11.6 NEXTGEN OPERATIONAL NEEDS AND THEIR INFLUENCE ON THE DEVELOPMENT OF WEATHER PERFORMANCE REQUIREMENTS

Cheryl G. Souders*
Frances Bayne
Federal Aviation Administration, Washington, District of Columbia

Robert Showalter
James Tauss
Lorraine Leonard
CSSI, Inc., Washington, District of Columbia

Jack May
AvMet Applications, Inc., Reston, Virginia

1.0 BACKGROUND

The Joint Planning and Development Office (JPDO) developed the Next Generation Air Transportation System (NextGen) Concept of Operations (ConOps) to identify the goals, objectives, and planned transformations needed to realize the NextGen vision. A key component to achieving NextGen capabilities is the assimilation of weather information into decision-making (JPDO, 2010). Assimilating weather information and its uncertainties into operational decisions is crucial to quantifying user risks (e.g., safety, comfort and convenience of flight, user business objectives, and Air Traffic Management (ATM) initiatives), which are based on operational thresholds and performance goals. Moreover, efficiencies can be realized if all National Airspace System (NAS) stakeholders use the same source of weather information. NextGen will provide a reliable, common source of weather information to a wide range of users. This supports collaborative decision-making by enabling air transportation decision-makers to be "in-sync" on the timing of Federal Aviation Administration (FAA) ATM, airline, or pilot actions.

2.0 PURPOSE

The intent of this paper is to aid the ATM and operational user communities in validating the NextGen Weather Performance Requirements Team's (NWPRT) assumptions and rationales for performance values based on the concepts in the NextGen ConOps. This operational feedback will provide a better understanding of ATM user needs and will result in the modification of any incorrect assumptions and the associated performance values. Additionally, the NWPRT advocates further validation of weather performance requirements by performing operational research coupled with modeling and simulation.

3.0 METHODOLOGY AND ASSUMPTIONS

The NWPRT reviewed various NextGen Segment Implementation Plan (NSIP) mid-term and NextGen far-term documents to understand desired operational performance improvements. These references for the envisioned NextGen ATM functionality support the following operational areas:

- Surface Movement Management
- Integrated Arrival/Departure Management
- En Route Operations
- Traffic Flow Management

3.1 Weather Information Consistency

Multiple operational areas often need the same type of weather information at the same time. For example, wet or icy airport surfaces affect braking distances on runways and taxiways, impacting surface movement initiatives. As a result, airport arrival rates are reduced, which in turn influences En Route and Traffic Flow Management decisions.

3.2 Solution-Independent Approach

The emphasis of the NWPRT was to develop operationally relevant, solution-independent weather performance requirements. For example, the team did not define precipitation intensity performance in terms of dBZ, i.e., radar

* *Corresponding author address:* Cheryl G. Souders, FAA, 800 Independence Ave, SW, Washington DC 20591; e-mail: Cheryl.Souders@faa.gov

reflectivity factor (Glossary of Meteorology, 2000) as it is solution specific (i.e., radar). Rather, the team developed requirements in terms of weather elements that impact operations. For example, the amount of liquid water suspended in the air has operational ties to in-flight icing. Thus, the team developed performance requirements for meteorological "ingredients" to determine the existence of in-flight icing, e.g., liquid water content (LWC), liquid water equivalent (LWE), and median volume diameter (MVD).

3.3 Weather Performance Drivers

NextGen operational decision-makers need to be confident that they can rely on the weather information they receive. Therefore, the values for observed and forecast weather elements must be sufficiently accurate for both NextGen decision-making and assimilation into their Decision Support Tools (DST). Decision-makers also need the weather information to be delivered at user-specified temporal and spatial resolution, forecast accuracy, and latency. For the concept of virtual aircraft departure queues, the availability of accurate weather supports effective departure scheduling -- where the aircraft is at the gate with engines off versus on the taxiways wasting fuel waiting in a departure queue.

The NWPRT identified performance values for weather elements that are required for NextGen operational decision-making. In general, these values require the highest performance in high-density terminal airspace (or Core airports) to ensure that 1) NAS decision-makers and the DSTs upon which they rely are continually apprised of weather conditions needed for landings and takeoffs, and 2) aircraft operating in high-density airspace will arrive and depart efficiently approximately every minute. Accordingly, the team selected an update rate of less than or equal to 1 minute for observations of convective weather elements in high-density terminal airspace.

As operational needs drive requirements, weather information must be observed and forecast at a sufficient density (e.g., at locations or points in space) to accurately represent the weather between known locations along a trajectory. It is also important to inform users if and how fast the weather is changing. This is especially true when the weather conditions approach or pass through operational users' thresholds. This alerts users of the potential need to adjust their operations. Faster weather updates are required where the greatest sensitivity to changing weather exists. They need to be continually aware of the potential impact of weather on operations, which dictates an increased weather forecast update frequency. For example, weather performance values are the most stringent for current and forecast weather conditions in high-density terminal airspace where there is the greatest number of operations, complexity of operations, and required precision of operations. NextGen operations conducted in the en route or global airspace require less constrained performance values. However, for those weather elements that impact safety (e.g., convection and turbulence) have the same required measurement performance regardless of airspace category.

3.3.1 Surface Movement Management

Surface movement management is extremely important, especially for Core airports. If congested runways and taxiways prevent aircraft from landing or departing efficiently, many NextGen-envisioned efficiencies aloft will go unrealized. In NextGen the efficiency and safety of surface traffic management is increased through the use of improved surveillance, automation, on-board displays, and data link of taxi instructions. Equipped aircraft will provide surface traffic information in real time. This information will be processed by cockpit and in-vehicle displays of traffic information, moving maps, and other DSTs to provide pilots and ground vehicle operators with improved surface movement surveillance capabilities. In addition, Airport Operations Centers and Flight Operations Centers will have access to this information to develop a real time picture of the locations of vehicles and aircraft on the surface. Enhanced surveillance and communications provide proactive alerts to pilots and ground vehicle operators, enabling them to take action to avoid runway incursions and surface collisions (JPDO, 2010).

A comprehensive view of traffic flows enables the Air Navigation Service Provider (ANSP) to more accurately manage arrival and departure *demand*; predict, plan, and manage surface movements; and balance runway assignments. This facilitates more efficient surface movement and arrival/departure flows. Automation monitors conformance of surface operations to ANSP instructions and updates estimated departure clearance times. Surface optimization automation includes activities such as runway snow removal and runway configuration (FAA, 2010). Trajectory Based Operations (TBO) migrates from en route cruise to arrivals within the NSIP mid-term timeframe, linking en route trajectories to top of descent and then through optimized profile descents to approach and landing. With the introduction of surface movement management tools, three-dimensional (3-D) trajectories (i.e., lateral, longitudinal and time) are used for sequencing aircraft for departures (JPDO, 2011).

In NextGen, increased safety and efficiency of aircraft and ground vehicle movements on the airport surface are enabled through (FAA, 2011):

- Resource management through the use of Surface Management Systems (e.g., maximize the effectiveness of existing resources, such as runways, taxiways, gates and terminals to increase airport efficiency)
- Virtual aircraft queues
- Surface impact mitigation capabilities

These capabilities will have a role in improving:

- Emergency response
- Surface movement, conformance, and management of aircraft
- Snow clearance/pavement deicing activities
- Aircraft deicing and anti-icing activities
- Holdover time estimates
- Airfield maintenance activities

Operational decisions related to terminal include metering/spacing decisions, arrival/departure route selection, runway and taxi route selection, and changes in airport traffic pattern. For high-density airports, observed and forecast weather information covering the entire airport complex are required to support surface management, because the terminal surface area at some airports is extensive, e.g., Denver. The horizontal resolution must be sufficiently constrained to depict any variability in operational impacting weather elements at the surface. Meteorological elements required include:

- Dew point
- Temperature
- Visibility
- Wind speed/direction/character
- Liquid water equivalent
- Lightning
- Ice accretion rate
- Precipitation rate
- Precipitation type
- Precipitation accumulation

Weather over the entire airport complex is needed to determine the need to restrict taxiways in the event of localized hazards such as fog, freezing drizzle, or freezing spray at susceptible coastal terminals. The impact of weather can have a cumulative effect on delay. Air traffic tools that calculate holdover or nominal taxi times consider weather conditions and other airport operational constructs that affect taxiing. For example, adverse weather could affect adjustments of taxi times for aircraft passing through deicing. When such adjustments are added to queue length and other constraints on surface movement throughput are factored in, takeoff times can easily be modified.

At airports that experience winter weather, strategic resource management tools will provide guidance to air traffic planners of the potential for delays. For example, delays originating at the airport may arise from deicing and anti-icing activities, snow removal, and runway treatment. Current conditions and accurate forecasts of freezing or frozen precipitation and surface icing accretion will help to mitigate these delays.

There are several weather elements that contribute to surface and aircraft icing including temperature, winds, precipitation type/rate of fall, and water content. Ground crews use the observed and forecast values of these elements when selecting and applying anti-icing or deicing chemicals to mitigate aircraft icing. In NextGen, these elements will be integrated into decision-making, thereby aiding ground crews in selecting and applying anti-icing and deicing chemicals to mitigate aircraft icing.

To support deicing and anti-icing guidance, the NWPRT determined that the required weather performance values are consistent with engineering data on solution effectiveness (Transport Canada, 2007). Forecasts of temperature and dew point with an accuracy of plus or minus 1 degree Celsius are required. The rationale for this level of performance is that it affects the effectiveness of the deicing and anti-icing fluids, which are very sensitive to these temperatures.

Winds influence the selection of operational runways and determination of crosswind component, as well as the time it takes to deice aircraft. These activities have an effect on how well the virtual departure queues perform, e.g., time to pass through deicing/anti-icing activities. Forecasts of wind direction accuracy of plus or minus 5 degrees and wind speed with an accuracy of plus or minus 1 knot (for winds less than or equal to 10 knots) or plus or minus 10 percent (for winds greater than 10 knots) also support the virtual departure queue functionality through reductions in aircraft fuel burn and airfield congestion along with associated delays. To facilitate the determination of holdover times, observation and forecast accuracies for the following weather elements are needed:

- Observed ice accretion rate – plus or minus 0.05 inch per hour
- Observed water equivalent of frozen precipitation accumulation – plus or minus 0.01 inch per hour
- Forecast rate of fall of liquid precipitation - plus or minus 0.01 inch per 6 minutes (Rasmussen, 2000)
- Forecast rate of fall of frozen precipitation - plus or minus 0.1 inch per hour for less than or equal to 1 inch per hour and plus or minus 10 percent for greater than 1 inch per hour
- Forecast ice accretion rate – plus or minus 0.1 inch per hour for less than or equal to 1 inch per hour and plus or minus 10 percent for greater than 1 inch per hour
- Forecast water equivalent of frozen precipitation accumulation – plus or minus 10 percent

Over time, any of the above elements can dilute the deicing solutions and potentially reduce their effectiveness.

Additionally, visibility observations and forecasts support collaborative surface management decisions between air traffic personnel, operational field personnel, ramp controller/manager, and the flight deck. Visibility information also influences gate hold times, departure queues, surface movement coordination, and airfield maintenance. The NWPRT determined that accuracy requirements for observing visibility will be the same in NextGen as today. However, forecasts of visibility will require higher accuracies and RVR values will also be forecast.

More frequent updating of forecasts and improved forecast verification skill will help build user confidence in the forecast information (FAA, 2007). In high-density terminal airspace, for convective and non-convective weather element, forecasts for periods less than or equal to 2 hours will be updated every 5 minutes or less; for periods greater than 2 hours to less than or equal to 4 hours; every 10 minutes or less. Forecast verification skill for periods less than or equal to 4 hours will be 90 percent or greater; for periods greater than 4 hours to less than or equal to 24 hours, 85 percent or greater. These performance values provide sufficient confidence to support proactive resource allocation and guidance for surface management automation.

For observations, the NWPRT determined a weather update rate of less than or equal to 5 minutes for high-density terminal and medium hub airport surfaces for non-convective weather elements supports surface management needs. These needs include surface movement throughput, queue length, deicing activities, etc. The weather observation update rate requirement is less than or equal to 20 minutes for designated global terminal surfaces. The 20-minute update rate is sufficient for flight planning and determining potential weather-related constraints.

The update rates are the same for all of the weather elements noted above that support surface management needs (e.g., wind speed is updated at the same rate as visibility). The NWPRT used the same rationale for updating all the weather elements as previously described for the spatial resolutions. This update performance value supports the need to provide weather changes at a rate consistent to mitigate weather impacts on airport surface movement. Update rates are the most constrained at high-density airspace terminals where operations are more robust in order to support the provision of near real time information and enhanced situational awareness for current runway, taxiway, and gate conditions. The update performance for designated global terminal surfaces is a function of distance to these airports and the need to know how fast the weather is changing (JPDO, 2007).

3.3.2 Integrated Arrival/Departure

The integrated arrival/departure concept creates additional Area Navigation (RNAV) arrival and departure routes that extend beyond the traditional terminal airspace area. This provides flexibility in assigning these routes to accommodate the increased *demand*. Specifically this flexibility is enabled by time-based metering functionality for Required Navigation Performance (RNP)/RNAV assignments that support arrival, surface, and departure flow operations. It also improves airport *capacity* through expanded implementation of Optimized Profile Descents (OPD). As the number of aircraft in the terminal airspace increases, so does the need to provide and expanded the area of accurate winds to perform compression calculations. It will be important in NextGen to reduce the effects of compression of aircraft due to winds (a.k.a. path-based wind shear) to conduct more precise OPDs.

The automation provides the ANSP with decision support for the following:

- Conflict resolution
- Managing/issuing clearances
- Managing lateral offsets
- Flexible airspace configurations
- Metering management
- Resource loading

Automated capabilities also enable the airlines to effectively manage their aircraft and provide better services. For example, automation enhances the response to a pilot request to deviate (e.g., conflict resolution) due to weather at the Top of Descent (TOD), or managing/issuing clearances when weather affects near surface or merging airspace. Flexible airspace configurations can be created when sudden or forecast weather changes create temporary restrictions in the use of the airspace, which enables metering management where en route flows are converging into integrated arrival/departure airspace. Resource loading is also a large consideration when managing the use of runways that will remain open during weather events.

Automation systems use weather information to develop guidance to help decision-makers achieve performance goals (JPDO, 2010). This includes the weather on airport surfaces, and approach and departure corridors, as well as optimum descent profiles and tailored arrivals. This automation supports the ANSPs ability to manage airspace to accommodate *demand*. Weather can also affect the horizontal, vertical, and timing of performance-based trajectories. Thus, the weather information needs to have a sufficient level of performance to support RNP capabilities. Weather observations and forecasts needed include:

- Wind speed and direction
- Ceiling
- Visibility
- Icing
- Turbulence
- Convective weather elements
- Space weather elements affecting communications and navigation for precision approaches

Weather can affect the ability of the aircraft to remain within RNP tolerances. For example, the terminal wind speed and direction affects the climb and descent vertical performance. Jetliner aircraft typically descend approximately 1,000 feet every 3 nautical miles. For a tailwind (headwind), the pilot will add (subtract) 1 nmi for every 5 knots of wind (FAA, 2008). More accurate wind speed and direction (both observations and forecasts) and the associated high-level precision wind profiles improve vertical descent conformance monitoring. The automation that monitors the vertical and horizontal performance (e.g., conformance) for merging flows (metering management) and predicts 3-dimensional conflicts from other aircraft or weather (e.g., low-level wind shear or microbursts) also needs this enhanced weather information.

In NextGen, performance-based navigation (PBN) encompasses a set of enablers with a common underlying capability to construct a flight path that is not constrained by the location of ground-based navigation aids. There are varying performances in the PBN family, from the 10 nautical mile (nmi) course width accuracy to the 0.1 nm precision and curved paths of RNP 0.1 Authorization Required (AR) approaches to the runway (JPDO, 2012). The NextGen landing precision of 0.1 nautical mile required at high-density airports is equivalent to 0.19 kilometer. RNP 1 is the NextGen requirement for a safe transition to arrival, and will have a safety containment of 2 nmi. (1 nmi either side of the centerline of flight path). To support improvements in arrivals in TBO, a RNP 1.0 at TOD will transition to a RNP 0.3 for terminal maneuvering. Precision landings will have a performance that uses RNP 0.1. To support this RNP precision, the NWPRT determined that accuracy values for observations of wind speed and direction are the same as for surface movement management to support the required navigation tolerances to meet climb and descent performance. Thus, observation accuracy values are the same for terminal and en route—plus or minus 0.5 degree for wind direction and plus or minus 1 knot for wind speed less than or equal to 10 knots and plus or minus 10 percent for wind speed greater than 10 knots. In addition, the NWPRT determined that the wind speed accuracy of plus or minus 10 percent is consistent with the need to support automation that ensures horizontal RNP 1 at TOD. Moreover, the NWPRT assumed these accuracy values would suffice for both the NSIP mid-term and NextGen far-term timeframes. Accordingly, the horizontal resolution of the grid on which these observation values would be represented is 0.5km for high-density terminal airspace for both convective and non-convective elements. For en route airspace, the horizontal resolution is less constrained—1km and 4km for convective and non-convective elements respectively.

In NextGen, for controllers to manage conflict resolution and metering, short-term forecasts of winds, icing, turbulence, and convective weather elements in the terminal airspace are essential. To support terminal operations, the NWPRT determined that the vertical accuracy would depend on two factors: height above the surface and forecast period. For example, from the surface to 5,000 feet AGL, weather elements would have a vertical accuracy of plus or minus 50 feet for forecast periods from 0 out to 10 hours. Forecasts beyond 10 hours and out to 7 days would have a vertical accuracy of plus or minus 100 feet. Above 5,000 feet AGL to the top of terminal/controlled airspace, vertical accuracy would be less constrained but use the same forecast periods as the lower level (surface to 5,000 feet AGL). Forecast periods out to 10 hours would have a vertical accuracy of plus or minus 250 feet, while forecasts beyond 10 hours and out to 7 days would be accurate to plus or minus 500 feet. The NWPRT also determined that these values would support NextGen automation that will monitor the vertical and horizontal performance (e.g., conformance) for merging flows (metering management) and predict 3-D conflicts from other aircraft.

In NextGen high-density terminal airspace, aircraft are able to fly at closer lateral separations and 'tighter' Reduced Vertical Separation Minimums (RVSM). Currently, strategic lateral offsets are only authorized in en-route oceanic or remote continental airspace. They are established at a distance of 1.85 km (1 nmi) or 3.7 km (2 nmi) to the right of the centerline relative to the direction of flight (ICAO, 2011). The NWPRT made the determination that these same strategic lateral offsets, or less, are valid for horizontal resolution of weather information in NextGen terminal airspace.

Scheduling decisions influenced by predicted weather allows for needed adjustments to minimize the impact of adverse weather on operations. Forecast weather conditions at the described performance accuracies support terminal automation equipped with arrival and departure tools, as well as merging and sequencing tools. These tools assist ANSPs with assessing departure routes relative to weather and traffic flow constraints. This includes pre-coordinating departure routes, developing departure schedule and sequences based on arrival traffic, flight operator schedules, and the available *capacity* of departure merge points. It is unlikely that changes to these decisions will occur at a greater rate than the weather forecast update times. When combined with traffic management initiatives, airport configuration, and aircraft performance, these tools enable more efficient traffic flows in and out of terminal airspace. The forecast weather will have particular importance at merging points or within merging airspace, because it affects the use of common departure fixes for aircraft from multiple airports and their subsequent ability to fit into TBO overhead flows**.**

The ability to change airspace boundaries (e.g., flexible airspace) in accordance with predefined configurations mitigates the impact of weather on operations, because it enhances the controllers' ability to accommodate increasing *demand*. This is especially true for proactively changing trajectories based on pilot or dispatcher requests. The forecast of convection and its associated attributes create the greatest need for modifying airspace boundaries. This occurs because convective weather elements can extend many thousands of feet vertically. Both ANSP and pilots will benefit greatly from knowing the extent of convection to manage flight over or around the affected airspace.

Any kind of deviation in flight path due to weather will affect timing performance – the need to have the aircraft arrive at a point in space within a time tolerance. For an aircraft from 80-120 miles out to within 3 miles from the end of runway, this tolerance is from plus 1 minute to minus 3 minutes (TBO report assumption) for a closed trajectory entering high-density terminal airspace. The tolerance increases to plus or minus 3 minutes for medium-density airports and plus or minus 5 minutes for low-density airports. The weather location and magnitude performance values enable the ability to deviate efficiently and to stay within this tolerance. Assuming an average commercial aircraft speed of 5 nmi/minute from TOD to 3 miles from the end of the runway, the flight time is approximately 20-25 minutes. To maintain timing tolerances, forecasts of weather elements in high-density terminal airspace will be updated every 5 minutes or less for the period from 0 to less than or equal to 2 hours.

As a result, the NWPRT determined that observations of convective weather and non-convective weather elements require a horizontal accuracy of plus or minus 0.25 km for high-density airports. The required horizontal accuracy for medium-to-small hubs is plus or minus 0.5 km for convective elements and 2 km for non-convective elements. Forecasts of convective and non-convective weather elements require a horizontal accuracy of plus or minus 0.25 km for periods out to 4 hours for high-density airports. For medium-to-small hubs and non-hub airports, the required horizontal accuracy for convective elements is plus or minus 0.5 km for periods out to 2 hours and plus or minus 1 km for periods greater than 2 hours out to 4 hours. For non-convective elements, the required horizontal accuracy is plus or minus 2 km for periods out to 4 hours. In part, the rationale for these performance values is consistent with traffic count, equipage, and the need to support the greatest operational performance capabilities in high-density terminal airspace (surface). The performance values for convective forecast elements are more constrained because of the greater potential for aviation impact (FAA, 2011).

3.3.3 En Route Operations

In en route, performance values for weather information do not need to be as constrained as they are in the high-density terminal airspace. At cruise altitude, the tempo of operations is less robust and while separation assurance is still critical, most aircraft are equipped with technology alerting them when their trajectories indicate loss of separation. Nonetheless, en route operations require greater efficiency for *capacity* to meet *demand*, particularly when areas of turbulence, patches of in-flight icing, or convective activity over large areas restrict or limit the ability of ATM to route or reroute the flow of traffic.

In the NextGen era, advanced techniques and emerging technologies will enable ATM to manage en route airspace more efficiently, enabling NAS *capacity* to meet or exceed that of *demand*. In addition, ATM will require knowledge of user thresholds for weather variables that impact operations, e.g., turbulence, in-flight icing, and convection. Accordingly, assimilation of these weather-impacting variables into automation/DSTs will provide ATM with throughput calculations around impacted routes and/or airspace with efficient vectoring recommendations. For en route, weather information will be required to support the following operations:

- RNP/RNAV flights
- Trajectory negotiation
- Conformance monitoring
- Arrival sequencing
- Merging
- Airspace configuration

These capabilities are detailed in the NSIP that delineates enhanced NextGen capabilities. For en route, Time-Based Flow Management (TBFM) will provide functionality to assure the smooth flow of traffic and increase the efficient use of airspace. This is accomplished in the NSIP mid-term with TBFM Operational Improvements (OI). OI 104120 - Point-in-Space Metering, works in conjunction with other metering OIs that will focus on scheduling and interval management tools that further expand Time-Based Metering (TFM) benefits down to the surface (FAA, 2012).

To ensure the continued use of metering during reroute operations in response to dynamic weather conditions, OI increment 104120-21 will enable traffic management coordinators to select from pre-defined meter points to establish alternative metering flows around congested airspace, convective weather, etc. This increment also includes the generation of updated trajectories and schedule assignments based on these alternative metering flows, for subsequent delivery to controllers for metering (FAA, 2012).

Current and forecast weather information to support en route operations includes:

- Hailstone size
- Ice accretion
- LWC and MVD of water droplets aloft
- Precipitation intensity
- Temperature
- Lightning
- Volcanic ash concentration/location
- Turbulence
- Wind speed
- Mesocyclone direction/speed of movement
- Vertical velocity aloft

TBFM automation requires accurate forecasts of weather elements to develop guidance in support of ANSP decision-making enabling them to meet performance goals of matching *capacity* with that of *demand*. This includes the en route airspace where aircraft predicted positioning is important for timing of optimum descent profiles down to tailored arrival fixes. Accordingly, weather information assimilated into TBO automation needs a sufficient level of performance to support the spatial and temporal position requirements of improved navigational capabilities of RNP in the NextGen era. For forecast winds up to the top of controlled airspace, wind direction accuracy will be plus or minus 5 degrees, and wind speed accuracy will be plus or minus 1 knot for wind speed less than or equal to 10 knots and plus or minus 10 percent for wind speed greater than 10 knots. The NWPRT determined these accuracy values were sufficient to support automation and trajectory modeling capabilities for both the NSIP mid-term and NextGen far-term timeframes for the en route airspace.

With the emphasis on TBFM and associated metering tools to track and monitor aircraft position, automation will be essential to NextGen. Not only will aircraft have to be tracked for separation assurance and monitoring of their position, but their future location and trajectory will need to be calculated as well. Such calculations are necessary for ATM functions such as 'conflict alert' to assess when loss of separation might occur. This improves the ability of the en route controller to discern if a pilot request for rerouting will result in a conflict with another aircraft on an intersecting trajectory. However, in the NextGen era, such calculations will increase several orders of magnitude and occur simultaneously for thousands of aircraft trajectories.

Another NSIP OI, 102137-23, is planned to improve trajectory modeling accuracy and conflict alert and detection algorithms. Trajectory predictions are subject to errors from a variety of sources. Increasing the accuracy of trajectory modeling is of utmost important to the performance and acceptance of many separation-management enhancements, with the accuracy of the trajectory modeler directly affecting missed and false-alert rates of Problem Detection. Increased trajectory modeling accuracy can be achieved through algorithmic improvements, updated aircraft characteristics data, expanded use of available flight information, expanded use of *weather* information (FAA, 2012) and the degree of constraint caused by weather in the NAS. Not only must the accuracy of the observed and forecast weather be improved (to support NextGen era automation), but the horizontal and vertical resolution (3-D grid spacing of the weather element values) must be finer (more constrained) to support the requisite improvements needed.

Knowing that assimilation of weather into automation and into trajectory modeling would be essential to decision-making during NextGen, the NWPRT determined accuracy values for weather forecast elements for the en route airspace which would include:

- Forecast wind speed: accuracy to plus or minus 1 knot for winds less than or equal to 10 knots; plus or minus 10 percent for wind speed greater than 10 knots
- Forecast verification skill would apply to all elements and vary by forecast period, e.g., greater than or equal to 92 percent out to less than or equal to 2 hours; greater than or equal to 88 percent for greater than 2 hours out to and including 4 hours; etc.

- Concentrations of volcanic ash aloft: accuracy of plus or minus 0.5 mg/cubic meter

Collaborative Air Traffic Management (CATM) coordinates flight and flow decision-making by flight planners and FAA traffic mangers to improve overall efficiency, provide greater flexibility to flight planners, and optimize the use of available airspace. Traffic managers impose Traffic Management Initiatives (TMIs) to account for congestion, *weather*, special activity airspace, or other constraints (FAA, 2012).

For TFM to manage metering and conflict resolution in en route using TMI automation, assimilation of medium-to-long range forecasts into automation is absolutely essential for the following elements—winds; in-flight icing; convective attributes, e.g., hailstone size, heavy precipitation; and turbulence. En route controllers, traffic flow managers, and airline dispatchers are already using automation to aid in their decision-making processes and to facilitate collaboration for routing/rerouting around weather impacts. In the NextGen era forecast weather information will not only be assimilated into aircraft flight-management systems but displayed to the crew as well. Quicker updates and finer resolution will enable tactical routing/rerouting to avoid emerging weather such as hail or turbulence. Examples of forecast accuracy values to support TFM in en route include:

- Hailstone size: accuracy of plus or minus 0.25 inch for diameter less than or equal to 2 inches, plus or minus 0.5 inch for diameter greater than 2 inches
- Turbulence: accuracy of plus or minus 10 percent of eddy dissipation rate (EDR)
- Airframe ice accretion rate 'ingredients': LWC accuracy – plus or minus 0.1g/cubic meter; MVD accuracy – plus or minus 5 microns for MVD less than or equal to 50 microns, plus or minus 10 percent for MVD greater than 50 microns; and Temperature accuracy – plus or minus 1 degree Celsius

LWE, LWC, and MVD of liquid water droplets support weather translations that specify the volume of airspace constrained by in-flight icing. With respect to airframe icing aloft, of particular concern is in-flight icing due to supercooled large droplets (SLD). While this kind of icing is similar to the icing formed by freezing precipitation, it poses a safety hazard even to aircraft equipped with wing deicing capabilities. With its reduced temperature, SLD promotes faster icing conditions and coupled with its larger droplet size tends to form just behind jetliner wing deicing equipment. SLD have a diameter greater than 50 microns and include freezing drizzle and freezing rain (FAA, 2007). The NWPRT determined that an observational accuracy of plus or minus 2.5 microns for droplet size less than or equal to 50 microns for the MVD of liquid water droplets will clearly define the crossover point from supercooled small droplets to supercooled large droplets (e.g., at droplet size of 50 microns) (FAA, 2012). In this case the flexibility is more horizontal in nature, since icing conditions tend to exist in narrow layers (GPO, 2012).

In looking at supporting performance values for observational weather elements in the NSIP-mid-term for the en route domain, the NWPRT determined that a vertical accuracy of plus or minus 500 feet from 3,000 feet AGL to the top of the controlled airspace would support automation that monitors the vertical and horizontal performance for traffic flow operations (with the exception of clouds). For horizontal accuracy, it would be plus or minus 0.25 km for convective weather elements and plus or minus 5 km for non-convective weather elements.

For forecast elements, performance requirement values would be less constrained than observations and also for longer forecast periods. For example, for forecasts from 0 hours to less than or equal to 8 hours, horizontal accuracy would be plus or minus 0.5 km for convective weather elements and plus or minus 5.0 km for non-convective weather elements. For forecasts greater than 8 hours but equal to or less than 48 hours, the horizontal accuracy would be plus or minus 5 km for <u>both</u> convective and non-convective weather elements. For vertical accuracy, the NWPRT determined that the forecast accuracy would remain the same as for observational weather elements—plus or minus 500 feet from 3,000 feet AGL to the top of the controlled airspace.

NWPRT rationale for these values was that in the en route airspace these horizontal accuracies would be sufficient to support separation management from convective weather and also accurate enough for assimilation into

TFM automation systems to support routing/re-routing decisions for TFM and TBFM.

4.0 SUMMARY

The FAA is implementing new technologies and processes to meet the NextGen need for increased capacity & efficiency. After reviewing numerous NextGen far-term and NSIP mid-term concept documents, the NWPRT developed weather performance requirements to support these new technologies and processes, and in particular, to support user decision-making. Although over 95 percent of weather information that is needed today will be needed in 2025, NextGen operations require higher performance values. The NWPRT selected the performance values based on changes in NAS Operations as the FAA moves toward NextGen. A complete, detailed rationale document will be available by the end of April 2013.

5.0 References

FAA AC 91-74A, Pilot's Guide to Flight in Icing Conditions, December 31, 2007.

FAA 2011 Aviation Weather Test bed Summer Experiment Final Report Summary, June 27-July 22, 2011.

FAA Instrument Procedures Handbook, FAA-H-8261-1A, May 21, 2008, 4-2.

FAA NextGen for Airports, http://www.faa.gov/nextgen/media/NextGen_for_Airports_9_2011.pdf, November 22, 2011.

Glossary of Meteorology, 2nd Edition, AMS, 2000, p 202, "dBZ – The logarithmic scale for measuring radar reflectivity factor"

FAA NextGen Mid-Term Concept of Operations for the National Airspace System (NAS), Version 2.1, September 30, 2010, 99.

FAA NextGen Mid-Term Concept of Operation (CONOPS) for the NAS, V2.0. Sep 30, 2010.

FAA NextGen Segment Implementation Plan, Segment Bravo Overview, Appendix G, Section G.4.1, January 27, 2012, G-12 et al.

FAA NextGen Segment Implementation Plan, Segment Bravo Overview, Appendix G, Section G.4.2.1.1, 2012, G-12.

FAA NextGen Segment Implementation Plan, Segment Bravo Overview, Appendix G, Section G.5.2.5.6, 2012, G-34.

FAA NextGen Segment Implementation Plan, Section 3, Collaborative Air Traffic Management, Section 3.1, 2012, 3-1.

GPO - http://www.gpo.gov/fdsys/pkg/CFR-2012-title14-vol1/pdf/CFR-2012-title14-vol1-part25-appC.pdf

JPDO ATM Weather Integration Plan, V 2.0. Section 3.3.2, Increase Arrival/Departures at High-Density Airports, September 24, 2010.

JPDO Next Generation Air Transportation Concept of Operations, Version 3.2, September 30, 2010, ES-2.

JPDO et.al, V3.2, 3-3.

JPDO Trajectory-Based Operations (TBO) Study Team, TBO Operational Scenarios for 2025, September 2010, 1.

Rasmussen, R., J. Cole, R. K. Moore, and M. Kuperman, Common Snowfall Conditions Associated with Aircraft Takeoff Accidents, , Journal of Aircraft, Vol. 37, No. 1, January-February 2000.

Transport Canada, Aircraft De-icing Fluid Freeze Point Buffer requirements, 2007.