wake observations and forecasts (e.g., transport, duration, descent rate). More efficient arrival and departure procedure management allows greater use of alternate separation procedures, positively impacting airport arrival and departure rates while maintaining safety.

e. Reduction of environmental impacts, in an environment where arrivals and departures are significantly increased from today. This allows noise and pollution impacts to be better understood and mitigated, allowing for increased airport arrival and departure rates (i.e., balance transportation needs with environmental standards).

f. Weather conditions in the terminal area that may impact airport operations or service levels. More efficient Tower operations improve airport efficiency, including airport arrival and departure rates, as well as help maintain safety.

g. Ramp operations that are impacted by lightning in the vicinity of the airport. Improved total lightning observations in the airport area, along with translation of these weather observations into the likelihood that lightning strikes at the airport are possibly imminent, make ramp operations safer and more efficient.

NGATS net-centric weather dissemination allows for remote Tower operations and completely revamps the airport weather infrastructure making a common weather operating picture available to all users; maintaining different user weather perspectives; revitalizing the weather dissemination infrastructure; providing more reliable weather forecasts; and fusing weather observations and forecasts into a common weather situation. This weather information infrastructure enables a consistent, common weather view and enhances the safety and efficiency of airport operations.

5.8. Unmanned Aircraft Systems (UAS) Support

In 2025, UASs are operating in all spectrums of the airspace from several feet above the ground (Agricultural) to operations at very high altitudes (e.g., Global Hawk and High Altitude Airships). In order to perform their missions safely and successfully, and to provide valuable information to the ATMs and aircraft flying in the NAS,
select UASs ingest many different meteorological data fields and are responsible for continuously monitoring and interpreting the conditions in the airspace. While the weather parameters are similar to current weather parameters that aircraft operating in the NAS depend upon today, some parameters are vastly different and mission dependent. Upon request, the UAS owner/operator may provide a threshold or condition to NDOTs which, if exceeded, cause a message to be issued to the UAS or UAS operator. The UAS operator or control system can then take necessary action, such as changing the altitude or aborting the mission.

5.8.1. Low Altitude Weather Needs

At low altitudes, most of the UASs are used for agricultural purposes, border patrol, search and rescue, and other surveillance missions. In these cases, real time weather parameters such as wind, visibility, cloud cover, relative humidity, and precipitation are important to these vehicles. NGATS incorporates real time surface wind observations for specific operating locations. Wind speed, direction, and shear are especially important to these low altitude UASs because of their close proximity to the ground. Each vehicle has a specific operating requirement for every weather element. For example, the wind constraint for a particular UAS is loaded into the NDOTs and during flight; the winds are constantly assessed to determine whether they are satisfactory at the selected altitudes. If the conditions are determined as unsatisfactory, a message is sent to the onboard control system, or the UAS Operator, causing the UAS to take action.

5.8.2. Mid Altitude Weather Needs

The safe operation of the UASs operating in the middle level of the NAS, or the high traffic regions is crucial to the safety and operations of manned aircraft flying in the same airspace. These UASs like those operating at the low and high altitudes are equipped with sensors to determine atmospheric conditions such as: such as turbulence, icing, wind, temperature, radiation, and TEC along a given flight path. They report this data directly to other aircraft in the vicinity, the vehicle’s onboard control system, or if remotely piloted, to the UAS operator.

5.8.3. High Altitude Weather Needs

Unique weather information needs for high altitude vehicles (e.g., Global Hawk and High Altitude Airships) are needed to support operations at the upper reaches of the atmosphere. UASs used for space station servicing missions are dependent on the conditions conducive to deep dielectric charging, TEC conditions, and other space weather conditions that may affect the vehicle’s operations.

Forecast weather information from 120 hours up to six months is needed for the nearly stationary high altitude communication platforms (Airships). Observations of wind and space weather conditions alert the operator and traffic managers of unstable conditions or potentially inaccurate positions and signal degradation.
## Appendix A

### Definitions/Acronyms

<table>
<thead>
<tr>
<th>Definitions</th>
<th>Description</th>
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<tbody>
<tr>
<td>Broad Area Precision Navigation</td>
<td>‘Instrument landing’ navigation precision with no ground-based navigation aids at any ‘air portal’</td>
</tr>
<tr>
<td>Climatology</td>
<td>Historical weather observations analyzed to extract information</td>
</tr>
<tr>
<td>Decision Assistance Tool</td>
<td>TBD</td>
</tr>
<tr>
<td>Decision Loop</td>
<td>Application that integrates data and through software produces a recommendation or decision</td>
</tr>
<tr>
<td>Equivalent Visual Operations</td>
<td>The concept that allows VFR-level operations to be maintained even under zero-level visibility.</td>
</tr>
<tr>
<td>Evaluator</td>
<td>An NGATS ATM automation tool</td>
</tr>
<tr>
<td>Formatter</td>
<td>TBD</td>
</tr>
<tr>
<td>Fully Performance Capable</td>
<td>Aircraft with all equipment required to operation in the most congested airspace</td>
</tr>
<tr>
<td>Invisible Weather</td>
<td>Fully integrated and transparent to users</td>
</tr>
<tr>
<td>Learning automation</td>
<td>Accounts for weather and its uncertainties in managing aircraft trajectories</td>
</tr>
<tr>
<td>Net Centric Information Sharing</td>
<td>Global secure access, information handled according to ‘communities of interest’</td>
</tr>
<tr>
<td>NGATS Decision Oriented Tools</td>
<td>All decision support tools used to make decisions (machine to machine) or to recommend decisions to humans</td>
</tr>
<tr>
<td>Part 121</td>
<td>Domestic, Flag, and Supplemental Aircraft and Commercial Operators of Large Aircraft</td>
</tr>
<tr>
<td>Part 135</td>
<td>Commuter and on demand operations (Business Jets and Air Charters)</td>
</tr>
<tr>
<td>Part 95</td>
<td>General operating and flight rules (General Aviation)</td>
</tr>
<tr>
<td>Private Weather</td>
<td>Weather products produced by vendors</td>
</tr>
<tr>
<td>Probability Forecasting</td>
<td>Forecasting method that manages the remaining uncertainty in forecast accuracy</td>
</tr>
<tr>
<td>Public Weather</td>
<td>Owned by government</td>
</tr>
<tr>
<td>Pulled</td>
<td>Data acquired by system needing it</td>
</tr>
<tr>
<td>Pushed</td>
<td>Data sent to system needing it</td>
</tr>
<tr>
<td>Tactical Decision</td>
<td>TBD</td>
</tr>
<tr>
<td>Strategic Decision</td>
<td>TBD</td>
</tr>
<tr>
<td>User</td>
<td>All users of the NGATS</td>
</tr>
</tbody>
</table>
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>4-D</td>
<td>Four Dimensional</td>
</tr>
<tr>
<td>AAR</td>
<td>Airport Acceptance Rate</td>
</tr>
<tr>
<td>ADDS</td>
<td>Aviation Digital Data Service</td>
</tr>
<tr>
<td>AIRMET</td>
<td>Aeronautical Meteorological Information</td>
</tr>
<tr>
<td>Alts</td>
<td>Alternatives; machine to human display of decision alternatives</td>
</tr>
<tr>
<td>AOC</td>
<td>Airline Operations Center</td>
</tr>
<tr>
<td>ASOS</td>
<td>Automated Surface Observing System</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATCSCC</td>
<td>Air Traffic Control System Command System</td>
</tr>
<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>ATS</td>
<td>Air Traffic Services</td>
</tr>
<tr>
<td>BUFR</td>
<td>Binary Universal Form for the Representation of meteorological data; a WMO data encoding scheme</td>
</tr>
<tr>
<td>CDM</td>
<td>Collaborative Decision Making</td>
</tr>
<tr>
<td>CNS</td>
<td>Communications, Surveillance, and Navigation</td>
</tr>
<tr>
<td>ConOps</td>
<td>Concept of Operations</td>
</tr>
<tr>
<td>CR</td>
<td>Cosmic Radiation</td>
</tr>
<tr>
<td>DHS</td>
<td>Department of Homeland Security</td>
</tr>
<tr>
<td>DOC</td>
<td>Department of Commerce</td>
</tr>
<tr>
<td>DOD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>EVO</td>
<td>Equivalent Visual Operations</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
</tr>
<tr>
<td>FAR</td>
<td>Federal Aviation Regulation</td>
</tr>
<tr>
<td>FIP</td>
<td>Forecast Icing Potential</td>
</tr>
<tr>
<td>FSS</td>
<td>Flight Service Station</td>
</tr>
<tr>
<td>GA</td>
<td>General Aviation</td>
</tr>
<tr>
<td>Gif</td>
<td>Graphics Interchange Format; a compressed graphic file used for images</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning Satellite</td>
</tr>
<tr>
<td>GRIB</td>
<td>GRIdded Binary; a WMO data encoding scheme</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
</tr>
<tr>
<td>IFR</td>
<td>Instrument Flight Rules</td>
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<tr>
<td>Info</td>
<td>Information Display; machine to human display that organizes information for decision support</td>
</tr>
<tr>
<td>IPT</td>
<td>Integrated Product Team</td>
</tr>
<tr>
<td>IR</td>
<td>Infrared</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<td>-----------</td>
<td>------------------------------------------------------------------------------</td>
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<tr>
<td>JPEG</td>
<td>Joint Photographic Experts Group; a file compression format commonly used for graphics</td>
</tr>
<tr>
<td>JPDO</td>
<td>Joint Planning and Development Office</td>
</tr>
<tr>
<td>LAX</td>
<td>Los Angeles International Airport, CA</td>
</tr>
<tr>
<td>M2M</td>
<td>Machine to Machine</td>
</tr>
<tr>
<td>MDCRS</td>
<td>Meteorological Data Collection and Reporting System</td>
</tr>
<tr>
<td>METAR</td>
<td>Meteorological Aviation Report</td>
</tr>
<tr>
<td>NAS</td>
<td>National Airspace System</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NCWF</td>
<td>National Convection Weather Forecast</td>
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<tr>
<td>NDOT</td>
<td>NGATS Decision Oriented Tool</td>
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<tr>
<td>NDOT-A</td>
<td>NDOT ATM</td>
</tr>
<tr>
<td>NDOT-F</td>
<td>NDOT Flight Community</td>
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<tr>
<td>NEO</td>
<td>Net Enabled Operations</td>
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<tr>
<td>NEXRAD</td>
<td></td>
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<tr>
<td>NEWIS</td>
<td>Network Enabled Weather Information Sharing</td>
</tr>
<tr>
<td>NGATS</td>
<td>Next Generation Air Transportation System</td>
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<tr>
<td>Nm</td>
<td>Nautical Miles</td>
</tr>
<tr>
<td>ORD</td>
<td>Chicago O’Hare International Airport, Illinois</td>
</tr>
<tr>
<td>ROV</td>
<td>Recoverable Orbital Vehicle</td>
</tr>
<tr>
<td>RTSP</td>
<td>Required Total System Performance</td>
</tr>
<tr>
<td>RWP</td>
<td>Required Weather Performance</td>
</tr>
<tr>
<td>SIGMET</td>
<td>Significant Meteorological Information</td>
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<tr>
<td>SMS</td>
<td>Safety Management System</td>
</tr>
<tr>
<td>TAF</td>
<td>Terminal Aerodrome Forecast</td>
</tr>
<tr>
<td>TAMDAR</td>
<td>Tropospheric Airborne Meteorological Data Reporting</td>
</tr>
<tr>
<td>TEC</td>
<td>Total Electron Count</td>
</tr>
<tr>
<td>TFM</td>
<td>Traffic Flow Management</td>
</tr>
<tr>
<td>TMU</td>
<td>Traffic Management Unit</td>
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<tr>
<td>TRACON</td>
<td>Terminal Radar Approach Control</td>
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<tr>
<td>UAS</td>
<td>Unmanned Aircraft System</td>
</tr>
<tr>
<td>VFR</td>
<td>Visual Flight Rules</td>
</tr>
<tr>
<td>WAAS</td>
<td>Wide Area Augmentation System</td>
</tr>
<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
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</tbody>
</table>