Joint Planning and Development Office

ATM-Weather Integration Plan:

Where We Are and Where We Are Going

September 24, 2010 Version 2.0

Next Generation Air Transportation System
Joint Planning and Development Office

Joint Planning and Development Office (JPDO)

Next Generation Air Transportation System (NextGen)

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EXECUTIVE SUMMARY

Weather has a tremendous impact on aviation operations. A study of National Transportation Safety Board accident reports from the years 1994 through 2006 conducted by the Office of the Federal Coordinator for Meteorological Services and Supporting Research revealed that 20 percent of aviation accidents and 23 percent of fatal aviation accidents were weather related. Weather delays account for 70percent[1] of the $41 billion annual[2] cost of air traffic delays within the United States National Airspace System (NAS), or $28 billion annually. Approximately two thirds ($19 billion) of these delays are considered to be avoidable.[3] The Weather – Air Traffic Management (ATM) Integration Working Group (WAIWG) of the NAS Operations Subcommittee of the Federal Aviation Administration's (FAA's) Research, Engineering and Development Advisory Committee (REDAC) conducted a 12-month study to examine the potential benefits of integrating weather and ATM. Although this subcommittee was focused on the benefits of weather integration, it is likely that significant safety benefits will result from effective integration of weather into ATM decisions though they have not been calculated. The report of this committee made several recommendations regarding integration of weather and the potential for weather integration to help reduce delays. The way to mitigate these delays and eliminate those that are avoidable is to improve the quality and method of use of weather information and evolve (integrate) the weather support to the NAS. At the same time, the advantages and potential benefits of integrating weather and airtraffic management will, in all likelihood, assist in reducing the number of weather related accidents.

This NextGen Weather Integration Plan (Plan) provides the approach, scope, and implementation roadmap to achieve the NextGen vision; to enable decision makers to identify areas where and when aircraft can fly safely with weather assimilated into the decision making. It also addresses agency roles and responsibilities and includes resource requirements. This plan establishes the approach to deal with the integration of weather information into the ATM decision-making process.

Integration, as used in this plan, refers to the inclusion of weather information into the logic of a decision process or a decision aid such that weather constraints are taken into account when the decision is made or recommended. The goal of weather integration is to minimize the need for humans to gauge NAS weather constraints and to determine the optimum mitigation of these constraints.

KEY POINT: Weather information is not presently integrated into all ATM decision systems and processes.

This plan addresses the following problems:

- Most weather support to ATM is manual, with weather displays that must be interpreted by the user.
- Weather products do not have the maturity required for direct insertion without interpretation nor are they translated into constraint information.

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[1] OPSNET
[2] Congressional Joint Economic Committee; May 2008
[3] REDAC Weather-ATM Integration Working Group Report; Oct 3, 2007

- Rules for interpretation and use of weather data are generally based on the experience of the user.
- ATM decisions based upon today's weather products sometimes vary from user to user.

The figure below illustrates the process of moving from raw current and forecast weather data through the creation of weather information that relates weather data to aviation constraints and on to the generation of rules for decisions to be made by ATM operators and other users and ultimately to the creation of automated Decision Support Tools (DSTs).

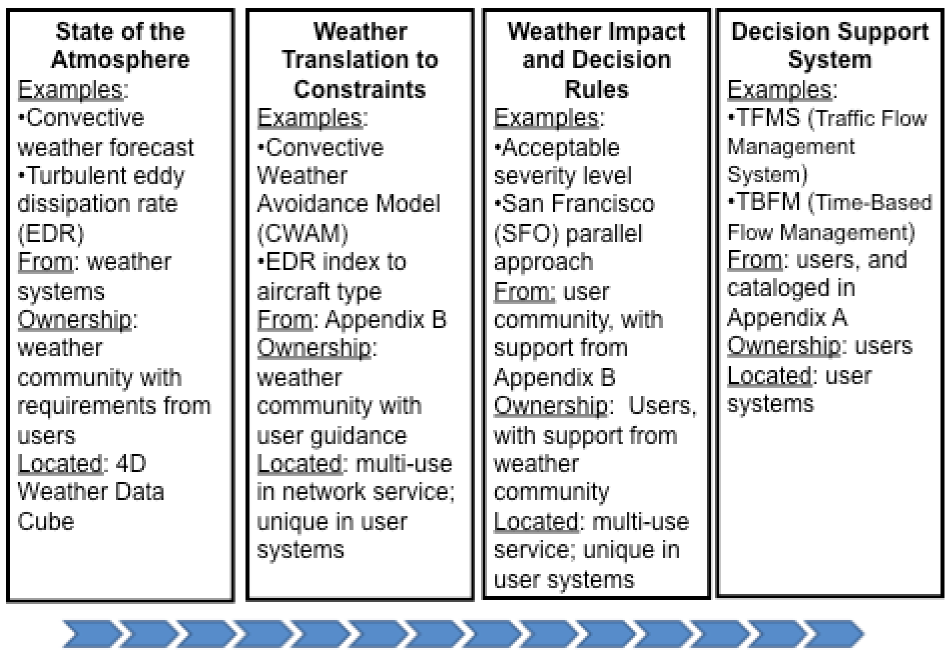

Figure ES-1 Flow of weather data from raw weather information to fully integrated weather information

KEY POINT: The process to flow information on the state of the atmosphere and translate it into constraints to feed decision rules for enhancing decision systems.

By 2013, some weather data will flow Machine-to-Machine (M2M) with integration into decision support tools (DST), but most integration of weather information will still be handled manually, with some data and displays provided to the cockpit for pilot decision. By the 2018 Mid-Term some DSTs will have integrated weather, and by 2025, weather information will be automatically translated to constraints and ingested into most decision algorithms, both on the ground and in the cockpit. This effort will require a concentrated effort from the research and development community to develop the capabilities, from the FAA certification and operational approval, and for the entire community for coordination with manufacturers and operators.

KEY POINT: An analysis of weather translation for decision tools has been done.

An analysis of the current state of weather integration was conducted and this Plan lays out the weather integration opportunity in the NextGen Solution Sets; Initiate Trajectory Based

Operations, Increase Arrivals/Departures at High Density Airports, Increase Flexibility in the Terminal Environment, Improve Collaborative ATM, Increase Safety, Security, and Environmental Performance, and Transform Facilities. Each solution set was broken down into Operational Improvements (OIs), with level Mid-Term capabilities, Mid-Term operational scenarios, and Mid-Term weather integration and needs analysis. This analysis is reflected in Section 3 of the Plan, along with the associated Appendix A.

KEY POINT: An analysis of available weather translation and decision methodologies has been done

ATM will require DSTs that can access information from the 4-D Weather Data Cube (4-D Wx Data Cube) that has been translated into NAS constraints and provide ATM with best choice options. The translation can be obtained by a network service for common use or by imbedding the translation capability in the DST for unique needs. Section 4 provides an overview of methodologies, the strategy for evaluation of the methodologies, and the initial identification of the best near-term strategies for further development. The associated Appendix B provides a survey that identifies technologies and methodologies for translating weather information into ATM constraints in the NAS and for using that information. The survey includes approaches for addressing weather-related uncertainty in ATM decision making and risk management processes. The survey is organized in two parts: ATM-Weather Constraint and Impact Models and ATM-Weather Integration Techniques. Following the survey, a matrix is provided that shows the full evaluation of all methodologies as discussed in Section 4.

The Plan presents a summary of each of the surveyed ATM constraint and impact models starting with models that were derived primarily for convection, and ending with a wide variety of models for several types of aviation hazards. Section 4 also contains an assessment of the maturity of the ATM constraint and impact models presented, and identifies gaps in technologies that must be addressed for NextGen.

KEY POINT: A foundation of mature, tested methodologies must be built and maintained, along with a capability for multi-use constraint translation.

Further research is required on the conversion of weather data into specific ATM constraints. It is expected that this research will be a collaborative effort involving the government, the private sector, and academia.

The execution of this Plan will occur in four steps. The steps will be executed in sequential order from the start, but the steps will be repeated many times as new weather techniques and ATM tools are developed and may be occurring simultaneously at some point in the future. The steps are as follows:

1. Align teams with each solution set and analyze weather integration requirements for a service- and performance-based approach for weather integration as associated with operational relevance.
2. Identify the specific weather integration insertion points, including performance criteria and value, into ATM tool or decision platform functionality.

3. Identify and recommend the specific weather integration techniques and technologies that best fit the requirements of a particular traffic flow management tool under development and in particular, the insertion points identified in the previous step.
4. Serve as the Subject Matter Expert (SME) for the ATM tool development team to assist in integration of the weather methodologies and to evaluate test results.

KEY POINT: A DST-by-DST weather support activity must assist in successful weather integration.

The key interaction for success in weather integration will be the relationships established between the Aviation Weather Group (AWG) and the ATM tool development community. The AWG role is to ensure proper use and application of weather data and techniques in development of specific DSTs. During development, the AWG will fund demonstrations for specific technologies in order to demonstrate both the quality and usability of weather information in the decision process. It is imperative that human factors (see C-5) be considered in the development of every DST. As DST development proceeds, weather data for specific DSTs will transition from a testing scenario to inclusion of production data directly from the 4-D Wx Data Cube.

Anticipated activities are as follows:

FY11:

Build weather translation and decision foundation, including test and evaluation capability.

- Delve more deeply into understanding user weather needs, with analysis of NextGen Solution Sets and specific targeted programs
- Select and refine technologies for translating weather into constraints
- Stand up Weather Integration Technology Evaluation Board

FY12:

Continue to development a weather translation and decision foundation, including test and evaluation activities.

- Integration Sub-Teams identify DSTs and methodologies for early implementation, continue research into promising methodologies, oversee execution of demonstrations, and continue research on emerging technologies
- Test and Evaluation (T&E) activities begin at the William J Hughes Technical Center (WJHTC)

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1 INTRODUCTION

There is a need for a multi-agency, synchronized plan to achieve solutions to the problem of weather integration into Air Traffic Management (ATM) operations and decisions. As articulated in the NextGen vision, the solution must enable decision makers to identify areas where and when aircraft can fly safely with weather assimilated into the decision making. The NextGen ATM-Weather Integration Plan (Plan), when fully developed, will provide the user needs and intended implementation roadmap to achieve the NextGen vision. It also addresses agency roles and responsibilities and includes resource requirements.

1.1 Background

Weather has a tremendous impact on aviation operations. A study of National Transportation Safety Board accident reports from the years 1994 through 2006 conducted by the Office of the Federal Coordinator for Meteorological Services and Supporting Research revealed that 20 percent of aviation accidents and 23 percent of fatal aviation accidents were weather related. Weather accounts for 70 percent[4] of all air traffic delays within the United States National Airspace System (NAS). The total cost of these delays has been estimated to be as much as $41billion[5] annually with weather delays costing over $28 billion annually[6]. It is estimated that approximately two thirds of weather delays have been are avoidable ($19 billion annually). The way to mitigate weather delays and eliminate avoidable delays is to improve the quality of weather information and to evolve weather support to the NAS both in quality and in methods of use, from its current levels to new targeted approaches. Although the Federal Aviation Administration (FAA) Research, Engineering and Development Advisory Committee (REDAC) subcommittee was focused on the benefits of weather integration, it is likely that significant safety benefits will result from effective integration of weather into ATM decisions, though they have not been calculated.

1.2 Purpose

This Plan establishes the approach to deal with the integration of weather information into the ATM decision making process.

1.2.1 Integration Definition

Integration as defined in this Plan refers to the inclusion of weather information into the logic of a decision process or a decision aid such that weather constraints are taken into account when the operational decision is made or options recommended. This applies whether the decision is made individually or jointly by air navigation service providers and airspace users.

A key ATM-weather integration concept is the process called Weather Translation. In general terms, this concept describes functionality that turns weather observations, analyses, and forecasts of meteorological parameters into operationally-meaningful, weather-related values such as threshold events and/or characterized NAS constraints.

[4] OPSNET
[5] Congressional Joint Economic Committee; May 2008
[6] REDAC Weather-ATM Integration Working Group Report; Oct 3, 2007

Separate, downstream ATM functionality then takes the threshold events and/or characterized weather constraints and converts them into forecast NAS state changes or capacity impact values, either of which can then feed into ATM Decision Support Tools (DSTs) to assist in the development of appropriate ATM strategies. In this way, Air Navigation Service Providers (ANSPs) will be able to use a common picture of weather constraints in their decision making, rather than having to develop individual (sometimes conflicting) interpretations of the underlying meteorological information. NAS operators will have the option of accessing this constraint information in order to help understand the ANSP rationale behind ATM strategies.

1.2.2 Integration Goal

The goal of weather integration is to minimize the need for humans to gauge NAS weather constraints or to determine the optimum mitigation of these constraints. Today, decision makers integrate or assimilate nearly all weather information manually after viewing stand-alone weather displays. As these capabilities are developed, there will be a need to address regulatory requirements that currently address the shared responsibility between the pilot-in-command and the aircraft dispatcher for the safe operation of the aircraft. Fulfillment of these goals will require a concentrated effort from the research and development community, FAA certification and operational approval, and coordination with manufacturers and operators. Weather integration in NextGen will be an evolving process, as follows:

- By 2013 some weather data will flow Machine-to-Machine (M2M) either through a weather translation process or directly (depending upon the application) to enable integration into DSTs.
  - Most integration of weather information will still be handled manually but with improved “high glance value” displays. Some of these displays will include translations of state of the atmosphere data into potential NAS constraints.
  - Some new data and displays will be provided to the cockpit for pilot decisions, and to Air Operations Centers (AOCs) and Flight Operations Centers (FOCs) whether in collaboration with the ANSP and therefore addressed by this plan, or otherwise.
- By the 2018 Mid-Term some DSTs will have integrated weather. Many new datasets that translate weather information into threshold events or NAS constraints will be available.
- By 2025, weather information will be automatically translated to threshold events or NAS constraints and ingested into most decision algorithms both on the ground and in the cockpit. The underlying weather data may also be available for display if necessary for safety or other reasons.

1.3 Scope

This Plan addresses actions to be taken by the weather community, generally under weather community funding. Although it calls for close interaction with various FAA user programs, it does not commit those programs or their managers to take any action or expend any funds. However, to benefit from the efforts described in the Plan, it is understood that the FAA user programs must cooperate and participate in the process.

The cost of implementing the methodologies developed under and presented in the Plan will be borne by the FAA user programs. For example, where weather integration is to occur in a NAS system, the manager of that system must write the software code that implements the methodology. The weather community will support this by providing any reusable code to which it has access.

In the event that any user tool or capability must be cancelled or postponed, its description in this Plan does not in any way obligate the program manager to continue the program.

The Plan is intended to address weather integration into ATM decisions made by the ANSP or by the ANSP in collaboration with the AOC/FOC or operators. AOC/FOC and flight deck decisions unique to the operator (i.e. excluding ANSP participation) are not a subject for intervention in the Plan. Those are principally left for market innovation to develop and implement.

1.3.1 Plan Limitations

The creation and production of appropriate weather analyses and forecasts will be addressed in the Joint Planning and Development Office (JPDO)-NextGen Weather Plan and is outside of the scope of the integration effort. However, the integration effort will address the identification of user requirements for weather information that will be conveyed to the developers. The requirements development will occur as specific weather integration needs are identified.

The regulatory approval process for the use of new weather analyses and forecasts will be addressed elsewhere and is outside of the scope of the integration effort. However, the integration effort will support the regulatory process by providing rationale and other supporting documentation on how the information is to be used.

The Service Oriented Architecture (SOA)/Information Technology (IT) infrastructure associated with publication of weather analyses and forecasts will be addressed elsewhere and is outside of the scope of the integration effort. However, the integration effort will act as an intermediary between the weather IT community and the user system owners to ensure that appropriate weather-related information flow occurs.

1.3.2 Roles and Responsibilities

Agency and community roles are as follows:

1.3.2.1 FAA

The FAA will be the primary actor to the extent that most ATM systems are owned by the FAA and the ATM-weather integration process resides primarily within the FAA. However, for success, other agencies and stakeholders must be involved.

The FAA will manage the Quality Management System (QMS) to oversee verification of Operational Aviation Weather Products to ensure compliance with the International Civil Aviation Organization (ICAO) standards.

1.3.2.2 National Aeronautics and Space Administration (NASA)

NASA is a key contributor and sponsor of techniques and methods for the integration of weather into ATM decision support tools. In particular, the Aviation Systems Division at NASA's Ames Research Center has made significant contributions and is conducting on-going research in several areas of benefit to NAS planning and decision making. Some specific examples of its work include:

- ATM-Specific Weather Forecasts
  - Use of probabilistic forecasts for marine stratus at San Francisco
  - Probabilistic Convective Scenario Forecasts
- ATM-Weather Translation Modeling
  - Traffic Flow Management (TFM) impacts due to non-convective weather
  - Continued development of Convective Weather Avoidance Model (CWAM) using flight tests and validation
- Capacity Estimation
  - Development of several capacity reduction models
  - Use of Weather Impacted Traffic Index (WITI) for TFM
  - Improvements of Mincut/Maxflow for TFM
  - Capacity estimates using ensemble convective forecasts
- ATM Advisories
  - Use of high fidelity terminal winds to improve ATM advisories
  - Several efforts using CWAM – pre-departure routing, 20 minute – 2 hour routing in Airspace Concept Evaluation System (ACES), 0 – 20 minute deterministic routing in Center-Terminal Radar Approach Control (TRACON) Automation System (CTAS), stochastic routing, and pre-departure delay vs. routing.
- Future On-going and Planned Research Areas (Several projects listed above under these areas will continue.)
  - ATM-Specific Weather Forecasts
  - ATM-Weather Translation Modeling
  - Capacity Estimation
  - ATM Advisories

1.3.2.3 Department of Defense (DOD)

The DOD has developed and is expected to continue to develop tools and methodologies that have application to the civil aviation community, including some relevant to weather integration efforts. To the extent possible, the DOD will share its developments with the broader NextGen weather integration community.

The DOD has developed and is expected to continue to develop tools and metodologies which have application to the civil aviation community, including the Battlespace on Demand operational concept (Navy) and the Joint Environmental Toolkit (Air Force). The AF has developed and is expected to continue to develop tools and methodologies which have application to the civil aviation community, including some relevant to weather integration efforts. To the extent possible, the AF will share its developments with the broader NextGen weather integration community. When appropriate/able, the AF will also cooperate in the development of weather integration capabilities such as in the development of weather integration capabilities in the following circumstances:

- Civil aircraft operate in military-controlled airspace.
- Civil aircraft operate at military airfields or joint-use fields operated by the DOD.
- Weather integration community considers the hand-off point/procedures of aircraft between civil and military control

AF has a highly integrated process to support its world wide aviation mission, leveraging the AF GIG (Global Information Grid). This automated process is then tailored to specific missions/aircraft types by highly trained weather personnel.

1.3.2.4 National Oceanographic and Atmospheric Administration (NOAA)

The primary role of NOAA is to be the principal provider of weather information in the NextGen 4-D Wx Data, rather than integration into ATM decisions. For more information on NOAA and the 4-D Wx Data Cube, see the NextGen Weather Plan, which is a companion document to this Plan.

NOAA will, however, provide expertise in the interpretation of weather information and in techniques for integrating weather into DSTs.

The Network-Enabled Verification System (NEVS), being developed jointly by NOAA and the FAA, will provide tools for verification of the data in the NextGen 4-D Wx Data Cube. Verification information is needed to support determination of the Single Authoritative Source (SAS) contents, and facilitate the future use of the 4-D Wx Data Cube data integration into DSTs. NEVS is discussed in more detail in Section 5.8 of this Plan.

1.3.2.5 Private Sector

This Plan does not in itself obligate the private sector to take any action. However, when weather-integrated ATM capabilities become operational, private sector users will be affected. To the maximum extent possible, writers and executors of this Plan will take the needs of the private sector into account, such as by refraining from unnecessary equipage requirements. Through the NextGen Institute, members of the private sector have participated in the preparation of the Plan and will be encouraged to continue their participation. The Government will make every effort to involve the private sector and keep the private sector informed of any decision which may affect the private sector. The private sector has a vital role to play in NextGen in terms of innovation and the provision of services and is clearly among the intended beneficiaries of the Plan. The JPDO will continue to include representatives from the private sector in its structure and will endeavor to stay informed of industry capabilities that already exist or are rapidly maturing to the point of foreseeable deployment. The purpose is to ensure that near term gains may be realized as the system progresses towards the end-state.

1.3.2.6 International Community

Both weather and aviation are international enterprises. As with other NextGen developments, the weather integration community will seek to harmonize itself and coordinate its efforts with related International efforts, such as those in Single European Sky ATM Research (SESAR), the ICAO, and the World Meteorological Organization (WMO).

2 NEXTGEN WEATHER INTEGRATION OVERVIEW AND CONCEPT

Weather integration pertains to the inclusion of weather information into the logic of a decision process or decision aid such that weather constraints have already been taken into account when the decision (e.g., any decision affecting TFM) is made or options recommended. Weather integration into NAS decisions is fundamentally the responsibility of the user community (i.e., Air Traffic Control (ATC) service providers and NAS operators), with the weather community in a supporting role. The ultimate goal of integration is to translate weather information as purely meteorological data into weather constraints on air traffic operations – essentially making weather transparent to its end users. The JPDO 4-D Weather Functional Requirements for ATM calls for “weather integrated directly into sophisticated decision support capabilities to assist decision makers.” Under the solution set of Reduce Weather Impacts (RWI) within FAA’s Operational Evolution Partnership (OEP) program is a goal of making weather information seamless to users by integrating it into decision-making automation. As more meteorological parameters are fully integrated into DSTs, the need for direct M2M ingestion of weather data will increase. At the same time, the numbers of human-readable graphical displays and text messages may be allowed to decrease as appropriate. The previous notwithstanding, it is clear that operational decision makers on the ground and in the air will require both the graphical and textual representation of meteorological information for the foreseeable future.

Decision support will evolve over the next decade and beyond. Today, most weather-related decisions are made by ATM in a completely manual mode. With few exceptions, weather data are displayed as graphics or text at the Air Traffic Control System Command Center (ATCSCC), at TRACONs, Air Route Traffic Control Center s (ARTCCs), Air Traffic Control Towers (ATCT), AOC/FOCs, Flight Services, and in cockpits all on stand-alone systems. By 2013, some weather data flow will be via M2M means. Most integration will remain in a manual mode but many weather displays will be improved to a “high glance value” mode. Data and graphics will also be provided to the cockpit for pilot decision via electronic flight bags and existing on-board systems on some aircraft. By 2025 it is expected that weather information will be automatically translated into probabilistic weather constraints on air traffic and be ingested into decision algorithms (ground and aircraft).

Figure 2-1 shows the process of moving from weather data that describes the state of the atmosphere at a current or future time through conversion of that data into weather impact parameters. As shown in the figure, the creation of the state of the atmosphere and then specific translations of raw weather information into constraints on aviation are the responsibility of the weather community in response to guidance from the user community. The user community subsequently generates the rules for decisions that rely on weather data and constraints and then develops automated DSTs that meet its specific operational needs. Once the process flow moves from weather constraints to development of decision rules, the weather community has the responsibility for support and advice to the user community related to the use and interpretation of the weather data or derived weather translations. There is an implied feedback loop; i.e. requirements flow from the right side of the diagram to the left.

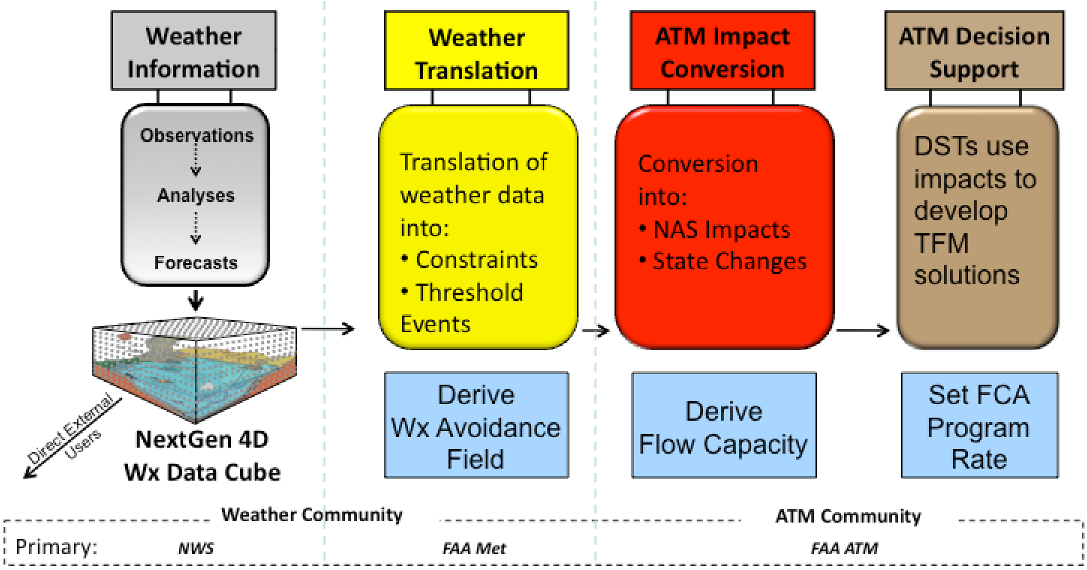

Figure 2-1 Conceptual Flow of Weather Integration

2.1 Problem Characterization

2.1.1 Problem Summary

- Most weather support to ATM is manual, with weather displays that must be interpreted by the user.
- Weather information and data streams do not have the IT maturity required for direct insertion without interpretation. (Note: this aspect of the problem is addressed in the NextGen Weather Plan.)
- Interpretation rules and use of weather data are generally based on the experience of the user.
- ATM decisions based upon today's weather data and displays are inconsistent from user to user.

2.1.2 Discussion of the Problem

Today's national air transportation system is susceptible to weather disruptions causing flight delays, the impacts of which can be wide spread. Fast moving summer or winter storms impacting one hub airport or key transcontinental route can ground aircraft thousands of miles away, further propagating flight delays and cancellations. Weather delays are more than an inconvenience; they cost the nation's airlines, cargo carriers, corporate, and private users in excess of $28 billion annually. While severe weather will likely continue to prevent airspace and airport access in the immediate vicinity of the event, many delays could be avoided with improved ways of dealing with weather throughout the national air transportation system.

The maturity level of current weather information is below the level that allows direct M2M, automated use of weather data. Today's weather displays generally require human evaluation and interpretation. Additionally, the skill in some key weather forecast output is inconsistent day-to-day and as a result, rules for making use of weather data in decisions are human derived, leading to inconsistent decisions by the user community. Many weather displays or tools are "bolt on" systems that must be interpreted by the user and figured into traffic decisions based on the user's past experience, amount of training or their understanding of the information presented. The weather data provided by these systems may not be provided in a manner that is useful in human-made traffic flow decisions. Automated systems, many of which are designed around fair weather scenarios, must be shut down when significant weather constrains the operational area of concern. Lack of automated tools necessitates a cognitive, reactive, inefficient weather-related decision making process and a meteorological competency of decision makers. The weather information used for this manual process is gathered from multiple sources. Individual controller perceptions are used to determine the "best source", which may be based on past experience or hand-me-down knowledge, rather than scientific evidence.

Where processes disregard weather data, this can often be traced to the fact that the present weather data system is a collection of diverse, uncoordinated observations, forecasts and supporting systems. This does not support the need for "information rather than data" where information implies an underlying process and system to help make an informed decision. Indeed, today's weather system infrastructure to support timely and collaborative air transportation decisions necessary to effectively deal with bad weather does not exist.

For integration in most DSTs and weather impacts determination, the weather community must take the intermediate steps of translating weather data into some characterization of a NAS constraint or determine that some threshold that is critical to a NAS function has been reached.

With respect to Weather Translation, the term threshold event applies to a situation in which an atmospheric parameter such as cloud ceiling height, visibility or wind speed crosses a regulatory or operational threshold and may result in an associated change in the state of the affected NAS element, normally an airport. Examples of state changes for an airport include a runway configuration change, landing minima change, or arrival/departure rate change. A state change may or may not result in an increase or decrease in the capacity of the affected NAS element. For instance, an airport arrival rate change caused by raising or lowering of a cloud ceiling implies either an increase or decrease in airport landing capacity, whereas a runway configuration change caused by a shift in wind direction does not necessarily result in any change in capacity.

In the context of this Plan, weather-related NAS constraints are meteorological phenomena that are potentially hazardous to aircraft. In the airport environment, these typically include hail and lightning, turbulence/winds/wind shear that exceed aircraft safety operating limitations, and freezing and frozen precipitation occurring at rates that exceed aircraft operating capabilities. The same phenomena affect aircraft operations in the en route airspace, with icing that exceeds aircraft operating limitations replacing freezing and frozen precipitation. For reasons of safety, aircraft do not operate to, from or through NAS elements known to contain hazardous weather. Because aircraft avoid airports or airspace containing these hazards, the efficiency of ATC procedures in, and overall capacity of, those airports and airspace is reduced.

A weather constraint can result in impact if the demand in the affected NAS element exceeds the capacity that has been reduced by that constraint. As used in the definition of Weather Translation, the term characterization of weather-related NAS constraint refers to the process of turning hazardous meteorological phenomena into values that reflect the degree to which the weather hazard would constrain the affected NAS element in the presence of air traffic. Although these characterizations are derived primarily from meteorological data, they are not expressed in traditional meteorological units of measure (e.g., feet, miles per hour, degrees). Rather, since they represent an amount of constraint, they are expressed in non-meteorological terms (such as airspace where pilots are unlikely to want to fly) and conveyed using representations such as avoidance fields. The "translated" weather information will be a primary input to downstream automated ATM processes. These processes will determine if the weather constraint is likely to have an actual operational impact on the affected NAS element. The impact assessment is then provided to ATM DSTs as a complete representation of the constraint and impact, to facilitate planning and coordination with the affected NAS elements and to inform ATM decision making, such as the Collaborative Decision Making (CDM) process.

Characterizations of weather-related NAS constraints that are derived from 4-D weather forecast data are likely to be presented in 4-D. The term 4-D representation refers to a gridded, volumetric framework of information in which each piece of information has four dimension (4-D) attributes: three spatial (location) dimension attributes (x, y and z representing, for example, latitude, longitude and altitude) and one temporal dimension attribute (t representing time). By inference, for any given 4-D forecast product or 4-D characterization, each grid location/time combination has an associated piece of information.

Finally, within the context of this Plan and when used to describe a group of people, automation resources or procedures, ATM is meant in the broadest sense, and should be thought of as including both ANSP and stakeholder participants, tools and processes.

2.2 Weather Impacts on Solution Sets

This plan addresses weather integration in terms of six of the NextGen OEP solution sets;

- Initiate Trajectory Based Operations (TBO)
- Increase Arrivals/Departures at High Density Airports (HiDensity)
- Increase Flexibility in the Terminal Environment (FlexTerm)
- Improved Collaborative Air Traffic Management (CATM)
- Increase Safety, Security and Environmental Performance (SSE)
- Transform Facilities (Facilities)

Weather impacts the operational improvements of the solution sets in several ways, depending on the type of decisions being considered and its time horizon in the life cycle of a flight or a traffic flow. The integration of weather and ATM decisions can span from strategic pre-planning decisions to real-time tactical decision making. Specific weather impacts are discussed in more detail in Section 3 and in Appendix A.

2.3 Weather Integration Context

Figure 2-1 provides a context for the entire weather integration process. The figure serves as an overview of the envisioned NextGen weather concept for enhancing ATM decision making in the face of adverse weather. The following description of the figure explains the various components and their interactions, with an emphasis on placing Weather Translation in the proper context.

2.3.1 Primary Classifications of Weather Integration Concept

There are four major components in the Figure 2-1 (the terms in bold will be used throughout this description):

- **Weather Information**: The figures on the far left of the diagram represent the observed, analyzed and forecast (predicted) meteorological parameters associated with the current or future state of the atmosphere. Where appropriate, forecasts are 4-D representations of the future state of the atmosphere. This includes the SAS, which is the subset of information that will be utilized to inform ANSP decision making. All of this weather information is managed by the NextGen 4-D Wx Data Cube and disseminated through the net-centric infrastructure.
- **Weather Translation**: The yellow box in the left center portion of the diagram represents Weather Translation functionality. This functionality ingests weather observations, analyses and forecasts from the NextGen 4-D Wx Data Cube and, through the framework of aviation operations filters such as Federal Aviation Regulations (FARs), flight standards, aircraft limitations and Standard Operating Procedures (SOPs), automatically produces relevant, standardized threshold events and characterizations of potential weather-related NAS constraints. Where appropriate, the characterizations will be represented in 4-D and will likely be identified in terms of airspace permeability and/or weather avoidance fields.
- **ATM Impact Conversion**: The red box in the right center portion of the diagram represents ATM Impact Conversion functionality. This capability takes information from the Weather Translation function, combines it with known ATM demand/capacity information, and converts it into potential NAS state changes (in the case of threshold events) or capacity impact (in the case of characterized weather-related constraints). In every case, safety is paramount and the major factor considered by the functionality as it attempts to measure the effects of the constraint, and the most accurate and up-to-date estimate of demand. In addition to weather constraints and demand, this functionality can ingest other potential constraint information such as Special Activity Airspace (SAA) and runway closure information.
- **ATM Decision Support**: The brown box on the far right of the diagram represents the various ATM DSTs and displays available to decision makers. These tools use the NAS impact analysis results from the ATM Impact Conversion functionality in developing traffic management plans, strategic through tactical, that suggest the best operating strategies to deal with forecast changes of the state of NAS components or that best mitigate the effects of the forecast set of constraints.

2.3.2 Weather and ATM Community Responsibilities

As illustrated by the two dashed vertical lines on the left half of the figure (and the legend at the bottom), Weather Information and Weather Translation are the responsibility of the meteorological community. Primary responsibility for Weather Information rests with the National Weather Service (NWS) with the FAA providing certain aviation-related observations and forecast support. The FAA meteorological community and the NextGen RWI solution set are primarily responsible for the Weather Translation functionality.

As indicated by the legend at the bottom of the figure, responsibility for ATM Impact Conversion and ATM Decision Support functionality belongs primarily to the ATM community within the FAA along with four of the NextGen solution sets CATM, TBO, HiDensity and FlexTerm. For example, in addition to establishing the operational and performance requirements for the weather constraint information that will be provided by Weather Translation, these stakeholders will have primary responsibility for the development of the ATM Impact Conversion functionality and the ATM DSTs that utilize the impact information to assist ANSPs in ATM decision making and mitigation strategy development.

The development of Weather Translation functionality (yellow box) and ATM Impact Conversion functionality (red box) will undoubtedly require the simultaneous, cross-functional involvement of both the meteorological and ATM communities. For example, establishment of functional and performance requirements for Weather Translation will be driven by the needs of ATM Impact Conversion.

One way to differentiate between Weather Translation and ATM Impact Conversion is by looking at their outputs. Those from Weather Translation functionality are threshold events and constraints based on all possible aircraft types, while the ATM Impact Conversion functionality outputs an assessment of the impact of the weather constraint or threshold event on specific flights and trajectories.

Another way to describe the difference between Weather Translation and ATM Impact Conversion is to note that the functions in the Weather Translation box are independent of the actual aircraft that are anticipated to use the NAS element during the time that the state change is forecast to occur or the constraint is forecast to be present. In contrast, the functions in the ATM Impact Conversion box are not only aware of the individual aircraft that are scheduled to use the NAS element during the affected time period, but also use the information from the Weather Translation box to statistically predict how those individual aircraft will behave in the face of the forecasted weather constraint, or whether they will be able to continue to operate subsequent to the NAS state change. It should be noted that behavior of civilian aircraft and military aircraft may be quite different depending upon mission requirements. Ultimately, aircraft behavior is up to the pilot-in-command; however, the ATM Impact Conversion will be able to address classes of aircraft and whether or not they would generally be able to operate under a given weather scenario. This, in turn, allows the ATM Impact Conversion functions to predict changes to the capacity of the affected element.

Weather Information (far left in the diagram) is the source of the observed, analyzed and forecast meteorological data used for Weather Translation. Within the Weather Information area, the major source of the meteorological data for Weather Translation is thought to be the NextGen 4-D Wx Data Cube. However, it is possible that weather information that is not available through the NextGen 4-D Wx Data Cube may be used by Weather Translation functionality to identify threshold events and weather constraints of interest to ANSP and stakeholder personnel. This is thought to be especially true during the transition period from today's disparate weather sources to tomorrow's full NextGen 4-D Wx Data Cube capability.

Because ATM decisions will be made based, in part, on the output of Weather Translation functionality, it follows that this output will be considered to be "official" or "sanctioned" information to inform ATM decision making. This is similar in concept to the aforementioned SAS designation given to the weather observation and forecast data that will feed Weather Translation functionality. But the "SAS" term will not be applied to either Weather Translation or NAS Impact Conversion.

Another key input to Weather Translation is represented by the box labeled ATM Aviation Standards. This box consists of safety and regulatory information such as FARs, flight standards, aircraft limitations, federal and company SOPs, and aviation specific hazard thresholds (turbulence vs. aircraft types). It may also include demand predictors such as pilot/flight crew behaviors in the face of various types of weather constraints. These are all critical to developing characterizations of potential weather constraints.

Weather Translation is a dynamic function. Depending on the type of subscription arrangement and pre-arranged criteria, the NextGen 4-D Wx Data Cube may push new meteorological data to Weather Translation whenever a parameter changes by more than some predetermined amount (i.e., a significance threshold). In a similar fashion and based on agreed-upon standards, Weather Translation will then determine if the weather changes should trigger a revision to currently depicted threshold events or characterized weather constraints. If a revision is appropriate, the new threshold event information or characterized weather constraint may then be pushed to the appropriate ATM Impact Conversion functionality. It is thought that similar relationships and processes will exist between ATM Impact Conversion functionality and ATM DSTs.

In addition to Weather Translation, there are two other key inputs to ATM Impact Conversion: ATM Aviation Standards (leftmost green box, as described previously) and ATM Efficiency Demand/Capacity (rightmost green box). The former provides the aviation filters through which the impacts of weather constraints on capacity will be calculated, while the latter provides the basis for evaluating capacity alongside projected demand in order to determine if a problem (demand exceeding capacity) is likely to exist as a result of the weather constraint.

Although the primary users of ATM Impact Conversion output are the ANSPs and their DSTs, it is assumed that Stakeholders and their DSTs will also be able to gain access to the same information via either a subscription service or on a request/reply basis following established protocols for the 4-D Wx Data Cube.

It is assumed that the NAS impact information from ATM Impact Conversion will be generally applicable to a wide range of ATM (ANSP and stakeholder) DSTs, which operate in all time horizons from tactical to long-term strategic. However, it is also assumed that this output will not necessarily be packaged in such a way as to meet the content and format requirements of every single ATM DST. Some ATM Decision Support functionality may be required to filter and/or reformat the content of the most appropriate ATM Impact Conversion output to meet its particular needs.

As seen in the Figure 2-1, information may flow directly between Weather Information and direct FAA users or DSTs without the need for translation or constraint assessment. For example, there is no value-added function required to modify/adjust upper level wind and temperature forecasts to support trajectory modeling. Therefore, it is not necessary for this information to go through Weather Translation or ATM Impact Conversion. It is assumed for now (and shown in the figure) that Weather Information will also be directly available to external NAS users. But, the final decision on this type of information flow will be made as part of architecture analysis.

Current plans are for Weather Information to be able to support trajectory- and volumetric-based retrievals of observations and forecasts by ANSPs from certain ATM DSTs in support, for example, of flight service pilot briefing requests. External users will have similar access to Weather Information.

It should be noted that the CDM process is likely to be an early, major beneficiary of Weather Translation and ATM Impact Conversion. These capabilities should naturally fit into the existing construct for CDM, and the improved weather related information should enhance its operational effectiveness.

2.3.3 Levels of Integration

DSTs are generally software applications used to automate the weather constraint evaluation and air traffic/customer response. Mission Data are input into the DST, typically in the form of a proposed 4-D trajectory through space and time. Along with trajectory information are added the particular weather sensitivities or risk tolerance of the flight under consideration. According to the spatial and temporal attributes of the mission (takeoff time/place, flight level, waypoints, and estimated landing time/place) relevant weather information is retrieved by subscription or by query/response from the 4-D Wx Data Cube using XML standard queries. The DST then automatically compares the weather parameters to particular sensitivities of the mission under consideration. By applying relevant rules and thresholds (e.g. pilot landing minima, aircraft weather avoidance limits, risk tolerance, FARs, etc.) the DST converts weather information into weather impacts. The result of this logical integration is an output decision aid. For instance, the latter segments of a proposed trajectory may enter an area of forecast turbulence. If this forecast turbulence exceeds certain severity or probability limits the DST automatically flags these segments as (for example: red). More sophisticated DSTs may recommend weather-optimized trajectories through an iterative process of query and response. Thus, the trajectory flagged as Red for turbulence initially may be rendered green by an earlier takeoff, a higher flight level, or a different route.

DSTs will take on a number of forms and functions as NextGen evolves.

Currently, most weather information is displayed on a separate screen from traffic information. Controllers and ATM planners must view both displays and manually "integrate" or assimilate the weather into their decisions. This use of weather information is defined as "Level 0" since weather is consulted for a decision; however, it is not physically integrated into a system. "Level 0" is displayed in Figure 2-2 but is not considered an actual level of integration. (Note: The following does not consider where or how a DST will be displayed or used. Additionally, individual DSTs may require human factors consideration). In addition to "Level 0" there are four levels of integration, each with increasing levels of complexity. As noted earlier, there will be data, displays and processes with varying levels of integration in the near-term, Mid-Term, and NextGen time frames. Although the ultimate goal may be Level 4 integration in most areas, the process of getting there will not happen simultaneously. In the late Mid-Term it is probable that Level 1 or Level 2 integration will still be in use. It is important to understand the appropriate level for each individual technology and/or program so that planning and development can take place to ensure the right level is reached at the right time. For this reason, it is necessary to understand each level of integration, and what steps are required to move to a higher level.

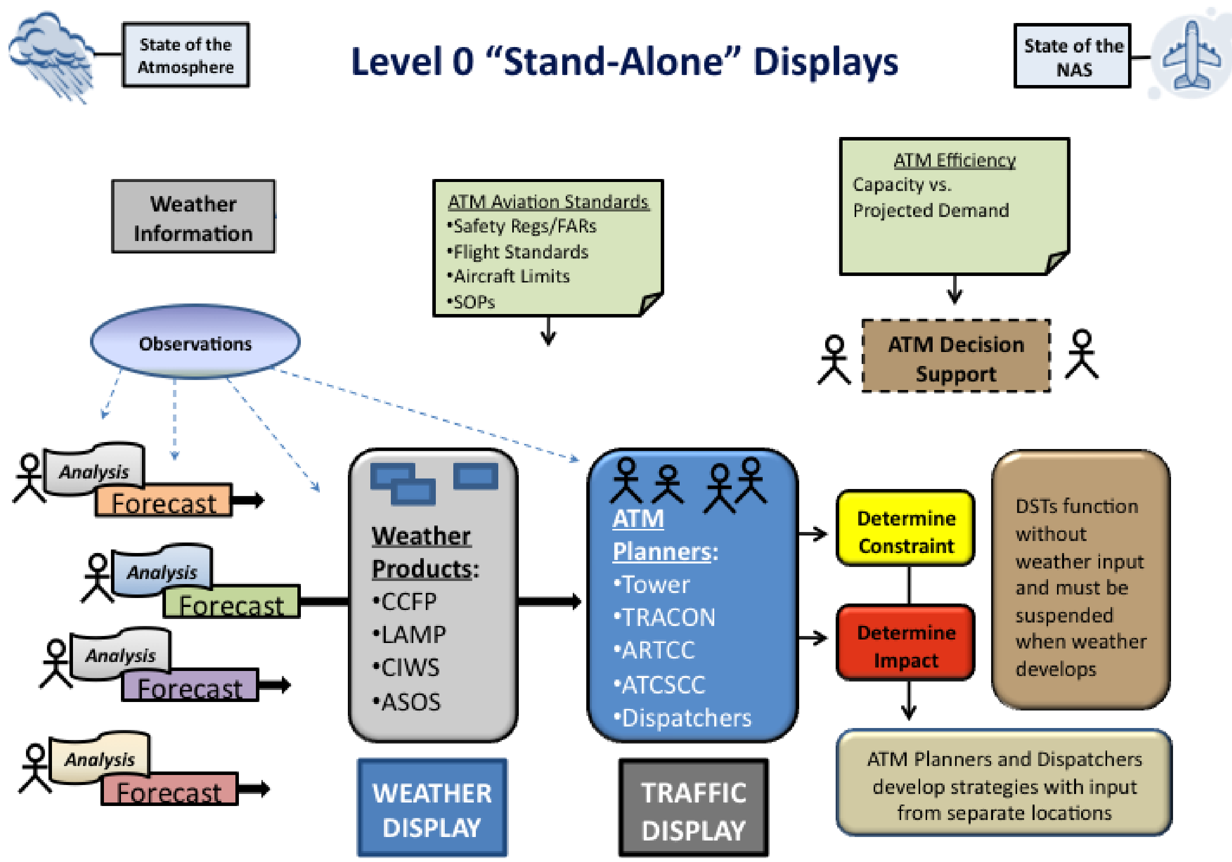

Figure 2-2 Level 0: "Stand-Alone" Displays

Level 0: Stand-Alone Displays

Traffic Management Advisor (TMA) is a good example of Level "0" stand-alone systems. Except for gridded wind data embedded in the trajectory algorithms, TMA functions completely without weather input and must be suspended when convective weather occurs in the terminal area – the time that TMA would be most effective. Traffic Management Unit (TMU) personnel commonly monitor as many as five different screens containing weather (Traffic Situational Display [TSD], Corridor Integrated Weather System [CIWS], Integrated Terminal Weather System [ITWS]) and traffic (TMA Plan View Graphical User Interface [PGUI], TMA Timeline Graphical User Interface [TGUI]) information. This is both physically and mentally challenging (combining spatially displayed weather information with temporally displayed TMA information), and is often not completed in sufficient time to implement a useful mitigation strategy. Note that Figure 2-2 and subsequent figures in this chapter serve merely to illustrate the different levels of integration. They are not intended to imply what the weather needs of any ATM participant may be.

Level 1: On the Glass Weather Integration

Level 1 is still a manual process, but provides much greater situational awareness to the user than "Level 0." Weather data is simply added to the existing traffic display and is therefore more easily factored into constraint assessment, impact determination, and resolution. Individuals manually determine the existence of a constraint by combining their knowledge of safety regulations, internal policy guidelines, and weather, often relying on intuition and past experience. During periods of severe weather, ATM planners and controllers determine potential constraints and apply projected capacity and demand figures to determine probable impact. From there they must develop a course of action including location, boundaries, and time. Outcomes in this manual process can vary widely depending on the individuals involved and their particular interpretation and experience.

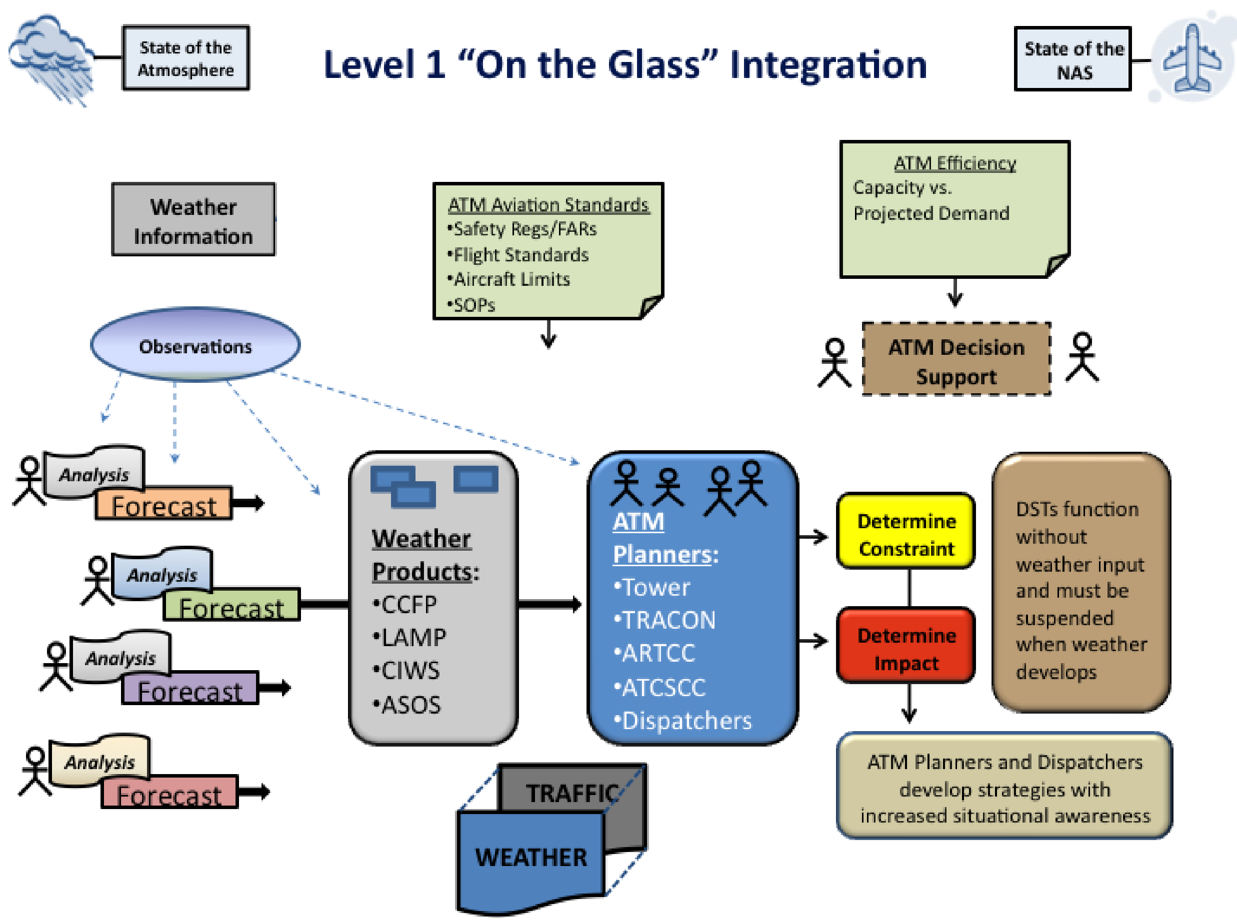

Figure 2-3 Level 1: "On the Glass" Integration

A current example of Level 1 integration is the Weather and Radar Processor (WARP). WARP processes Next Generation Weather Radar (NEXRAD) data and disseminates regional radar mosaics directly onto the controller's Display System Replacement (DSR) via En Route Automation Modernization (ERAM).

Level 2: Translated Weather Integration

Level 2 integration is in use today and will continue to be in use after the advent of the 4-D Wx Data Cube. Therefore, it is shown in Figure 2-4 both with and without input from the 4-D Wx Data Cube. The 4-D Wx Data Cube will provide the benefits of a single authoritative source, but Level 2 integration does not rely on the 4-D Wx Data Cube as a single source of weather data. In addition to a Weather Avoidance Field (WAF), operations-oriented weather constraint data provided to the user such as "stop light" displays or color coded views of aircraft trajectories according to weather constraint are all Level 2 integration. This information allows the user to mentally factor traffic information into a known area of constraint when developing a solution.

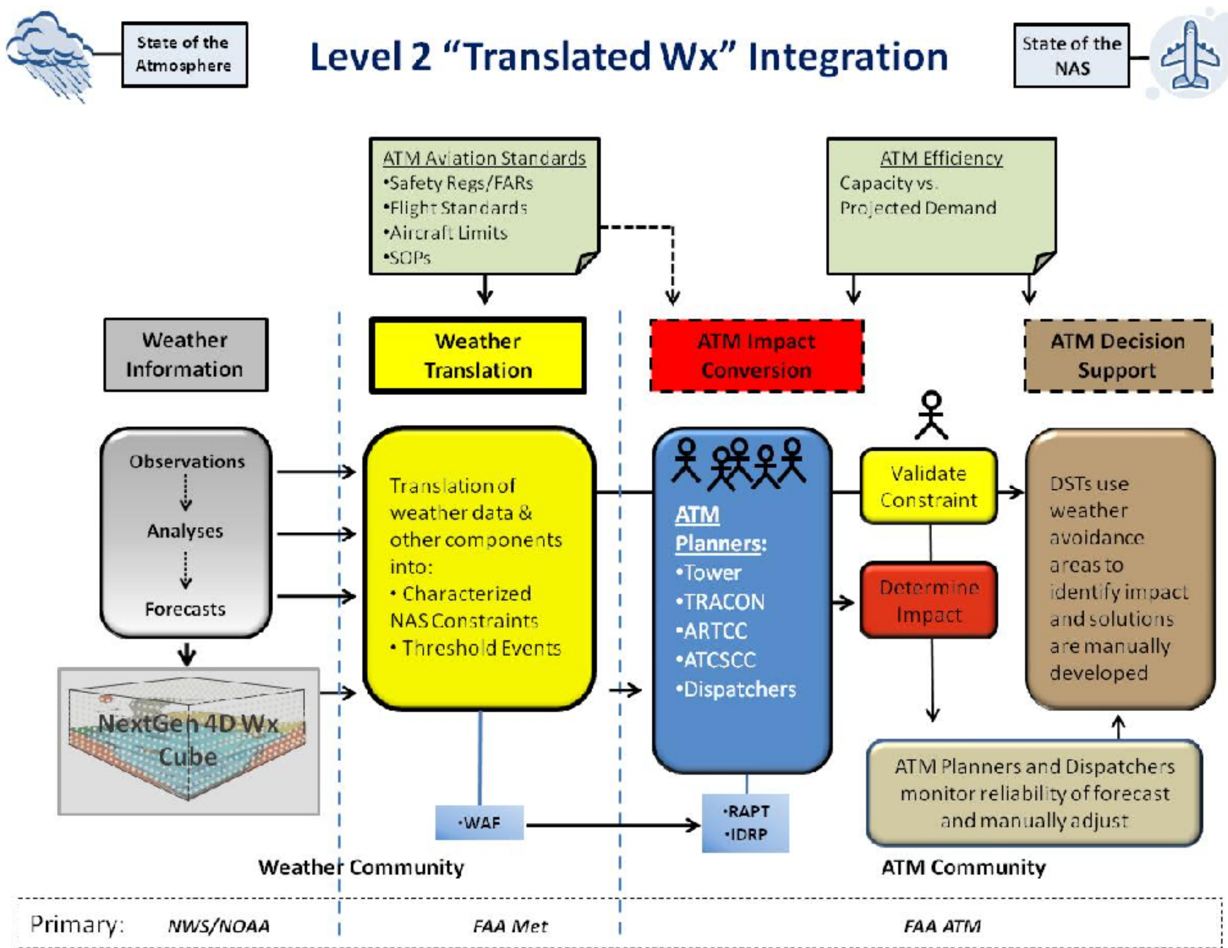

Figure 2-4 Level 2: "Translated Weather" Integration

Although currently a standalone weather system, the wind shear function of the ITWS is an example of Level 2 integration, with weather data being translated into a threshold event, e.g. a wind shear alert. If a weather avoidance area is put "on the glass" as it may eventually be with Time Based Flow Management (TBFM) that would be Level 2 integration. However, once it is combined with traffic information, even a generic model such as the Route Availability Planning Tool (RAPT), has moved to Level 3.

Level 3: Impact Integration – User-in-the-Loop Tools

As noted above, Level 3 integration builds upon Level 2 technologies. These are "red box" tools. They ingest constrained area information and apply NAS traffic and other pertinent information (outages, construction, etc.) to determine impact. This impact is then fed to a DST for resolution, which the user can accept, reject, or modify, or manually use to determine the best solution. There is a Human In The Loop (HITL) on the "ATM side" providing oversight of the conversion output and its reliability, oversight of the traffic and facility information, as well as involvement in selection of the proposed solutions. Level 3 is the "learning to trust" phase of integration and the level of oversight may vary greatly as users gain confidence in these systems.

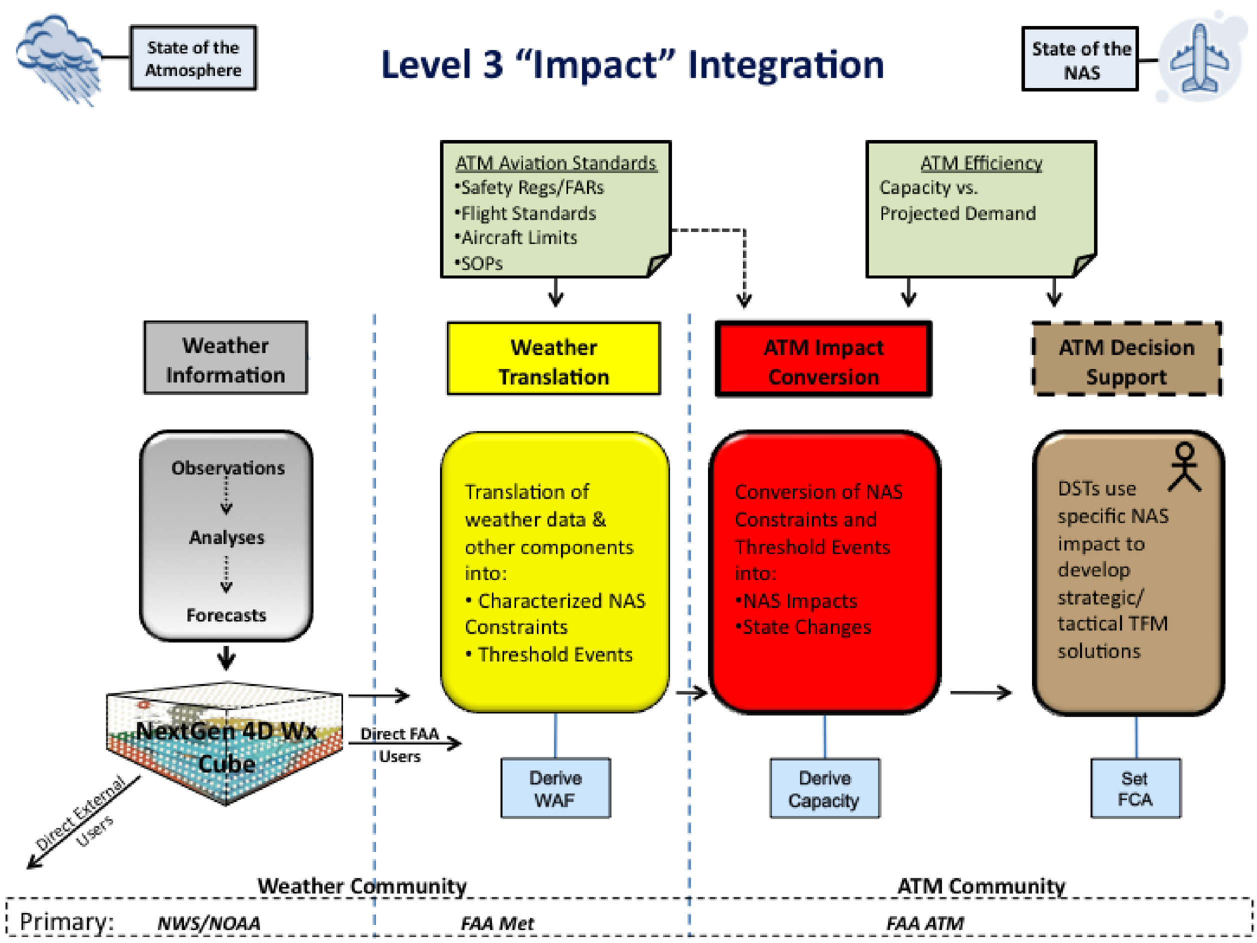

Figure 2-5 Level 3: "Impact" Integration

Level 4: Machine-to-Machine Integration

Level 4 integration fully automates all of the previously discussed steps. As Figure 2-6 shows, Translation, Conversion, and Decision Support may reside in a single tool, or as two or three individual tools working in concert with each other. At this level, there is very little human involvement other than strategic oversight of decisions and overall performance. In these fully automated DSTs, interpretation of weather will not be required by the user, but the user will be able to drill down into the decision if desired.

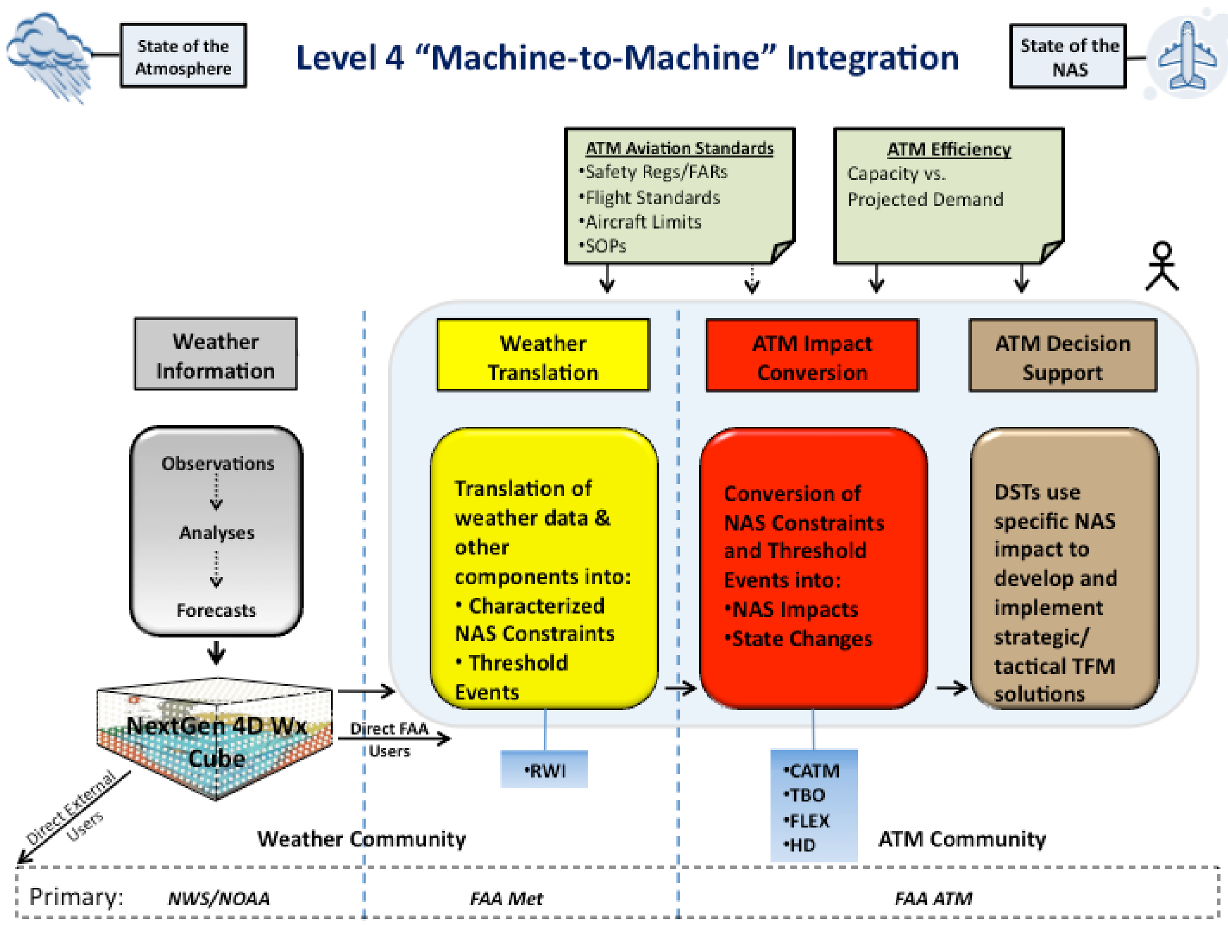

Figure 2-6 Level 4: "Machine-to-Machine" Integration

Although work is ongoing, there are currently no Level 4 integration tools in use based on the model of translating weather elements into constraints, and those constraints into ATM impacts for use in DSTs through M2M integration. This should not be confused with the direct weather machine-to-machine interface that has been applied over the years in DSTs that require pure weather data (e.g winds aloft) for their computations or algorithm processing. Examples of this form of M2M integration include computer flight planning systems, Traffic Flow Management System (TFMS), TMA, and User Request Evaluation Tool (URET), which require wind and temperature input to accurately perform trajectory calculations.

ATM will require DSTs that can deal with the information from the 4-D Wx Data Cube that has been translated into NAS traffic impact values impacts and provide ATM with best choice options. The translation can be obtained by a network service for common use or by imbedding the translation capability in the DST for unique needs. Section 4 and the associated Appendix B provide a survey that identifies technologies and methodologies for translating weather information into ATM impacts in the NAS. The survey includes approaches for addressing weather-related uncertainty in ATM decision making – risk management processes. The survey has two parts: ATM-Weather Impact Models and ATM-Weather Integration Techniques. The Plan presents a summary of each of the surveyed ATM-impact models starting with models that were derived primarily for convection, and ending with a wide variety of models for several types of aviation hazards. This section assessed the maturity of the ATM-impact models presented, and identified gaps in technologies that must be addressed for NextGen.

ANSP needs are associated with weather impact on traffic flow and airspace constraints; AOC/FOC needs are associated with weather impact on system-wide airline operations (e.g., connecting flights); flight deck needs are associated with weather impact on current operation such as safety and comfort. As noted in Paragraph 1.3, AOC/FOC and flight deck decisions unique to the operator (i.e. excluding ANSP participation) are not a subject for intervention in the Plan. Those are principally left for market innovation to develop and implement.

By 2025, weather information will be integrated into decision making, but weather per se will not necessarily appear in the output decision at all. Whether the output decision takes the form of a human-readable display, or is relayed to a larger decision support mechanism, automated integration basically renders weather transparent to NextGen decision makers. Probabilistic weather data will introduce more complexity; e.g. the DST will have to compare input risk tolerance to probabilities of occurrence of the relevant weather phenomena in order to render a decision-quality output. For instance, a particular flight may be able to tolerate a 30percent probability of thunderstorms along the planned route of flight, but it could not tolerate a percent% probability, in which case alternatives would be sought.

The expectation is that the number, complexity, and sophistication of automated DSTs will increase over time as the 4-D Wx Data Cube matures, expanding its available sets of gridded data. At present the number of automated decision tools in the NAS is fairly limited, with inputs provided by point-to-point weather data feeds. As the 4-D Wx Data Cube assimilates grids of all meteorological parameters relevant to aviation, developers will build DSTs tailored to the particular needs and decision spectra of particular users. Development of tailored DSTs will be largely the province of the commercial sector where there is tremendous opportunity for ingenuity in applying weather to a whole range of decisions. The prime requirement for the weather community is that the weather information available by subscription from the 4-D Wx Data Cube be in a form, at a resolution and at a quality level that meets user needs and can be readily translated into impacts and assimilated by the users' DSTs. In order for this integration to be successful, human factors research must be conducted to ensure that developers understand how weather is used in decision making so that the impact of weather data can be correctly translated into DSTs. This research will also be critical in determining the level or amount of weather transparency needed given the user's role in decision making. In some cases, anomalies or special circumstances may require users to view weather data as opposed to DST output.

2.4 Alternatives Considered for Integration

This section briefly discusses three alternative approaches to weather integration. The emphasis of this discussion is on weather integration itself. The source of weather data (i.e., the 4-D Wx Data Cube) and the network infrastructure that will distribute this information are considered separately.

Table 2-1 Alternatives Considered for Providing Weather Information

Alternatives	Description	Feasibility	Ability to Deliver NextGen Vision
Status quo – do nothing	Maintain current stand-alone text and graphical weather products	Green	Red
Improve Weather Products to Enhance Usability by ATM	Overlay weather data onto ATM displays and develop new weather displays with "high glance value"	Green	Yellow
Integrate Weather Information into ATM DSTs	Leverage net-centric standards and incorporate on-going research into weather impacts to add new weather algorithms to existing and developing TFM decision support tools.	Green	Green

2.4.1 Status Quo – Do Nothing

There are currently very few instances of the integration of weather data into ATM tools. Flight planning systems incorporate winds aloft and temperatures. Some tools are available involving the timing of deicing. Generally, weather is interpreted manually, with stand-alone tools and displays. This situation requires controllers and decision makers to consult several unrelated displays in a manual mode in order to make critical decision. As stated earlier, weather accounts for more than 70percent of flight delays. The current system is inadequate to mitigate this problem.

The baseline, multi-agency weather data processing, access, and dissemination architecture consists of multiple distributed processing systems collecting sensor data and producing value-added analysis and forecast products. Organizations access the data by approaching weather processing systems and agency telecommunication systems to arrange for point-to-point transport of the weather products. Some data is also available via access to special web pages (e.g., Aviation Digital Data Service [ADDS]). The status quo is an unacceptable option because it involves diverse architectures, technologies, and standards; it does not meet numerous NextGen requirements (e.g., publication/subscription registry, push/pull access, tailored information, and a single authoritative source of weather information).

By maintaining the status quo, integration and automation would not be achieved.

2.4.2 Improve Weather Products to Enhance Usability by ATM

The second alternative considered is to improve current weather products in ways that improve their usability by TFM decision makers. This may amount to more user-oriented displays of presently-available information. Weather information can be overlaid on air traffic displays and weather displays can be upgraded to reduce the amount of interpretation required for rapid understanding of the weather situation. These "high glance value" displays reduce TFM decision-makers' requirement to have a deep understanding of weather situations.

This alternative can be accomplished without general improvements to the underlying weather delivery systems; however, significant improvements are required in weather processing to achieve reductions in avoidable delays. This alternative would not achieve NextGen goals nor would it allow for improvements in TFM tools such as TMA, which now require the tool to be turned off during adverse weather because of lack of weather integration. Accordingly, the integration of a common weather picture into all of the ATM decision support systems and planned automation systems would not be achieved.

2.4.3 Integrate Weather Information into ATM Decision Support Tools

The last alternative is to integrate weather information into ATM DSTs. This alternative meets the goals and recommendations set out by the Weather – ATM Integration Working group of the National Airspace Systems Operations Subcommittee, FAA, REDAC in their report dated October 3, 2007. A key finding of this report "is that a risk management approach with adaptive, incremental decision making, based on automatically translating weather forecasts into air traffic impacts, presents a major new opportunity for reducing weather related delays in the future NAS." Achievement of this alternative requires development of a new weather data architecture by heavily leveraging net-centric standards and incorporating legacy architectures. This option overcomes the deficiencies of the other alternatives, meets all NextGen goals and requirements, is the most cost effective, and involves acceptable implementation risk. It also allows for the provision of current regulatory weather products (e.g., convective Significant Meteorological Information [SIGMETS]), while policy is changed to transition the NAS from a 'product' to an 'information' environment. This option includes distributed data processing, with centralized publication/subscription, using much of the current baseline architecture; and develops a single authoritative source of weather information for collaborative decision making involving ground and airborne platforms. The underlying architecture developed to achieve NextGen goals provides the necessary platforms and capabilities for the integration of weather information directly into DSTs.

2.5 Recommended Solution: Integrate Weather Information into ATM Decision Support Tools

The recommended solution is to integrate weather directly into ATM DSTs. Weather integration will simplify the decision process for humans and make weather data seamless to NAS users. Weather integration allows user decision tools to have the best available weather information and to use that information in a wide range of decisions both on the ground and in the cockpit.

The 4-D Wx Data Cube is not part of this plan; however, this alternative assumes the existence of the 4-D Wx Data Cube, a virtual database of information - separate weather databases located in different locations such as NWS, other agency processing facilities, research or laboratories, etc. and connected via a net-centric infrastructure. Rapid updates of weather data used in TFM tools is essential to successful weather integration and therefore, the underlying infrastructure being developed for NextGen is key to the success of the weather integration effort. The 4-D Wx Data Cube is essential to the development of DSTs which integrate weather directly into the decision-making process.

2.6 Anticipated Benefits and Impact

Advances in weather information content and dissemination provide users and/or their decision support with the ability to identify specific weather impacts on operations (e.g., trajectory management and impacts on specific airframes, arrival/departure planning) to ensure continued safe and efficient flight. Users will be able to retrieve (and subscribe to automatic updates of) weather information to support assessment of flight-specific thresholds that indicate re-planning actions are needed. In particular, the 4-D Wx Data Cube (and later The 4-D Weather Single Authoritative Source [4-D Wx SAS]) will support enhanced volumetric extractions, by time frame of interest, of weather information by NAS users to quickly filter the enhanced weather content to the region of interest for impact analysis. This will streamline the process by which the user with decision support ATM tools - conducts system-wide risk management in planning for both individual flight trajectories and flows.

Because of the profound impact of adverse weather on the safety, efficiency, and capacity of the NAS, improved decision making when weather impacts operations is a key NextGen objective. The initial 4-D Wx SAS, a subset of the 4-D Wx Data Cube, provides a consistent, de-conflicted common weather picture (e.g., observations, forecasts, and climatology, from the surface to the top of the NAS) that will provide ANSPs and airspace users with a common view of the weather situation.

Using the 4-D Wx SAS, ANSPs, users and their decision support systems will be able to make trajectory-oriented or area-oriented requests for weather information so that they can determine its effect on the flight trajectory being evaluated. This customized weather information will be integrated into initial tactical and strategic decision support tools developed under the TBO, CATM, FlexTerm, and HiDensity Solution Sets. These tools will assess the risk management of the operational impact of weather on flights/trajectories and provide candidate actions to the ANSP that mitigate these impacts on safety and traffic flow. These tools support real time "what if" assessments, support common situation awareness within and between domains, and can be tailored to support different user preferences (e.g., displays, lists, alert modes, flight specific probabilistic thresholds, and format tailoring). The 4-D Wx SAS provides a single and authoritative definition of the current weather state and prediction of the future weather, as well as the user-requested high resolution, high temporal characteristics of importance to aviation users. The 4-D Wx SAS will also provide proactive updates ("push") to requestors based on user requests.

The combination of consistent weather information integrated into decision support tools will enable more effective and timely decision making by both ANSPs and users, for meeting capacity, efficiency and safety objectives. This also supports the alignment of traffic flows that best achieve a balanced capacity, safety and end user desires. It effectively enables a common understanding of the uncertainty of the future state of the atmosphere, supports traffic flow management by trajectory, and provides for improved weather avoidance.

3 NEXTGEN WEATHER INTEGRATION: DECISION SUPPORT TOOLS

3.1 Introduction

This chapter contains an analysis of the need and opportunity for weather integration into NAS operations. Compared to Version 1.0, Chapter 3 is expanded to include weather integration capabilities and their alignment with FAA programs, including an initial look at the timelines and links between select NAS Enterprise Architecture (EA) Automation Roadmaps and newly developed Weather Roadmaps. Along with Appendix A it is to be expanded and refined as more information becomes available and as weather is integrated into various FAA programs and tools. Updates will be applied when more refinement of the concepts and weather integration requirements of those capabilities have been delivered. In some cases, where clear requirements to meet the weather needs of planned concepts and capabilities have not been identified, assumptions are used. Scenarios that depict nominal and off-nominal events, equipped and non-equipped aircraft and emergency operations will need to be developed.

3.2 Chapter Structure

Section 3. is directed at NextGen solution sets as defined in the NextGen Implementation Plan (NIP): TBO, HiDensity, FlexTerm, CATM, SSE, and Facilities. Each solution set is built upon capabilities, referred to as Operational Improvements (OIs), and categorized in "swim lanes." Capabilities fall within either the Near, Mid, or Far-Term time frames and are identified in each solution set. Where possible, an assessment of each capability was done with reference to its link to weather and the current development phase, ranging from Concept Exploration (CE) through Concept Development (CD) and on to Prototype Development (PD). Beginning with a set of assumptions, the value of integrated weather was examined within the context of an overarching scenario or Concept of Operations (ConOps). Where possible, the scenario was deconstructed into individual use cases to help define and draw out user needs and points of integration and decision support tools, information threads, and weather linkages were closely examined to fully inform the integration solution. The work is iterative and will require continued effort as time, resources and understanding evolve. An expanded view of this section is provided in Appendix A.

Section 3.4 of the Plan now contains FAA Program-Oriented Weather Integration Analyses. Because these analyses draw from the information found in the expanded Solution-Set oriented analyses in Appendix A, connectivity is established or strengthened between the NextGen Solution Sets and existing or future FAA Programs.

The FAA Program-Oriented Analyses are very similar in format to the NextGen Solution Set-Oriented Analyses. Weather-impacted NextGen capabilities identified in the Appendix A analyses are collected, logically grouped and then associated with the FAA programs intended to be enablers of those capabilities. High level weather integration analyses of those programs are conducted and program/weather integration gaps are identified. Derived from this work are graphical representations, based on NAS EA timelines, designed to visually link the program and weather activities. In this format, dual value is achieved as the weather community receives a more robust understanding of the program weather needs, and the program office is introduced to pending weather services or information well-suited to their program capability needs.

The ATM Weather Integration Plan Version 1.0 analysis process followed the solution-set swim-lane timelines as a basis for determining the potential weather integration insertion points. In version 2.0, the analysis was expanded to include current programs, their roadmaps for near-term implementation, and the alignment with the goals and expectation of NextGen capabilities.

Figure 3-1 depicts the general analysis process used in identifying and aligning Mid-Term capabilities with weather requirements and techniques that are identified as potential candidates for inclusion into DSTs.

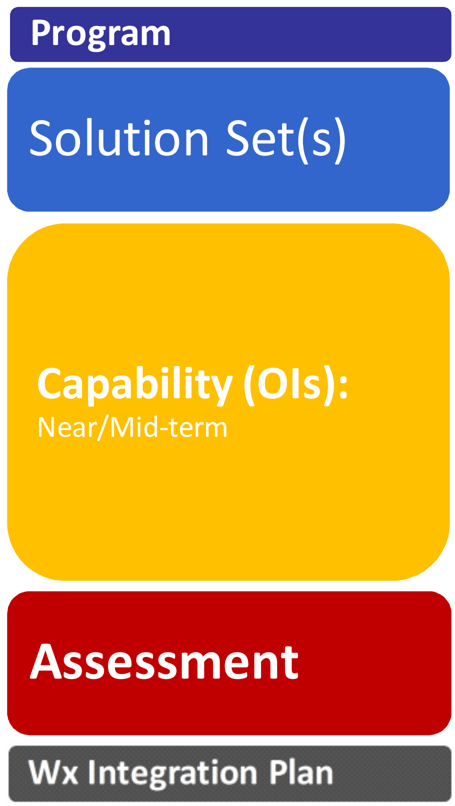

Figure 3-1: ATM/Weather Integration Analysis Process

Figure 3-2 provides an example of this flow using the TBFM program in this analysis process.

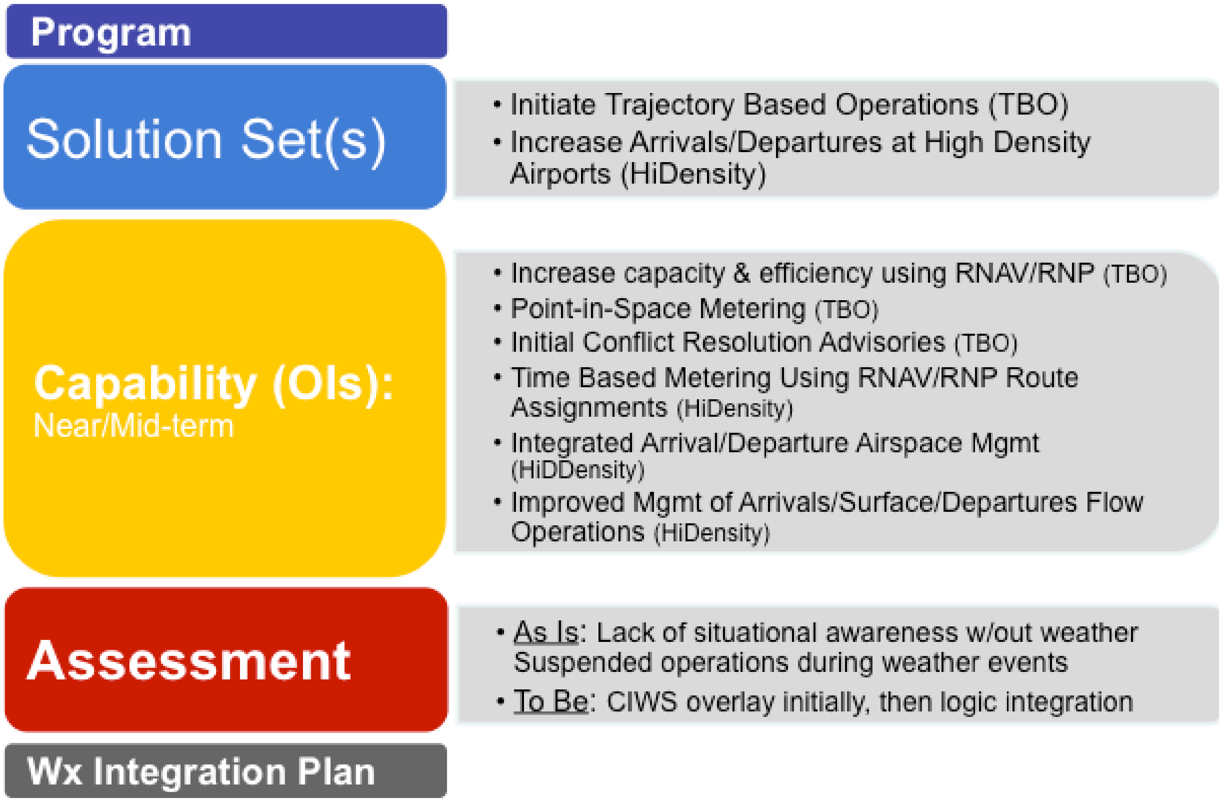

Figure 3-2: Example of ATM/Weather Integration Analysis Process for TBFM

The capabilities addressed in the ATM Weather Integration Plan bring forth a wide range of maturity to the analysis. Much more discussion, debate and trade studies are required to make each area whole in its understanding and comprehensiveness within the entire portfolio of ATM/Weather integrated capabilities.

General Assumptions

One of the assumptions associated with all the solution sets is that near-term stand-alone DSTs will begin to move from the current state of little to no weather integration to being fully integrated with weather (including uncertainty) in the far-term. There are situations today where weather can be and usually is stand-alone information (Level 0: “Stand-Alone” Displays), or there can be four levels of integration, each with increasing levels of complexity. The four levels of weather integration that will be applied are as follows:

Level 1: “On the Glass” Integration

Level 2: “Translated Weather” Integration

Level 3: “Impact” Integration

Level 4: “M2M” Integration

Another assumption is that weather is addressed for temporal and spatial operational needs for all airspace from strategic planning and risk assessment to the tactical environment that surrounds, or is on the airport surface.

3.3 Solution Set-Oriented Weather Integration Analysis

Solution set-based capabilities that form the focal point of the NextGen Mid-Term ATM/weather integration related efforts consist of the following six areas:

- Initiate Trajectory Based Operations
- Increase Arrival/Departures at High Density Airports
- Increase Flexibility in the Terminal Environment
- Improve Collaborative ATM
- Increase Safety, Security, and Environment Performance
- Transform facilities

The Plan identifies within each solution set capability a brief description of any potential weather integration opportunities, what these descriptions are based on, and an on-going discussion of the Mid-Term OIs contained in the solution set. The analysis documents OI goals, needs/shortfalls, descriptions, and design/architecture while describing the weather integration opportunities in more detail. A weather integration scenario is developed as needed for concept clarification and identifies potential Mid-Term functional weather requirements. The plan should be considered a work in-progress intended to help communicate and refine the developing Mid-Term weather integration scope and context as it applies to the NAS operational areas. Over time, far-term OIs (represented by the light blue shaded timelines in the figures) may be added. A full description of each solution set is located within Appendix A of this Plan.

3.3.1 Initiate Trajectory Based Operations (TBO)

The TBO depends on a major paradigm shift as the control of air traffic changes from clearance-based to trajectory-based methods. “Aircraft will fly negotiated trajectories and air traffic control moves to trajectory management. The traditional responsibilities and practices of pilots and controllers will evolve due to the increase in automation, support, and integration inherent in management by trajectory. This solution set focuses primarily on en route cruise operations, although the effects of the trajectory-based operations will be felt in all phases of flight.” [FAA Solution Set Smart Sheet: Initiate Trajectory Based Operations (TBO), 2008]

Initiate Trajectory-Based Operations, (Figures 3-3 and 3-4) depicts the solution set capabilities along the associated swim lane timelines: Separation Management (SM), Trajectory Management (TM), and Capacity Management (CM).

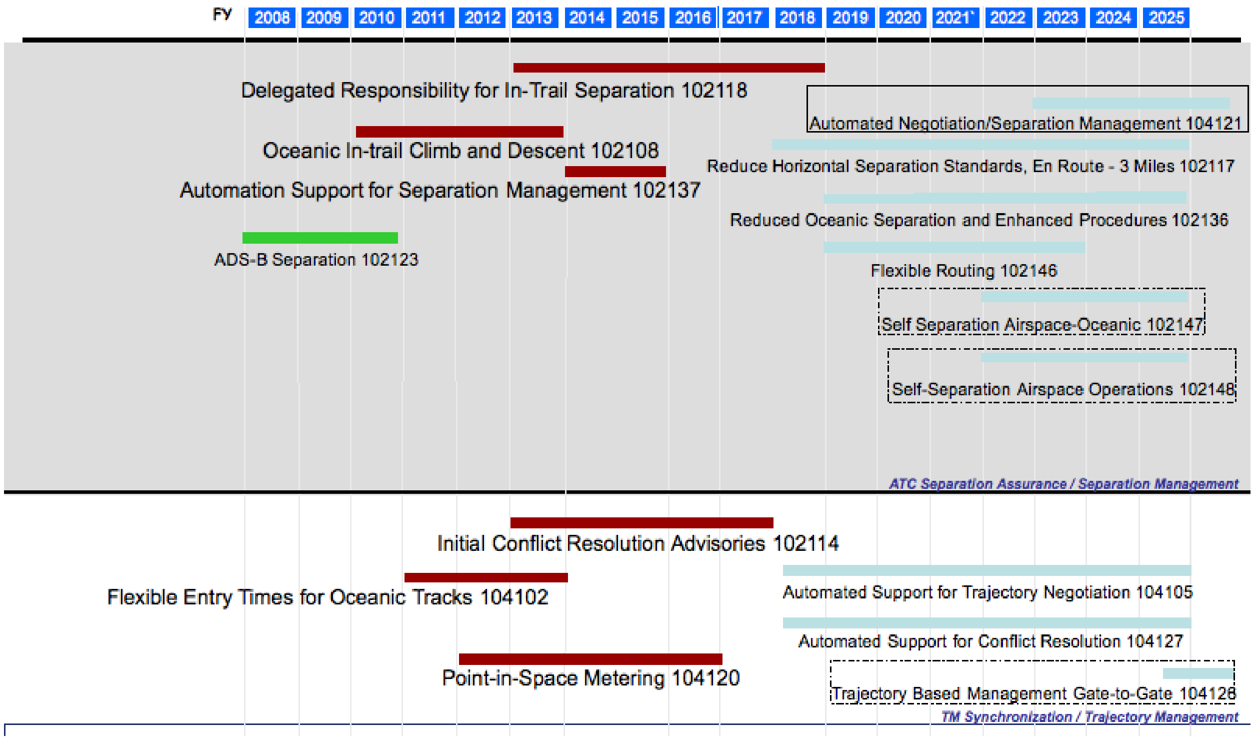

Figure 3-3: Initiate Trajectory-Based Operations 1 of 2 from the Initiate Trajectory-based Operations Solution Set Smart Sheet

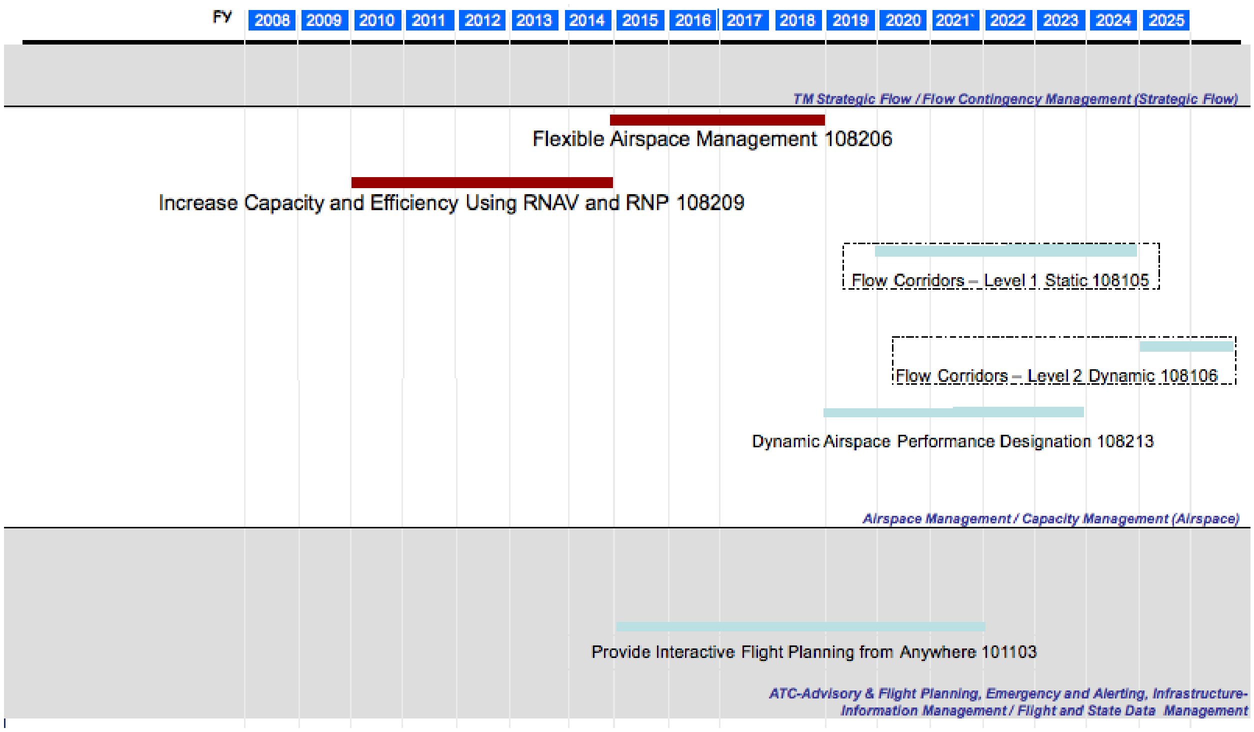

Figure 3-4: Initiate Trajectory-Based Operations 2 of 2 from the Initiate Trajectory-based Operations Solution Set Smart Sheet

3.3.1.1 ATC Separation Assurance/SM Mid-Term Capabilities

- Delegated Responsibility for In-Trail Separation
  - Delegated Responsibility for In-Trail Separation extends today's visual flight rules capabilities for clear weather, pair-wise, "in sight" delegated longitudinal separation to operations conducted in Instrument Meteorological Conditions (IMC) leveraging Automatic Dependent Surveillance Broadcast (ADS-B), Cockpit Display of Traffic Information (CDTI), and improved avionics.
- Oceanic In-trail Climb and Descent
  - Oceanic In-trail Climb and Descent will take advantage of improved communication, navigation, and surveillance coverage in the oceanic domain to allow participating aircraft to fly more advantageous trajectories.
- Automation Support for SM
  - The goal of Automation Support for SM is to allow the controller to better manage aircraft in an environment with mixed navigation equipage and aircraft with varying wake performance characteristics.

3.3.1.2 Traffic Management Synchronization/TM Mid-Term Capabilities

- Initial Conflict Resolution Advisories

    - Initial Conflict Resolution Advisories reduce sector controller workload by integrating existing conflict detection and trial flight planning capabilities with those for conflict resolution advisory and ranking while also introducing data link clearances.

- Flexible Entry Times for Oceanic Tracks
    - Flexible Entry Times for Oceanic Tracks allows greater use of user-preferred trajectories by looking ahead to plan near-term climbs when loading oceanic tracks.
- Point-in-Space Metering
    - Point-in-Space Metering provides smooth metering of traffic to a downstream capacity-constrained point by providing an automated sequence of upstream CTAs, at various airspace boundaries along a flight path, to meter traffic rather than impose Miles-in-Trail (MIT) constraints.

3.3.1.3 Airspace Management/CM (Airspace) Mid-Term Capabilities

- Flexible Airspace Management
    - Flexible Airspace Management enables ANSP automation to support the assessment of alternate configurations and to reallocate resources, trajectory information, surveillance, and communications information to different positions or different facilities.
- Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigational Performance (RNP)
    - This capability creates more en route structured routes, taking advantage of both RNAV and RNP to enable more efficient aircraft trajectories. RNAV and RNP combined with airspace changes can increase airspace efficiency and capacity.

3.3.2 Increase Arrival/Departures at High Density Airports

The Increase Arrivals/Departures at High Density Airports solution set involves airports and the airspaces that access those airports in which one of the following applies:

- Demand for runway capacity is high
- There are multiple runways with both airspace and taxiing interactions
- There are close proximity airports with the potential for airspace or approach interference, as in a Metroplex environment

High density airports require all the capabilities of flexible terminals and surrounding airspace plus integrated tactical and strategic flow capabilities. DSTs may require higher performance navigation and communications capabilities, including higher fidelity weather information integrated into DSTs for both ATM functions and the aircraft itself. High density corridors will serve as transitions to and from trajectory-based en-route airspace. High density operations will seamlessly integrate surface operations through transition altitudes to en-route airspace.

The Mid-Term HiDensity OIs of interest are depicted in NIP charts as red timelines.

Increase Arrivals/Departures at High Density Airports, Figure 3-5, depicts the solution set capabilities along the associated “swim lane timelines”: SM, TM and CM.

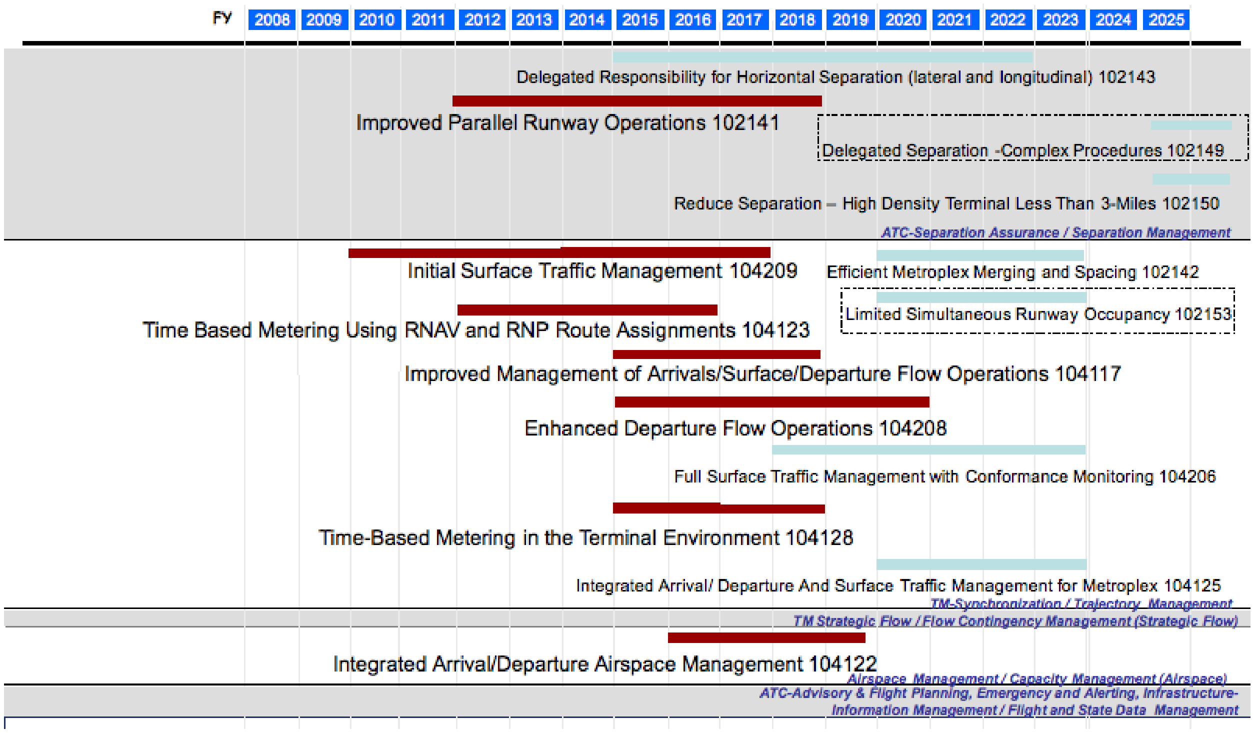

Figure 3-5: Increase Arrivals/Departures at High Density Airports from the Increase Arrivals/Departures at High Density Airports Solution Set Smart Sheet

3.3.2.1 ATC-Separation Assurance/SM Mid-Term Capabilities

- Improved Parallel Runway Operations
  - Improved Parallel Runway Operations enables operations for closely spaced parallel runways (runways spaced less than 4,300 feet laterally) in reduced visibility weather conditions. This operational improvement promotes a coordinated implementation of policies, technologies, standards, and procedures to satisfy the requirement for increased capacity while meeting safety, security, and environmental goals.

3.3.2.2 TM-Synchronization/TM Mid-Term Capabilities

- Initial Surface Traffic Management
  - Surface traffic management integrates automation DSTs, data and processes (e.g., surveillance data, weather data, departure queues, aircraft flight plan information, runway configuration, expected departure times, and gate assignments). The concept envisions collaboration between airport stakeholders to improve

information flow to decision support systems as well as the ability for aircraft operators to meet operational and business objectives.

- Time-Based Metering Using RNAV and RNP Route Assignments
  - Time-Based Metering Using RNP and RNAV Route Assignments achieves orderly metering of aircraft flows in and out of the extended terminal area of high-density airports to maximize capacity and support user-efficient operations. Arrival flows are managed via assignment of a Controlled Time of Arrival (CTA) to arrival points. This sequencing of streams of aircraft applies appropriate spacing to efficiently conduct a variety of procedures such as airborne merging and spacing, optimal profile descents, parallel runway operations and wake-based spacing. Departure routing is improved by increasing the accuracy of predicted trajectories.
- Improved Management of Arrival/Surface/Departure Flow Operations (IASDF)
  - Improved Management of Arrival/Departure Flow Operations assembles a wide range of capabilities in a choreographed fashion in order to enable cohesive, coordinated end-to-end air traffic management processes and solutions. Some of these capabilities would appear to be associated with other solution set capabilities, primarily from within the HiDensity Solution Set. It leverages advanced communications and automation technologies as the primary means of accomplishing its goal.
- Enhance Departure Flow Operations
  - Enhance Departure Flow Operations leverages and integrates surface traffic management systems to incorporate taxi instructions, surface movement information, and aircraft wake category performance calculations. Clearances are developed, delivered, monitored and provided in digital data or textual format that is used by the flight deck display to support taxi, takeoff and departure flows in all conditions. At high-density airports clearances and amendments, requests, NAS status, airport flows, weather information, and surface movement instructions are issued via data communications. This capability appears to overlap, but could be complementary to the previously discussed OI entitled Initial Surface Traffic Management (NAS OI-102141). Both would seem to be intended to lay the foundation for the far-term OI entitled Full Surface Traffic Management for Conformance Monitoring (NAS OI-104206).
- Time-Based Metering in the Terminal Environment
  - Time-Based Metering in the Terminal Environment expands the use of metering from the metering fix, which can reside at the boundaries outside the terminal, all the way to the runway threshold. Aircraft are time-based metered inside the terminal environment, enhancing efficiency through the optimal use of terminal airspace and surface capacity. ANSP automation develops trajectories and allocates time-based slots for various points (as needed) within the terminal environment, applying RNAV route data and leveraging enhanced surveillance,

data communications, and closely spaced parallel, converging, and intersecting runway capabilities, where applicable.

3.3.2.3 Airspace Management/Capacity Management (Airspace) Mid-Term Capabilities

- Integrated Arrival/Departure Airspace Management
  - Integrated Arrival/Departure Airspace Management optimizes terminal area airspace configurations by tailoring capacity to meet demand, managing delay, giving consideration to environmental factors, and better addressing Metroplex interdependencies.

3.3.3 Increase Flexibility in the Terminal Environment (FlexTerm)

The FlexTerm Solution Set has a focus on improvements to manage the separation at all airports. Such capabilities will improve safety, efficiency and maintain capacity in reduced visibility high density terminal operations. At airports where traffic demand is lower, and at high density airports during times of low demand, operations requiring lesser aircraft capability are conducted, allowing access to a wider range of operators while retaining the throughput and efficiency advantages of high density operations. Both trajectory and non trajectory-based operations may be conducted within flexible terminal operations.

FlexTerm, Figures 3-6 and 3-7, depict the solution set capabilities along the associated swim lane timelines; SM, TM CM and Flight and State Data Management (FSDM).

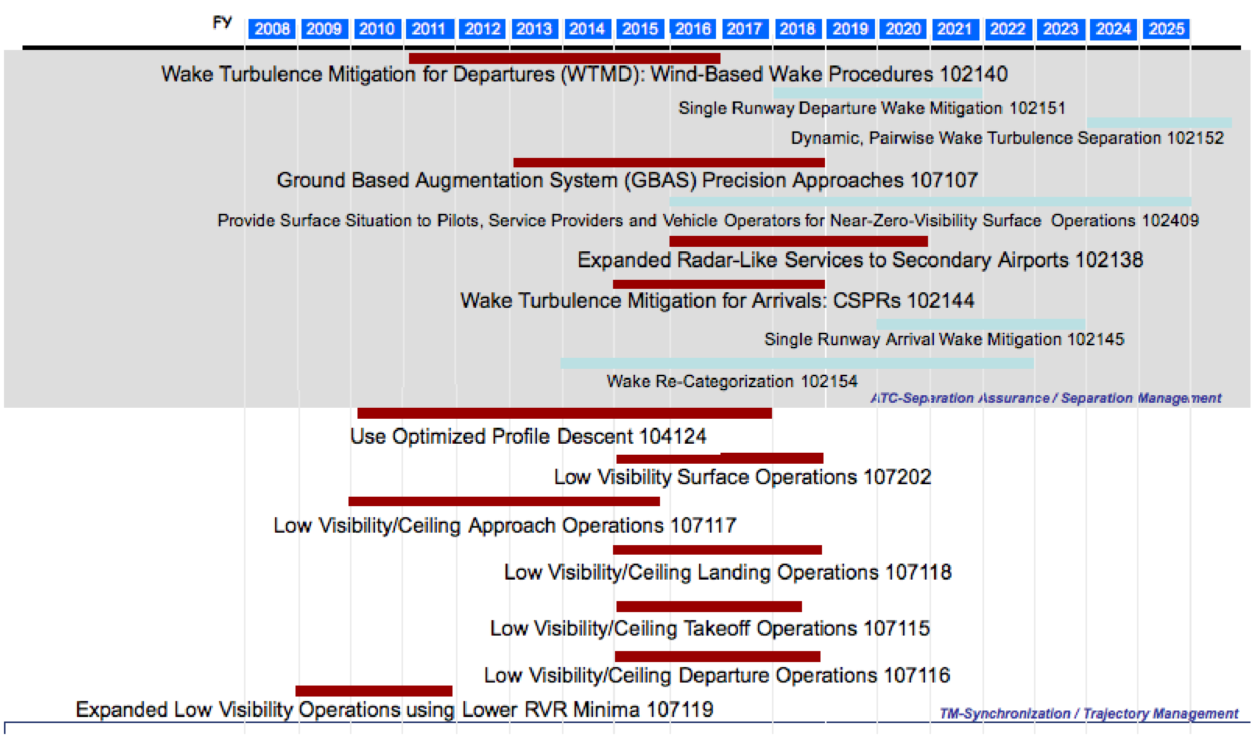

Figure 3-6: Increase Flexibility in the Terminal Environment (1 of 2) from the Increase Flexibility in the Terminal Environment Solution Set Smart Sheet

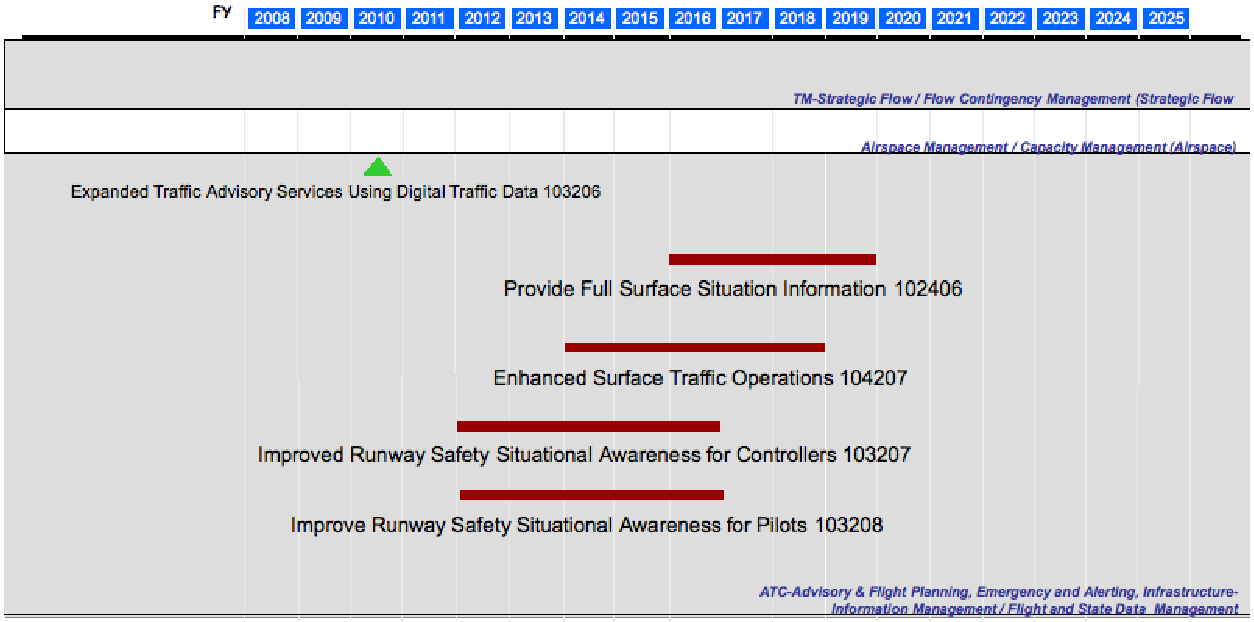

Figure 3-7: Increase Flexibility in the Terminal Environment (2 of 2) from the Increase Flexibility in the Terminal Environment Solution Set Smart Sheet

3.3.3.1 ATC-Separation Assurance/SM Mid-Term Capabilities

- Wake Turbulence Mitigation for Departures (WTMD): Wind-Based Wake Procedures
  - WTMD applies new technology, rules, and procedure based on the results of wake measurements and safety analysis in order to maintain departure throughput rates of an airport during operationally favorable wind conditions. The changes to the wake rules would be implemented based on wind measurements and procedures to allow more closely spaced departure operations to maintain airport/runway capacity. Procedures are developed at applicable locations based on the results of wake measurements and safety analysis through wake modeling and visualization. Weather sensors and algorithms are used to predict stable wind conditions that allow reduced separations due to wake movement. Procedures based on site-specific wake measurement and safety analysis will be developed. During peak demand periods, these procedures allow airports to maintain airport departure throughput during favorable wind conditions where wake will not be a factor. A staged implementation of changes in procedures and standards, as well as the implementation of new technology, will safely reduce the impact of wake vortices on operations. This reduction applies to specific types of aircraft and is based on wind blowing an aircraft's wake away from the parallel runway's operating area.
- Ground-Based Augmentation System (GBAS) Precision Approaches
  - GBAS Precision Approaches, using Global Positioning System (GPS)/GBAS, support precision approaches to Category I (as a non-federal system), and

eventually Category II/III minimums for properly equipped runways and aircraft. GBAS can support approach minimums at airports with fewer restrictions to surface movement and offers the potential for curved precision approaches. GBAS also can support high-integrity surface movement requirements. The cost and flexibility of GBAS will lead to more runway ends being equipped with qualified electronic precision approach guidance, resulting in significant safety and efficiency benefits.

- Expanded Radar-like Services to Secondary Airports
  - Expanded Radar-like Services to Secondary Airports increases both safety and capacity. During IMC navigation and when communications equipment and services normally would not be available, this capability will enable equipped ADS-B aircraft to utilize the smaller facility as if it were in a radar environment. Additionally, enhanced surveillance coverage in areas of mountainous terrain where radar coverage is limited, especially to smaller airports, enables ANSPs to provide radar-like services to ADS-B equipped aircraft. This capability enhances alerting and emergency services beyond normal radar coverage areas.
- Wake Turbulence Mitigation for Arrivals: Closely Spaced Parallel Runways (CSPRs)
  - Wake Turbulence Mitigation for Arrivals at CSPRs increases airport/runway capacity in IMC while maintaining established safety parameters. Crosswind-dependent wake-based arrival procedures at specific airports will be deployed with corresponding operating periods. Procedures are developed at applicable locations based on the results of wake measurements and safety analysis through wake modeling and visualization. As technology matures and further study provides more detail and accuracy for wake turbulence drift and decay predictions, the amount of time that reduced wake separation procedures will be available will increase.

3.3.3.2 TM-Synchronization/Trajectory Management Mid-Term Capabilities

- Use Optimized Profile Descent: Optimized Profile Descents (OPDs)
  - OPDs provide more fuel-efficient, noise reduced arrivals flow into an airport.
  - OPDs, also called Continuous Decent Arrival (CDA) permit aircraft to remain at higher altitudes on arrival to the airport and use lower power settings during descent. OPD arrival procedures will decrease noise and be more fuel-efficient. The air navigation service provider procedures and automation accommodate OPDs when operationally advantageous.
  - An OPD, in its optimal form, is an arrival where an aircraft is cleared to descend from cruise altitude to final approach using the most economical power setting at all times. Based on published arrival procedures at final approach, the aircraft begin a continuous rate of descent using a window of predetermined height and distance. Thrust may be added to permit a safe, stabilized approach-speed and flap-configuration when following the glide slope to the runway.

- Low Visibility Surface Operations
  - Low Visibility Surface Operations increases safety and vehicle access during low visibility conditions at the airport. Aircraft and ground vehicles determine their position on an airport from GPS, Wide-Area Augmentation System (WAAS), Local-Area Augmentation System (LAAS), via ADS-B and Ground-Based Transceivers (GBT) systems with or without surface based surveillance. Location information of aircraft and vehicles on the airport surface is displayed on moving maps using CDTI or aided by Enhanced Flight Vision Systems (EFVS), Enhanced Vision Systems (EVS), Synthetic Visions Systems (SVS) or other types of advanced vision or virtual vision technology.
- Low Visibility/Ceiling Approach Operations
  - Low Visibility/Ceiling Approach Operations improves the ability to complete approaches in low visibility/ceiling conditions for aircraft equipped with some combination of navigation derived from augmented GNSS or ILS and Head-up Display (HUD), EFVS, SVS, advanced vision system and other cockpit-based technologies that combine to improve human performance. Cockpit-based technologies allow instrument approach procedure access with reduced requirements on ground-based navigation and airport infrastructure. Due to onboard avionics airport access is maintained in low visibility/ceiling conditions.
- Low Visibility/Ceiling Landing Operations
  - Low Visibility/Ceiling Landing Operations improves the ability to land in low visibility/ceiling conditions for aircraft equipped with some combination of navigation derived from augmented Global Navigation Satellite System (GNSS) or Instrument Landing System (ILS) and other cockpit-based technologies or combinations of cockpit-based technologies and ground infrastructure.
- Low Visibility/Ceiling Takeoff Operations
  - Low Visibility/Ceiling Takeoff Operations improves access by allowing properly equipped aircraft to takeoff in low visibility conditions. Currently, visibility minimums for takeoff depend on aircraft equipment, ground infrastructure, and runway marking and lighting. This ensures that pilots are able to visually maintain the runway centerline during both nominal and aborted takeoffs. By using cockpit-based technologies such as HUD, EFVS, SVS or other advanced vision system technologies, the pilot will be able to maintain an equivalent awareness of runway centerline with reduced dependence on airport infrastructure when visual conditions are below those normally required for takeoff.
- Low Visibility/Ceiling Departure Operations
  - Low Visibility/Ceiling Departure Operations increases airport access and enhance safety. In order to depart an airfield and enter the en route structure the aircraft must be able to achieve a minimal prescribed climb performance in order avoid any natural or manmade hazard. If an aircraft cannot meet the required climb performance the aircraft will be able to either use precision navigation or visual

"see and avoid" procedures that enable the aircraft to avoid the hazard while flying at a lower required rate of climb.

- Precision navigation will allow for the pilot to safely depart the airfield at a lower climb rate while still maintaining a safe buffer from the hazard.
- When the pilot elects to use a "see and avoid" option for the departure, the pilot would normally be required to meet a minimal visibility and/or ceiling requirement to go along with a lower than normal climb performance. By using EFVS, SVS, or an advanced vision system, the pilot would be able to elect the "see and avoid" procedure by achieving an equivalent level of safety to the natural vision requirements.

- Expanded Low Visibility Operations using Lower Minima
  - Expanded Low Visibility Operations using Lower RVR Minima increases capacity and flexibility, improves performance in IMC, and reduces costs to the FAA and stakeholders.
  - Lowering Runway Visual Range (RVR) minima from 2,400 feet to 1,800 feet. (or lower depending on the airport and requirement) at selected airports using RVR systems, aircraft capabilities and procedural changes provides greater access to OEP, satellite and feeder airports during low visibility conditions. Utilization of these improvements will increase NAS capacity and traffic flow during periods of IMC and allow a greater number of aircraft to complete scheduled flights under marginal weather conditions.
  - This improvement allows increased runway capacity during periods of low visibility by providing increased arrivals/departures at high density airports. It also allows the airlines to maintain planned scheduled flights in marginal weather conditions.

3.3.3.3 ATC-Advisory and Flight Planning; Emergency and Alerting; Infrastructure Information Management/Flight and State Data Management Mid-Term Capabilities

- Provide Full Surface Situation Information
  - Full Surface Situation Information provides all stakeholders with common situation awareness and increases safety of ground operations, including reducing the risk of runway incursion.
  - Automated broadcast of aircraft and vehicle position to ground and aircraft sensors/receivers provides a digital display of the airport environment. Aircraft and vehicles are identified and tracked to provide a full comprehensive picture of the surface environment to ANSP, equipped aircraft, and FOCs.
  - Surface Situation Information complements visual observation of the airport surface. DST algorithms use enhanced target data to support identification and alerting of those aircraft at risk of runway incursion.

- Enhanced Surface Traffic Operations
  - Enhanced Surface Traffic Operations provides digital data communications between the aircraft and ANSP for use in exchange of clearances, amendments, requests, and surface movement instructions at select airports. As a step towards NextGen capabilities, digital data communication between aircraft and ANSP will be used to provide for a more efficient ground information exchange and an additional means of communication between flight crews and controllers. In the Mid-Term timeframe, the current automation capability that provides Proposed Departure Clearances (PDCs) from the tower to an AOC computer will be retained but will also be enhanced to generate and transmit departure clearances and revisions, and taxi route instructions via data link directly to the aircraft. This enhanced capability will allow revisions to departure clearances, which are currently provided only by voice communication, to be provided via data link. The concept also includes a provision for sending the pre-departure clearance automatically, without controller intervention. This automated capability is similar to the current “automode” capability for PDCs, which sends the PDCs directly to the AOC without controller intervention. Operational procedures will determine whether this enhancement will be used for initial departure clearances or for revisions.
- Improved Runway Safety Situational Awareness for Controllers
  - Improved Runway Safety Situational Awareness for Controllers increases safety. At large airports, current controller tools provide surface displays and can alert controllers when aircraft taxi into areas where a runway incursion could result. Additional ground-based capabilities will be developed to improve runway safety that include expansion of runway surveillance technology (i.e., ASDE-X) to additional airports, deployment of low cost surveillance for medium-sized airports, improved runway markings, and initial controller taxi conformance monitoring capabilities. These ground-based tools will provide a range of capabilities to help improve runway safety for medium- to large-sized airports.
- Improved Runway Safety Situational Awareness for Pilots
  - Improved Runway Safety Situational Awareness for Pilots increases safety by providing pilots with improved awareness of their location on the airport surface as well as runway incursion alerting capabilities. To help minimize pilot disorientation on the airport surface, a surface moving map display with ownship position will be available. Both ground-based (e.g., Runway Status Lights [RWSL]) and cockpit-based runway incursion alerting capabilities will also be available to alert pilots when it's unsafe to enter the runway. Additional enhancements may include cockpit display of surface traffic (e.g., vehicles and aircraft) and the use of a cockpit display that depicts the runway environment and displays traffic from the surface up to approximately 1,500 feet above ground level on final approach and used by the flight crew to help determine runway occupancy.

3.3.4 Improve Collaborative ATM (CATM)

The CATM Solution Set covers strategic and tactical flow management, including interactions with operators to mitigate situations when the desired use of capacity cannot be accommodated.

This solution set includes flow programs and collaboration on procedures that shift demand to alternate resources (e.g. routings, altitudes, and times). CATM also addresses the management of aeronautical information necessary for all operations within the NAS, including the management of airspace reservation and flight information from pre-flight planning to post-flight analysis.

The CATM Solution Set has the greatest number of ATM-weather integration opportunities and needs, and the Continuous Flight Day Evaluation Operational Improvement is the key to the success of CATM.

As Figure 3-8 depicts, the CATM Solution Set is the doorway to ATM/Weather integration and the Continuous Flight Day Evaluation is the key to that door. Detailed discussion can be found in the Appendix A along with treatments of the TBO and HiDensity Solution Sets.

The OI connectivity is provided by System Wide Information Management (SWIM). The information exchange between OIs is enabled by the following NextGen Information Services:

- Initial Integration of Weather Information into NAS Automation and Decision Making, which will rely on the 4-D Wx Data Cube and its SAS, and the downstream translation of weather into constraints.
- On Demand NAS Information (i.e., an information service that disseminates constraint information; capacity, demand, and congestion models; and mitigation strategies).

Collaboration is enabled through common ANSP/customer access to the information provided by these information services. Access to this information by DSTs across solution sets and NAS domains enables an integrated NextGen system.

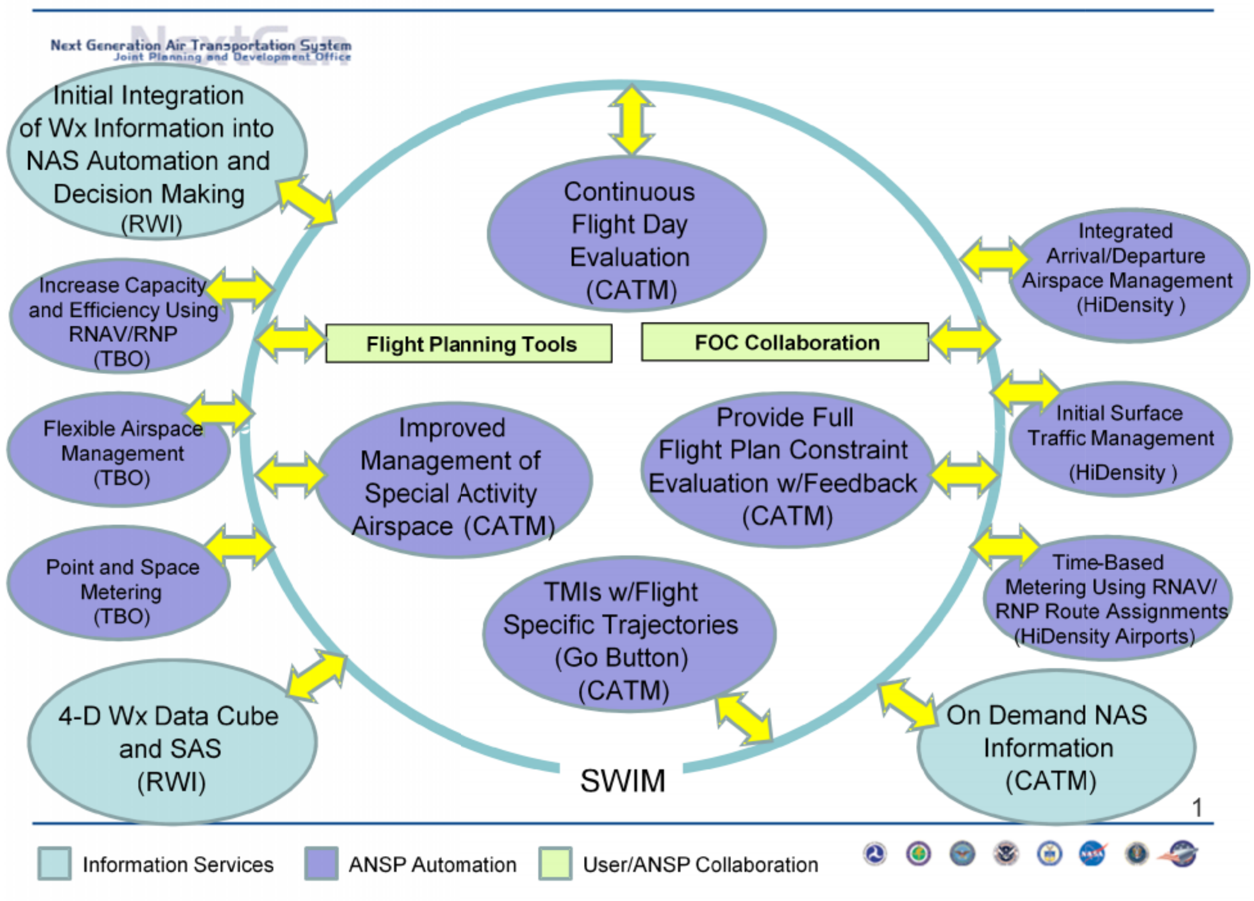

Figure 3-8: CATM ATM/Weather Integration Connectivity

Improved Collaborative Air Traffic Management, Figure 3-9, depicts the solution set capabilities along the associated "swim lane timelines": Flow Contingency Management (FCM), CM and FSDM.

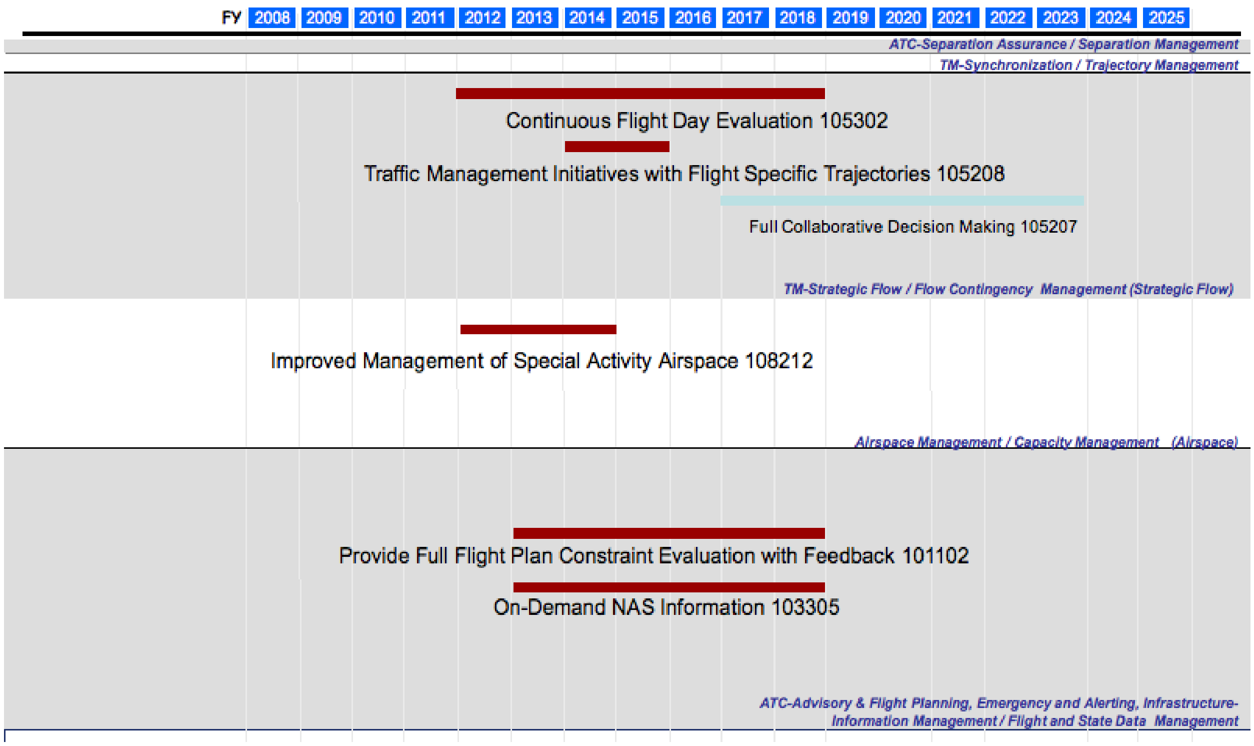

Figure 3-9: Improve Collaborative ATM from the Improve Collaborative ATM Solution Set Smart Sheet

3.3.4.1 TM-Strategic Flow/FCM (Strategic Flow) Mid-Term Capabilities

- Continuous Flight Day Evaluation
  - Continuous Flight Day Evaluation improves the long-term planning environment, through continual performance assessment, and imposes fewer en-route capacity constraints by applying tailored incremental responses to predicted congestion.
- Traffic Management Initiatives with Flight Specific Trajectories
  - Traffic Management Initiatives with Flight Specific Trajectories, also called “The Go Button,” provides a mechanism to implement TMIs generated by Continuous Flight Day Evaluation in a tailored flight-specific manner.

3.3.4.2 Airspace Management/CM Mid-Term Capabilities

- Improved Management of Special Activity Airspace
  - Improved Management of SAA provides transparency in real-time status and scheduling of DoD reserves of airspace to enhance its flexibility of use by civilian aircraft operators. This capability will allow increased awareness and predictability of SAA usage so that civilian flight operators can more reliably plan and utilize flight routes that cross through inactive SAA without affecting the DoD’s mission needs.

3.3.4.3 ATC-Advisory and Flight Planning; Emergency and Alerting; Infrastructure and Information Management/Flight and State Data Management Mid-Term Capabilities

- Provide Full Flight Plan Constraint Evaluation with Feedback
  - Provide Full Flight Plan Constraint Evaluation with Feedback increases the aircraft operator's route flexibility and reduces large nonlinear cost (e.g., diversions) through negotiated trajectory resolutions which include operator business objectives and preferences for avoiding congested areas.
- On-Demand NAS Information
  - On-Demand NAS Information is the timely distribution of NAS asset status and aeronautical information so all aircraft operators can plan and conduct safe flights under the most up-to-date current conditions.

3.3.5 Increase Safety, Security, and Environmental Performance (SSE)

TBD

3.3.6 Transform Facilities (Facilities)

TBD

3.4 Program Oriented Weather Integration Analysis

3.4.1 Introduction and Description

Section 3.3 contained highly condensed summaries of the NextGen Solution Set-Oriented weather integration analyses located in Appendix A. New for this version of the Plan are the FAA Program-Oriented weather integration analyses which follow. Because these analyses draw from the information found in the Solution Set-oriented analyses contained in Appendix A connectivity is maintained between the NextGen Solution Sets and existing or future FAA programs.

The FAA Program-Oriented Analyses are very similar to the NextGen Solution Set-Oriented Analyses. First, weather-impacted NextGen weather-related capabilities identified in the Appendix A analyses are collected and then associated with the FAA programs designated or thought to be enablers of those capabilities. High level weather integration analyses of those programs are then conducted and program/weather integration gaps are identified. Derived from this work are graphical representations, based on NAS EA timelines, designed to visually link the program and weather activities.

3.4.2 Section Structure

3.4.2.1 NextGen Solution Set Required Mid-Term Weather-Related Capabilities

For each Solution Set/OI pair, all explicit or implicit required Mid-Term weather-related capabilities are identified and listed in a table. One or more FAA programs or systems into which the weather-related capability will, or is most likely to, be integrated are also identified. For the purpose of this analysis, the term FAA Program will be used to represent programs, systems or a combination of the two.

3.4.2.2 FAA Programs Mid-Term Weather Integration Analyses

A weather integration analysis will be conducted for each of the FAA Programs identified in the previous section. TBFM is the only fully developed program analysis as of Version 1.5 of this Plan. Each analysis will, at a high level, consist of the following sections:

3.4.2.2.1 Program Name, Description and Objectives

The name and description of the FAA Program will lead off this section, followed by a summary of the objectives of the program, and the capabilities (NextGen and otherwise) it is intended to deliver.

3.4.2.2.2 Program-Based Weather Integration Analysis

The weather integration activities associated with the program being analyzed will be identified from, and examined through the lens of, each of the required Mid-Term weather-related capabilities associated with the program. Actual or proposed weather integration points in the program development and implementation timeline will be identified where known.

3.4.2.2.3 Program Weather Integration Gaps

If the program does not appear to be considering required weather integration issues or providing the necessary integrated weather capabilities, these issues will be identified and listed as gaps. Conversely, if the program lists weather requirements that are not likely to be met, they, too, will be identified and listed as gaps.

3.4.2.2.4 NAS EA/Weather Integration Timeline Charts

Based on the results of the Program/Solution Set Weather Integration Analyses, a corresponding graphic will be produced. This chart, which is intended to provide interested parties with a useful graphical representation of how the program and weather will interact, will visually depict much of the same information contained in the analyses.

3.4.3 NextGen Solution Set Required Mid-Term Weather-Related Capabilities

Table 3-1 below lists the NextGen Solution Sets, associated Mid-Term OIs that have or may have weather-related capabilities, the Required Mid-Term Weather-Related Capabilities associated with those OIs, and the FAA program(s) into which the capability is intended or most likely to be integrated.

Table 3-1 NextGen Solution Set Required Mid-Term Weather-Related Capabilities

Nbr.	NextGen Solution Set	Operational Improvement (OI)	Required Mid-Term Weather-Related Capability	Target FAA Program(s)
HD1	Increase Arrivals/ Departures at High Density Airports	Improved Parallel Runway Operations (102141)	Airport observations and forecasts of ceiling, visibility, wind speed and direction at appropriate resolutions, update rates and latencies	UNK

Nbr.	NextGen Solution Set	Operational Improvement (OI)	Required Mid-Term Weather-Related Capability	Target FAA Program(s)
HD2	Increase Arrivals/ Departures at High Density Airports	Improved Parallel Runway Operations (102141)	Wake vortex transport and decay forecasts at appropriate resolutions, update rates and latencies	UNK
HD3	Increase Arrivals/ Departures at High Density Airports	Improved Parallel Runway Operations (102141)	Space weather (communications-impacting solar activity) forecasts at appropriate resolutions, update rates and latencies	UNK
HD4	Increase Arrivals/ Departures at High Density Airports	Initial Surface Traffic Management (104209)	Airport forecasts of ceiling, visibility, wind speed and direction and convection and terminal area volumetric forecasts of wind speed and direction and convection at appropriate resolutions, update rates and latencies	*ASMD* *CATM (G5C)* *TFDMS*
HD5	Increase Arrivals/ Departures at High Density Airports	Time-Based Metering Using RNP and RNAV Route Assignments (104123)	Terminal area volumetric forecasts of wind speed and direction, temperature, dew point, pressure, icing and turbulence at appropriate resolutions, update rates and latencies	*ERAP* TBFM/IES
HD6	Increase Arrivals/ Departures at High Density Airports	Improved Management of Arrival/Surface/ Departure Flow Operations (IASDF) (104117)	TBD	*ATC/ATM DST* *CATM (G5C)* *TBO (G1C)* *TFDMS*
HD7	Increase Arrivals/ Departures at High Density Airports	Enhanced Departure Flow Operations (104208)	TBD	*ADS-B* *CATM (G5C)* *HD (G2S)* *ITWS* *TFDMS* *TBO (G1C)*
HD8	Increase Arrivals/ Departures at High Density Airports	Time-Based Metering in the Terminal Environment (104128)	TBD, but appears to be same as Time-Based Metering Using RNP and RNAV Route Assignments (HD5)	TBFM/IES
HD9	Increase Arrivals/ Departures at High Density Airports	Integrated Arrival/Departure Airspace Management (104122)	Airport forecasts of wind speed and direction, ceiling and visibility and terminal area volumetric forecasts of wind speed and direction and convection at appropriate resolutions, update rates and latencies	*ATC/ATM DST* *CATM (G5C)* *TFDMS*

Nbr.	NextGen Solution Set	Operational Improvement (OI)	Required Mid-Term Weather-Related Capability	Target FAA Program(s)
HD10	Increase Arrivals/ Departures at High Density Airports	Integrated Arrival/Departure Airspace Management (104122)	Airport and terminal area volumetric forecasts of convection at appropriate resolutions, update rates and latencies	*ATC/ATM DST* *CATM (G5C)* *TFDMS*
TB1	Initiate Trajectory Based Operations	Delegated Responsibility for In-Trail Separation (102118)	Observations and forecasts of convective weather within 20 minutes (~160NM) of the pathfinder and following aircraft at appropriate resolutions, update rates and latencies	*ADS-B* *HD (G2S)*
TB2	Initiate Trajectory Based Operations	Oceanic In-Trail Climb and Descent (102108)	None	N/A
TB3	Initiate Trajectory Based Operations	Automation Support for Separation Management (102137)	None	*ERAP*
TB4	Initiate Trajectory Based Operations	Initial Conflict Resolution Advisories (102114)	Observations and forecasts of convective weather within 20 minutes (~160NM) of the affected aircraft at appropriate resolutions, update rates and latencies	ERAM
TB5	Initiate Trajectory Based Operations	Flexible Entry Times for Oceanic Tracks (104102)	Enroute (oceanic) winds forecasts at appropriate resolutions, update rates and latencies	TBFM/IES?
TB6	Initiate Trajectory Based Operations	Point-in-Space Metering (104120)	Enroute area volumetric forecasts of wind speed and direction and turbulence at appropriate resolutions, update rates and latencies	*ATC/ATM DST* *CATM (G5C)* *ERAP* *NF (G3C)* TBFM/IES
TB7	Initiate Trajectory Based Operations	Flexible Airspace Management (108206)	NAS-wide climatological weather information	*ATC/ATM DST* *CATM (G5C)* *ITWS* *NF (G3C)*
TB8	Initiate Trajectory Based Operations	Flexible Airspace Management (108206)	NAS-wide multi-hour forecasts (e.g., 3 hourly) of winds aloft, icing, turbulence and convection at appropriate resolutions, update rates and latencies 1 to 5 days out	*ATC/ATM DST* *CATM (G5C)* *ITWS* *NF (G3C)*
TB9	Initiate Trajectory Based Operations	Flexible Airspace Management (108206)	NAS-wide forecasts of winds aloft, icing, turbulence and convection at appropriate resolutions, update rates and latencies 1-24 hours out	*ATC/ATM DST* *CATM (G5C)* *ITWS* *NF (G3C)*

Nbr.	NextGen Solution Set	Operational Improvement (OI)	Required Mid-Term Weather-Related Capability	Target FAA Program(s)
TB10	Initiate Trajectory Based Operations	Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigational Performance (RNP) (108209)	TBD	*ATC/ATM DST* *ERAP*
FT1	Increase Flexibility in the Terminal Environment	*Wake Turbulence Mitigation for Departures (WTMD): Wind-Based Wake Procedures (102140)*	TBD	*ARTS* *TFDMS*
FT2	Increase Flexibility in the Terminal Environment	*Ground-Based Augmentation System (GBAS) Precision Approaches (107107)*	TBD	TBD
FT3	Increase Flexibility in the Terminal Environment	*Expanded Radar-Like Services to Secondary Airports (102138)*	TBD	*ADS-B* *CATM (G5C)* *HD (G2S)*
FT4	Increase Flexibility in the Terminal Environment	*Wake Turbulence Mitigation for Arrivals: CSPRs (102144)*	TBD	*CATM (G5C)* *TFDMS*
FT5	Increase Flexibility in the Terminal Environment	*Use Optimized Profile Descent (102124)*	TBD	TBD
FT6	Increase Flexibility in the Terminal Environment	*Low Visibility Surface Operations (107202)*	TBD	*ADS-B* *ASMD* *HD (G2S)* *LCGS* *TFDMS*
FT7	Increase Flexibility in the Terminal Environment	*Low Visibility/Ceiling Approach Operations (107117)*	TBD	TBD

Nbr.	NextGen Solution Set	Operational Improvement (OI)	Required Mid-Term Weather-Related Capability	Target FAA Program(s)
FT8	Increase Flexibility in the Terminal Environment	*Low Visibility/Ceiling Landing Operations (107118)*	TBD	TBD
FT9	Increase Flexibility in the Terminal Environment	*Low Visibility/Ceiling Takeoff Operations (107115)*	TBD	TBD
FT10	Increase Flexibility in the Terminal Environment	*Low Visibility/Ceiling Departure Operations (107116)*	TBD	TBD
FT11	Increase Flexibility in the Terminal Environment	*Expanded Low Visibility Operations using Lower RVR Minima (107119)*	TBD	TBD
FT12	Increase Flexibility in the Terminal Environment	*Provide Full Surface Situation Information (102406)*	TBD	*ADS-B* *ASMD* *HD (G2S)* *LCGS* *TFDMS*
FT13	Increase Flexibility in the Terminal Environment	*Enhanced Surface Traffic Operations (104207)*	TBD	*TBO (G1C)* *TFDMS*
FT14	Increase Flexibility in the Terminal Environment	*Improved Runway Situational Awareness for Controllers (103207)*	TBD	*ASMD* *LCGS* *TFDMS*
FT15	Increase Flexibility in the Terminal Environment	*Improved Runway Situational Awareness for Pilots (103208)*	TBD	*ADS-B* *ASMD* *HD (G2S)* *LCGS* *TFDMS*
CA1	Improved Collaborative Air Traffic Management	Continuous Flight Day Evaluation (105302)	Probabilistic and/or ensemble forecasts of convective weather (CONUS) and winter weather (e.g., snow, freezing mix) 5 days in advance and at appropriate resolutions, update rates and latencies to determine potential impacts on controller staffing levels	*ATC/ATM DST* *CATM (G5C)*

Nbr.	NextGen Solution Set	Operational Improvement (OI)	Required Mid-Term Weather-Related Capability	Target FAA Program(s)
CA2	Improved Collaborative Air Traffic Management	Continuous Flight Day Evaluation (105302)	Probabilistic forecasts of convective weather (CONUS), high density terminal airspace (150NM radius up to FL270) winds, high density terminal airspace convection and airport ceiling and visibility24 hours in advance and at appropriate resolutions, update rates and latencies to enable the determination of alternative strategic plans	*ATC/ATM DST* *CATM (G5C)*
CA3	Improved Collaborative Air Traffic Management	Continuous Flight Day Evaluation (105302)	Probabilistic forecasts of convective weather (CONUS), high density terminal airspace (150NM radius up to FL270) winds, high density terminal airspace convection and airport ceiling and visibility8 hours in advance and at appropriate resolutions, update rates and latencies to enable the refinement of strategic plans	*ATC/ATM DST* *CATM (G5C)*
CA4	Improved Collaborative Air Traffic Management	Continuous Flight Day Evaluation (105302)	Probabilistic forecasts of convective weather (CONUS) 2 hours in advance and at appropriate resolutions, update rates and latencies to enable the selection of strategic planning alternatives	*ATC/ATM DST* *CATM (G5C)*
CA5	Improved Collaborative Air Traffic Management	Continuous Flight Day Evaluation (105302)	Probabilistic forecasts of convective weather (CONUS) 0-40 minutes in advance and at appropriate resolutions, update rates and latencies to enable tactical modification of strategic plans implemented 2 hours in advance	*ATC/ATM DST* *CATM (G5C)*
CA6	Improved Collaborative Air Traffic Management	Traffic Management Initiatives with Flight Specific Trajectories (105208)	TBD	*ATC/ATM DST* *CATM (G5C)* *ERAP*
CA7	Improved Collaborative Air Traffic Management	Improved Management of Special Activity Airspace (108212)	None	*ATC/ATM DST* *CATM (G5C)* *ERAP* *HD (G2S)*

Nbr.	NextGen Solution Set	Operational Improvement (OI)	Required Mid-Term Weather-Related Capability	Target FAA Program(s)
CA8	Improved Collaborative Air Traffic Management	Provide Full Flight Plan Constraint Evaluation with Feedback (101102)	Trajectory-based probabilistic forecasts of convective weather, icing, turbulence, airport ceiling, visibility, winds and precipitation type up to 18-24 hours in advance at appropriate resolutions, update rates and latencies to enable the identification of weather constraints for a specific flight plan using user supplied assessment criteria	*ATC/ATM DST* *CATM (G5C)* *ERAP*
CA9	Improved Collaborative Air Traffic Management	Provide Full Flight Plan Constraint Evaluation with Feedback (101102)	Trajectory-based probabilistic forecasts of winds and temperatures aloft up to 18-24 hours in advance at appropriate resolutions, update rates and latencies to enable routine flight plan trajectory calculations	*ATC/ATM DST* *CATM (G5C)* *ERAP*
CA5	Improved Collaborative Air Traffic Management	On-Demand NAS Information (103305)	None	*ATC/ATM DST* *CATM (G5C)* *ERAP* *HD (G2S)*

3.5 FAA Programs Mid-Term Weather Integration Analyses

3.5.1 TBFM[7]

3.5.1.1 TBFM Description and Objectives

TBFM is the next step of evolution in metering technology and will replace TMA. TBFM expands the role and scope of Time-Based Metering (TBM) operations to provide benefits more broadly throughout the NAS. The TBFM program focuses on the addition of new capabilities to maximize usage of available NAS resources, while minimizing delays and disruptions to aircraft operators and their customers, as well as reducing fuel burn to decrease user operational costs and cutting engine emissions to decrease environmental impact. TBFM system development is planned for the performance period of 2010-2015. While TBFM is a stand-alone development program, it is being developed and implemented in a manner that it will provide a suitable and robust platform for a follow-on program, the Integrated Enterprise Solution (IES). It is envisioned that the IES will integrate and extend TBFM functionality into the capabilities provided by the ERAM system and/or the TFMS after 2015.

3.5.1.2 Evolution of TBM

TBM is an approach to traffic management based on scheduling flights to en route trajectory points applied in either the arrival and/or en route/departure phase of flight. TBM is most commonly used to sequence and schedule the flow of aircraft through congested areas to

[7] FAA Concept of Operations for Time Based flow Management, January 10, 2010

efficiently allocate NAS resources. It is an efficient means of dynamically managing demand/capacity imbalances in comparison to the limitations of traditional MIT spacing.

The current ARTCC DST used for TBM is TMA. TMA is used to optimize the flow of aircraft into capacity-constrained terminal areas and calculates an Estimated Time of Arrival (ETA) and corresponding Scheduled Time of Arrival (STA) at various points along the aircraft flight path to an airport. When flights approach a congested airport, TMA is used to determine how the multiple streams of incoming flights can be sequenced and scheduled to fully utilize the runway and other airport resources and avoid unnecessary delay in compliance with all operational constraints.

Adjacent Center Metering (ACM) extends the use of TMA and the TBM approach beyond the boundaries of one Air Route Traffic Control Center (ARTCC). When the primary adjacent ARTCC has a sector without enough airspace/time to absorb delay to the TRACON boundary, an adjacent upstream ARTCC will help by metering their arrivals prior to handoff to the primary ARTCC.

Convective weather presents a number of unique challenges to TBM, specifically the lack of situational awareness of convective weather as compared to the available metering and traffic information. The use of TBM has historically been limited during convective weather. Because TMA is not an "integrated" system and weather (except for wind data used for trajectory modeling) resides on a separate display, NAS efficiency is degraded when Traffic Management Coordinators (TMCs) cannot display current or forecast convective weather along with traffic on the metering displays.

Accurate and precise wind data is critical to the accuracy of trajectory and time-of-arrival calculations. TMA does not receive atmospheric data from the most up to date services and that reduces the accuracy of the scheduled ETA/STA times. TMA presently uses older Rapid Update Cycle (RUC) 2 weather files generated by the National Center for Environmental Protection (NCEP).

The TBFM program is a key element of the FAA TFM operational environment. TBFM expands the role and scope of TMA TBM operations, to provide operational benefits more widely throughout the NAS.

3.5.1.3 TBFM Operational Enhancements

- Extended Metering
  - Flexibility for TMCs in conducting ACM by segmenting long arrival streams
  - Scheduling and sequencing of merging flows of aircraft into en route or arrival traffic flows
  - Sequencing departure flows feeding adjacent ARTCC airspace, allowing departures to be scheduled into available slots one or more ARTCC away
- Integrated Departure/Arrival Capability (IDAC), which provides traffic managers in the ARTCC the ability to monitor departure and en route demand, initiate departure flow initiatives and monitor the traffic flow. IDAC allocates departure times to the affected

airports, and traffic managers at the airports assign these times to the departures at their facilities.

- Display Convective Weather Enhancement:
  - Display ofweather information on the PGUI. This allows the TMC to see the location of current and forecasted severe weather and its relationship to air traffic in the area, improving the ability to manage metering operations during convective weather situations. The increased situational awareness can increase the amount of time that TBM is conducted during severe weather and help traffic managers better predict when to suspend and resume metering in the presence of convective weather or when to alter traffic flows around the weather cells. This may help reduce the length and size of delays introduced by convective weather.
  - System retrieves convective weather data from FAA approved sources and reformats the information for display on the PGUI. Weather data to be displayed includes current as well as forecast conditions for a period of up to 2 hours in the future. Retrieved weather data includes current and forecast weather, atmospheric data, winds, temperature, atmospheric pressure, geo-potential height, terminal weather reports, precipitation, jet streams, radar tops, and lightning.
- This initial step would make TBFM a Level 1 "On the Glass" Integrated Tool.
  - System Re-architecture Operational Enhancements: new weather data provides more accurate winds and temperature aloft data in the generation of 4D trajectory calculations to improve ETAs. A separate engineering string capability gives the TMC the ability to preview the effects of contemplated metering constraint changes prior to implementing those changes. Post Metering and Analysis capability provides recommended solutions geared toward establishing the effectiveness of system metrics and supplying specific recommended actions that will improve site metering operations.

3.5.1.4 System Enhancements

System enhancements include flexible scheduling, the implementation of RNAV/RNP routes and procedures, TBFM information sharing, and improved weather.

The overall objective of TBFM is for the operational user to see a positive impact from the implementation of capabilities in the following areas:

- ETA/STA prediction
- TBM
- Application of TMIs into the traffic flow
- Flexibility to schedule into open arrival/departure slots
- Delay planning
- Reduced staffing requirements at workstations
- Preview ability for predictive decision making

- Metering analysis and improvement tools
- Local and weather restrictions
- Information sharing to collaborate with industry

Once the functionality provided by TBFM is implemented, the operational user will notice significant improvements in schedule based metering and traffic management decision making.

3.5.1.5 TBFM Weather Integration Analysis

When considering weather integration into TBFM, the primary factor is to determine which weather phenomenon effects the precise calculation of ETA/STA predictions. Any weather condition that either directly or indirectly causes a deviation from the calculated trajectory, altitude, or ground speed is examined. It should be noted that wind information, currently from the RUC-2, is used by TMA for trajectory calculations, along with temperatures aloft. With the implementation of TBFM, RUC-2 is scheduled to be replaced by RUC-13 (RUC model resolution is improved from 20km to 13km). Each of the primary weather conditions that impact ETA/STA is discussed below. Icing in the terminal environment was considered, but was deemed not to have an impact as aircraft generally climb and descend through the condition rather than deviate because of it.

- **Wind** is a factor in both the terminal and en route environments. Therefore the need to: accurately forecast wind paths; successfully anticipate wind shifts and; timely react to drastic wind changes are crucial to maintaining efficient traffic flow with the use of TBFM.
    - **Enroute Wind:** In the en route domain, foreast flight path winds, jet stream locations, and atmospheric pressure all combine to affect the accuracy of ground speed predictions.
    - **Terminal Wind:**
        - Aircraft ETA/STA and Departures: In the terminal environment, airport winds do not directly affect an aircraft’s ETA/STA; however, unanticipated changes in runway configuration, as a result of winds, can negatively impact arrival and departure flow efficiency.
        - Wind Shifts: Additionally, in the terminal area, large shifts in headwinds/tailwinds speed and direction can cause wind compression between arriving aircraft. Although wind compression does not lessen the actual published airport arrival rate, it ofter requires traffic flow managers to: (1) issue aircraft holding patterns and/or; (2) increase miles in trail between arriving aircraft in order to maintain required separation. These traffic management initiatives (which are used to compensate for wind compression) ultimately impact overall airport operational efficiency.

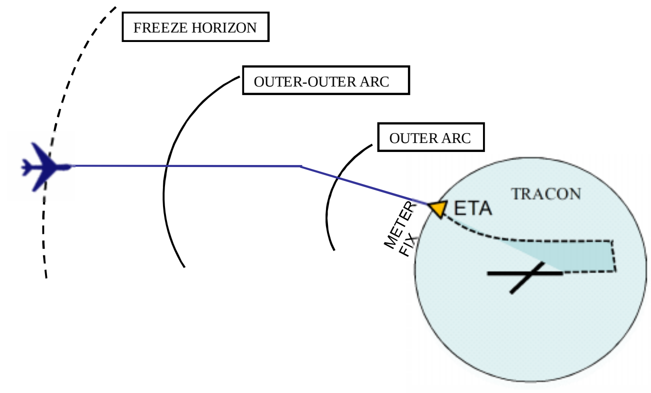

Figure 3-10: Wind speed and direction can change dramatically with altitude or when crossing frontal boundaries, generally causing aircraft to speed up or slow down and altering ETA/STA.

Convective weather is applicable in both the en route and terminal environment, however greater impact may arise from weather in the terminal environment as there is less time to correct for and/or accommodate deviations. When storms are encountered in the en route domain aircraft are sometimes able to fly above the convective activity. For this reason radar "tops" are an important factor. Knowing the vertical and lateral deviation a pilot is likely to take when avoiding weather is crucial to ETAs and/or revised ETAs. This is true for both en route and terminal environments. Precipitation levels and lightning data are also very important, particularly in the terminal area as they are likely to affect arrival rates.

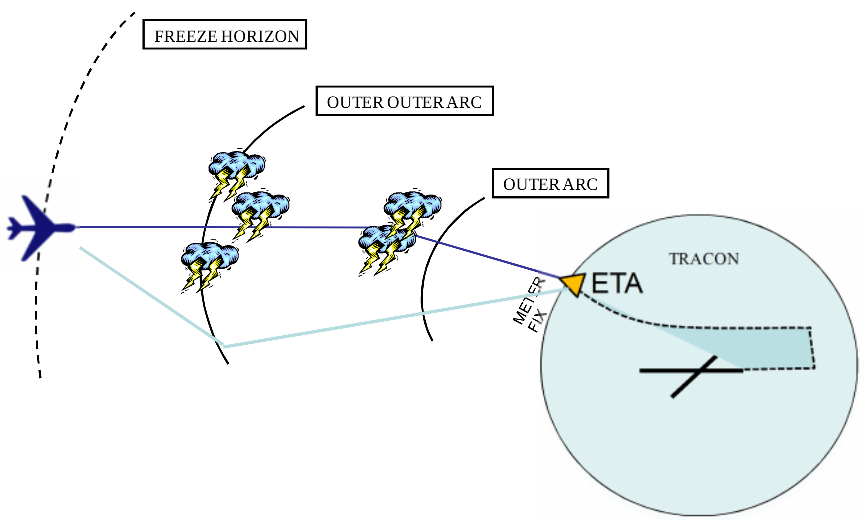

Figure 3-11: Aircraft frequently deviate around storms causing them to miss their STA at a metered fix and disrupting the overall flow of traffic

- **Turbulence** can cause potential disruptions to ETA/STA predictions in the en route environment if a metered aircraft departs their assigned altitude and ascends or descends into airspace with a marked change in temperature, pressure, wind speed, or wind direction. Aircraft rarely make lateral deviations to avoid turbulence.

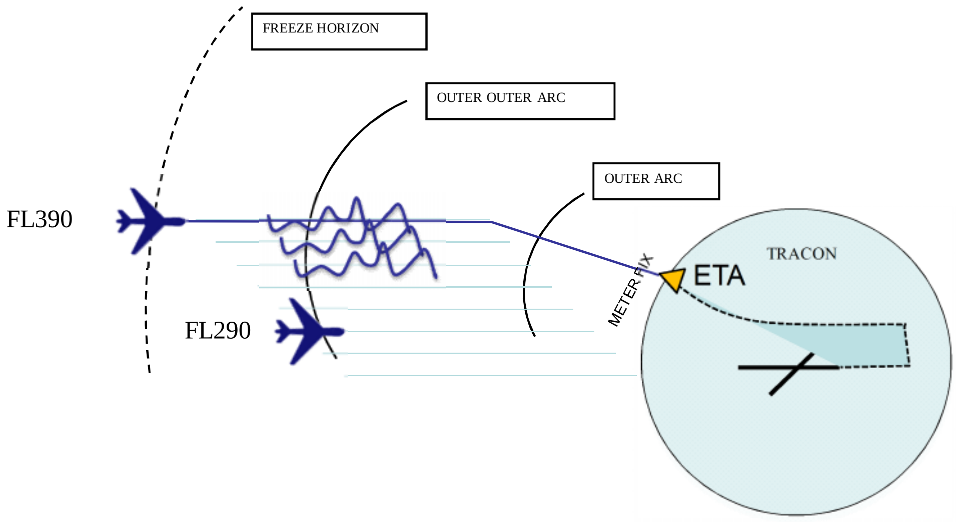

Figure 3-12: Changing altitude to avoid turbulence can have an impact on ETA/STA

3.5.1.6 TBFM Weather Integration Gaps

Turbulence: The current system development plan for TBFM does not call for any ingestion of turbulence information. This is an area that should be considered to address those situations where aircraft make a vertical deviation that subsequently causes a change in ETA/STA. This would lessen controller workload while trying to makeup or lose time in a sector.

Higher Levels of Integration: TMA is essentially a "Level 0" tool with reference to weather integration. The evolution to TBFM will bring with it weather "on the glass" in the form of the CIWS and eventually the Consolidated Storm Prediction for Aviation (CoSPA). This will make TBFM a tool with Level 1 integration. However, due to the nature of TBFM (NAS traffic is inherently part of the system), moving to Level 3 integration and its associated benefits would only require the inclusion of a WAF. Because of the benefits derived from a WAF (provides objective forecast of pilot behavior, eliminates individual interpretation of weather constraint, and requires no meteorological knowledge or training), and the maturity of this concept (e.g. currently being used in RAPT), immediate consideration should be given to incorporating this technology into TBFM. Additionally, there is currently no plan to incorporate the highest level of integration, that is, having the TBFM/IES suggest traffic management solutions currently being determined by humans.

Source of Wind Data: TBFM is scheduled to use RUC-13, with 13km gridded data as the source of wind information for trajectory calculations. It seems logical that TBFM would benefit from the higher resolution 3km data that will be provided by the upcoming High Resolution Rapid Refresh (HRRR). However, the HRRR may or may not meet latency, update rate, or bandwidth requirements. Consideration should be given to planning for possible HRRR input.

Other: Currently, weather data information is ingested into TMA via the CREWS system, while the majority of all other weather data for FAA systems is provided via the WARP system. Whether there is any value or necessity in continuing to support this duplicate system should be evaluated.

3.5.1.7 TBFM NAS EA/Weather Integration Timeline Chart

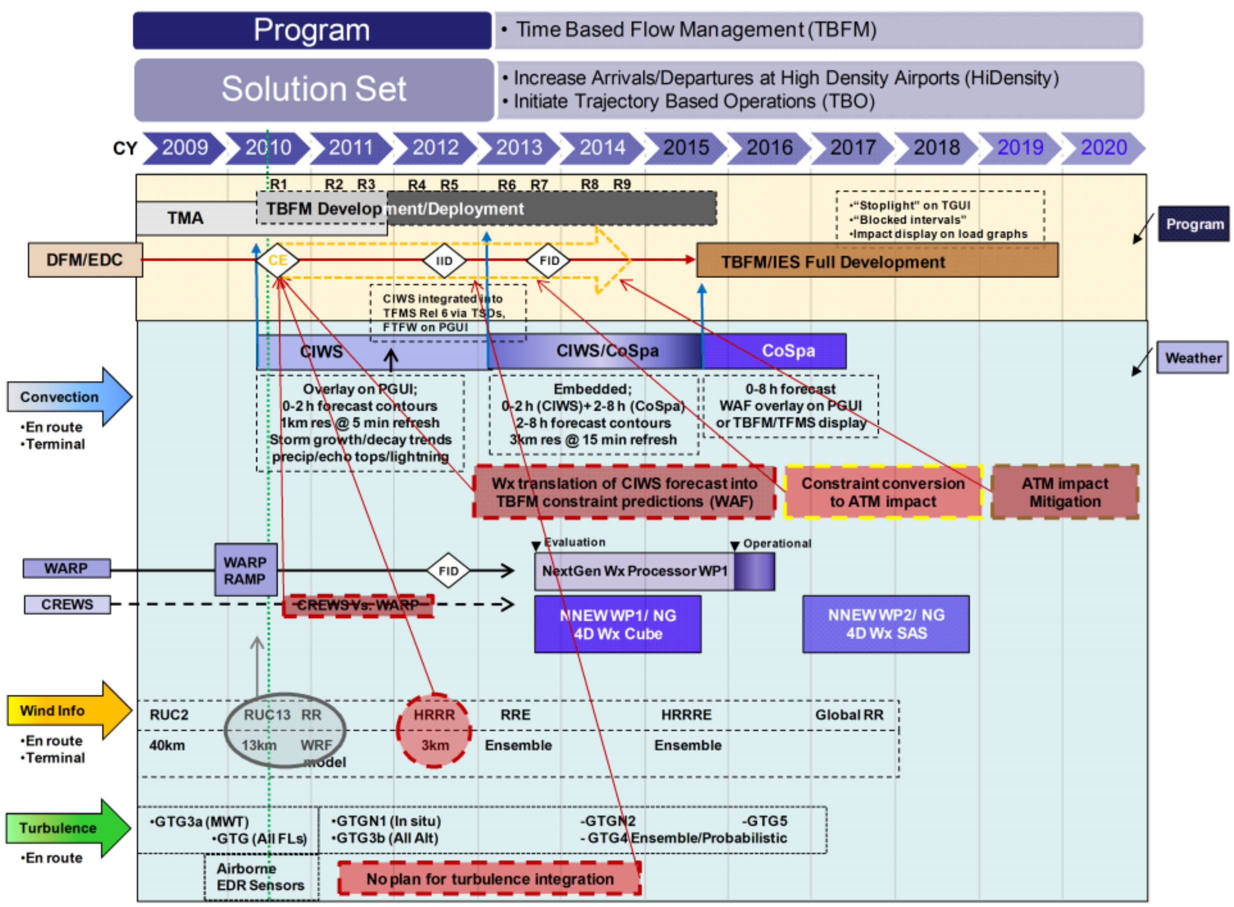

Figure 3-13: TBFM Automation Roadmap and Weather Integration Timeline Chart

Figure 3-13 (based upon Weather Infrastructure Roadmap Version 4.0-a-V8-19 August 2010) is a graphic depiction of the TBFM program and the associated weather capabilities and technologies available through the Mid-Term time frame. It is meant to highlight gaps and identify weather insertion points so that the program can adequately prepare for and partner with the appropriate office to enhance further evolution of the TBFM program.

At the top of the chart is the program name and associated solution sets. Below that is the yellow "program box." The most recent Automation Roadmaps (January 6, 2010) were used to depict the planned evolution of TMA, through TBFM, and on to IES. For readability, several investment decision points were left off. A dashed yellow arrow starting with the CE diamond in 2010 is meant to depict ongoing concept engineering as TBFM evolves. In addition, the nine TBFM releases are shown above the TBFM Development/Deployment box.

In the main "weather" section of the chart, the three major areas of weather impact – convection, winds, and turbulence – are each examined relative to known developments in those areas. The Weather Roadmaps (Appendix E) were consulted where appropriate. Red areas on the chart indicate a potential gap in integration, and the arrows point to the approximate time at which this item becomes relevant or should be considered.

In the area of convection, the CIWS is shown as the primary weather input to TBFM. CIWS will be overlaid on the PGUI and will provide a 0-2 hour forecast of storm growth and decay trends, precipitation, echo tops, and lightning. CIWS will be combined with the HRRR numeric weather prediction model to provide CoSPA, which will provide similar forecasts in the extended 2-8 hour time frame. Underlying the successful implementation of the CoSPA model development is availability of the HRRR model, currently planned for a February 2011 release.

A red box highlights the need to determine where TBFM will get its weather data from WARP or CREWS, as well as any associated planning that should accompany that decision.

In the area of winds, the new RUC-13 model and the follow-on Rapid Refresh (RR) model, which covers all of North America, are depicted as the source of wind data for TBFM. The 3km HRRR, as well as the follow-on Rapid Refresh Ensemble (RRE) and High Resolution Rapid Refresh Ensemble (HRRRE) are shown in their approximate time frame of development. Determining operational and more importantly functional requirements will facilitate selection of the most compatible capability, whether it is in development, or in the earliest stages of concept exploration.

There have been, and continue to be steady advances in turbulence detection and reporting. The Graphic Turbulence Guidance (GTG) 3 is an automatically-generated deterministic turbulence capability that predicts the location and intensity of turbulence over the continental United States (CONUS). GTG3 relies on the 13km Rapid Refresh model and provides forecasts for all altitudes. The GTG Nowcast (GTGN1) capability will add in-situ eddy dissipation rate (EDR) readings from airborne aircraft sensors in FY11. In FY14, there will be a GTG4 ensemble capability that will move to a probabilistic forecast and will include clear air turbulence. Also in FY14, the GTGN2 capability is scheduled for release, expanding in-situ nowcast forecasts to all altitudes.

3.5.2 Surface and Terminal Introduction

Presently there are multiple initiatives to enhance and improve airport surface operations in the NextGen Mid-Term time frame; some of these capabilities include, but are not limited to, Surface Trajectory-Based Operations (STBO), including Collaborative Departure Queue Management (CDQM), Tower Flight Data Manager (TFDM), Surface Decision Support System (SDSS), CATM, DataComm, and Surface Collaborative Decision Making. Eventually, the ATM/Weather Integration Plan will address all of the capabilities under development for surface and terminal operations; however, for version 2 of the Plan, this section will focus on the Surface Decision Support System, along with system enhancements and operational requirements for ATM/Weather integration insertion points.

3.5.2.1 SDSS Description and Objectives

The SDSS is a DST intended to help controllers, traffic managers, and supervisors in ATCTs, TRACONs, and ARTCCs manage the movement of aircraft on the surface of busy airports, thereby improving capacity, efficiency, safety, and flexibility. SDSS is designed to support cooperative planning with other arrival and departure traffic management DSTs to provide these, as well as additional benefits on the surface and in the terminal environment. SDSS is currently being used as a research platform by the FAA to research STBO concepts, such as CDQM (at Memphis and Orlando).

3.5.2.2 Evolution of Surface Decision Support System

The SDSS is based on previous FAA/NASA research and development of surface management technologies. The Surface Management System (SMS), developed by NASA Ames Research Center provides decision support capabilities to improve the efficiency and flexibility of airport surface traffic management. SMS supports improvements in the use of airport capacity by providing ATCT personnel, such as supervisors or TMCs with more complete and precise information about departure demand, arrival demand, predicted pushback times, and runway utilization. SMS information is conveyed via a Graphical User Interface (GUI) that incorporates at-a-glance traffic information and decision support advisories to help ATCT controllers manage surface movements. SMS information is also provided to ramp tower controllers and other air carrier positions, as well as ANSPs in ARTCCs and TRACONs to enhance collaborative decision-making at the facility. If desired, information could be provided by SMS to support TFM at the ATCSCC and other FAA user facilities.

3.5.2.3 Operational Enhancements

The initial capabilities of SDSS will provide airport information to users and allow the exchange of data between the ATCT, ramp towers, and other facilities such as the TRACON, the ARTCC, and the airline FOCs/AOCs. In addition to displaying necessary airport surface and flight plan information in a comprehensive user interface, SDSS will generate predictions and provide decision support to the user. Analysis of data collected during SMS development program site visits, simulations, and SMS field activities revealed areas of operations associated with high controller workload and/or system inefficiency. Many of these areas will benefit from the deployment of SDSS, which will provide:

- Situational awareness through graphical representations of surface position and flight data
- Means of communicating intent or constraints between users
- Providing predictive capabilities to aid scheduling and routing of aircraft
- Allocation of airport resources

3.5.2.4 System Enhancements

An enhancement to SDSS is the function of managing departure queues at the facility. CDQM is a concept that applies to surface departure operations and serves to enhance the efficiency of departure queues. Procedures and algorithms used in CDQM would apply to operations during periods where the departure demand exceeds the available departure capacity.

The CDQM capability will be used to enhance operations on the surface of the airport. The surface of an ATC controlled airport has two distinct areas. The non-movement area is the ramp space designated by the airport authority and ATC generally for the purposes of parking aircraft. Aircraft may move in these areas without contacting or receiving permission from ATC. At larger airports some or all of the non-movement area may be controlled by one or more ramp towers. The ramp towers typically control the pushback and movement of aircraft in non-movement ramp areas containing multiple gates. Once aircraft move from a non-movement to a movement area, ATC must manage the taxiways and queues as these aircraft wait for hand-off to local control.

Departure queues must be managed more effectively and kept at a length that ensures a departure demand on the runway but does not waste fuel with extensive starting and stopping during taxi or create complex issues for ATC operations and traffic management. Saturated ground control frequencies and clogged taxiways are undesirable consequences of a high volume of departures during First Come First Served (FCFS) operations.

Data exchange between ATC, flight operators, and ramp operations must be continuous and informative. It must be presented in a manner that allows each party to plan and execute their operations in a cooperative manner and to meet mission goals. The system that presents data to users must be able to collect information from a variety of sources, formulate and calculate an effective plan, and redistribute the information to all system users. SDSS and CDQM are technologies and concepts being developed to meet these broad objectives.

3.5.2.5 Weather Integration Analysis

The surface and terminal environment have numerous decision points that require weather information as part of the operational processes. Key weather parameter candidates include:

- Surface Winds (Speed, Gust and Direction)
  - Current report
  - Forecast
- Winds aloft (lower atmosphere <10,000 ft)
  - Current report
  - Forecast
- Surface visibility
  - Current report
  - Forecast
- Runway visibilities (RVR)
- Terminal Doppler Weather Radar (TDWR)
- Low Level Wind Shear alert system (LLAWS)
- Current observations: temperature, pressure, altimeter setting, Automated Surface Observing System (ASOS)/Automated Weather Observing System (AWOS)
- Precipitation (runway conditions)
- Ceilings

3.5.2.6 Weather Integration Gaps

Current level of integration TBD

3.5.2.7 NAS EA/Weather Integration Timeline Chart

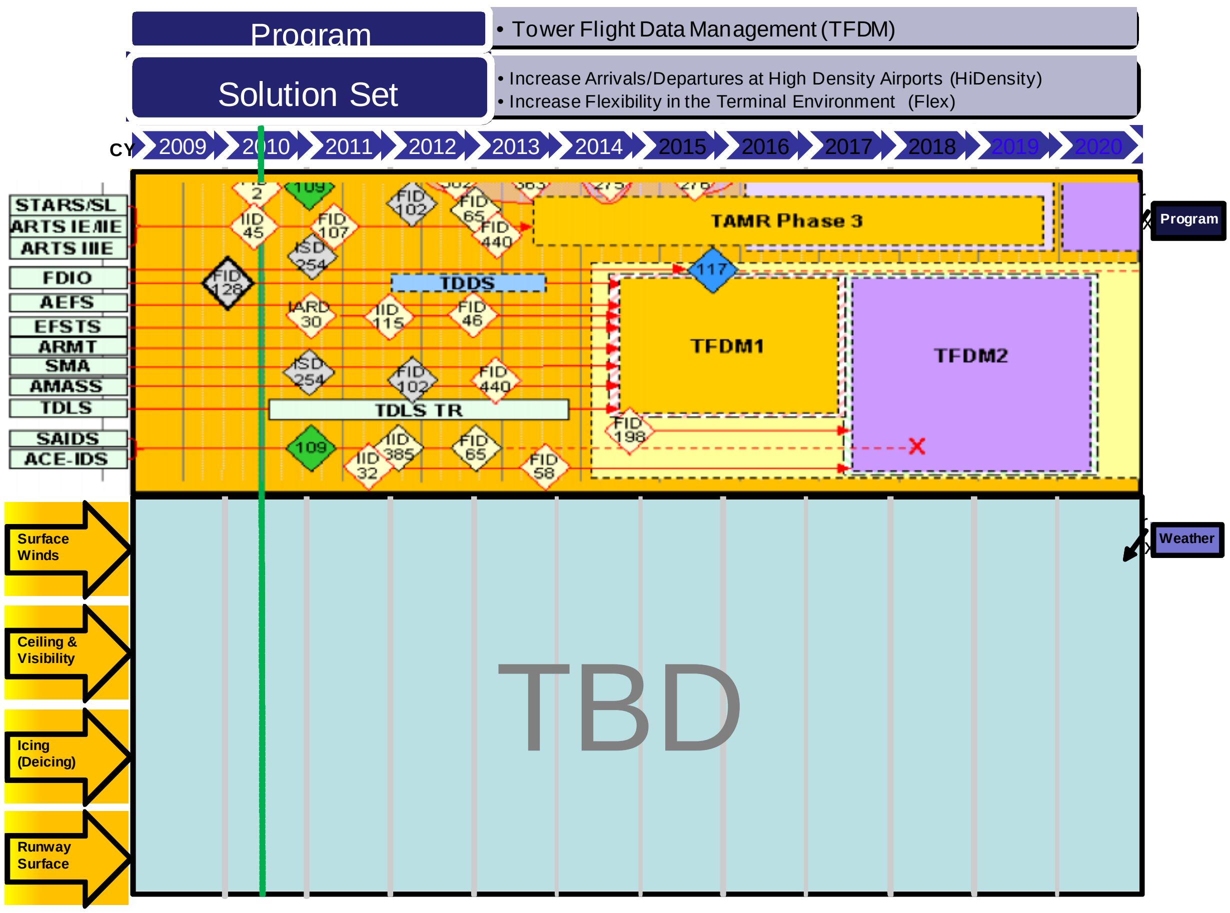

Figure 3-14: TFDM Automation Roadmap and Weather Integration Timeline chart

3.6 Maturing Capabilities

3.6.1 Integrated Departure Route Planning (IDRP)

Background: "The Operational Problem"

The operational problem is a multifaceted one that deals with multiple ATM domains, including ARTCCC's, TRACON's and towers, as well as, collaboration with pilots and airline operations centers about route status and route amendments caused by constant changes in the operating environment. Fundamentally, the problem is one of utilizing the available departure airspace and managing the airport resources effectively under dynamic and quickly changing conditions. The ability of the system, in total, to accurately monitor airport departure demand, departure routes and fix status, airport field condition, flight delay, and taxi queues while coordinating shifting resources and communicating the change in status to all stakeholders involved in the decision process is challenging.

The Decision

The decision environment spans both the regional/local TFM (i.e., strategic planning) in developing a Severe Weather Avoidance Plan (SWAP) for airspace departure routes and departure fixes, as well as the ATC tactical environment, where taxi management, departure clearance and airplane movement from the airport surface into the departure airspace takes place.

The Weather Constraint

The weather constraint consist of thunderstorm activity of significant intensity over an airport's departure route or departure fix that warrants a pilot deviation from their flight plan route. The weather constraint effectually reduces airspace capacity and the Airport Departure Rate (ADR). Uncertainty in the convective weather; growth, decay, movement, and altitude (cloud tops height) are important parameters in the weather forecast used for TFM planning of the severe weather event.

The Resultant ATM Impact

Route/Fix blockage of an airport's departure structure causes numerous impacts to the ATM system. Common occurrences under these conditions are the applications of SWAP, and flight departure delays, both at the gate and on the airport surface. Airport arrivals can also be affected when the available airport surface resource becomes saturated with delayed or canceled flights. Timely notification of a change in operating status of the airport, its routes, or other airspace resources becomes difficult to communicate and coordinate due to the dynamic nature of the weather constraint and its forecast.

ATM Decision Support

The IDRP decision aid translates weather constraints into ATM impacts, and thus helps decision makers evaluate and implement different Traffic Management Initiatives (TMIs) in response to the projected ATM impacts. The concept takes into account multiple factors that can have significant effects on departure management when weather constraints are present, including the weather constraint and the individual flight trajectories planned into the departure airspace based on the proposed time of departure. In evaluating the impact of congestion and downstream weather constraints on departure operations and potential actions to mitigate those impacts, traffic managers must consider filed flight plans and acceptable alternatives, surface departure queues, predicted weather impacts (route availability) along both departure and arrival corridors and nearby en route airspace, the current state of departure routes (open, closed, MIT, etc.), predicted congestion and flight times along weather avoidance reroutes, and the weather forecast uncertainty. By bringing all of these factors into an integrated environment, IDRP can reduce the time needed to make departure management decisions and to efficiently coordinate their implementation.

The current IDRP prototype has been designed to help the ARTCC's Departure Director (DD) better manage departure traffic. With integrated traffic, weather, and available airspace resource information, the DD can better maintain situational awareness and manage the departure traffic strategically. With IDRP suggesting feasible reroute options that consider factors affecting route usability for each option—route blockage, fix and sector congestion, need for coordination within/between facilities to get the route approved, and extra flying time—the DD will be able to solve tactical problems quickly and refocus on strategic planning.

During 2010 the IDRP prototype will be evaluated in the New York operational environment. This initial evaluation phase utilizes the RAPT infrastructure that is already installed in the evaluation locations.

It is important to note that IDRP alone is not enough to fully eliminate all of the challenges in today's or tomorrow's departure traffic management. An integrated collaborative departure traffic management concept needs to be developed to fully optimize routing decisions. Roles and responsibilities need to be redistributed among the departure management decision makers. Functions and capabilities to support the new roles and responsibilities need to be identified and added to IDRP.

3.6.2 San Francisco International Airport (SFO) Ground Delay Program Parameters Selection Model (SFO GPSM)

Background: "The Operational Problem"

A reduction in the airport arrival rate (AAR) routinely occurs at SFO during the months of May through October due to the formation of marine stratus clouds along the pacific coast over night. This stratus layer, in combination with runway layout and inadequate centerline-to-centerline separation distance creates a situation below visual approach minimums and reduces the arrival rate from roughly 60 to 30. The runway separation of 750 feet is less than required for simultaneous instrument approaches to these closely spaced parallel runaways when conditions are less than visual approach minimums. At SFO the visual approach minima for use of runways 28 left and 28 right is a 3,500 foot ceiling. This condition effectually reduces by half the acceptance rate of the airport when scheduled demand requires the need for use of both runways.

The Decision

The timing of strategic TMIs, such as a national Ground Delay Program (GDP), is extremely hard to manage for the San Francisco area due to the unpredictable nature of the marine stratus layer. There is a delicate balance when timing the GDPs valid time: starting the GDP too early or stopping it too late wastes arrival capacity and causes unnecessary delays at departure airports. Likewise, implementing it too late or ending too early results in holding aircraft in the surrounding airspace, excess fuel burn, diversions, and overall safety concerns.

The Weather Constraint

SFO has a fairly unique weather phenomenon and the behavior of marine stratus evolves on a daily cycle, filling the San Francisco Bay region overnight, and dissipating during the morning. Often the low ceiling conditions persist throughout the morning hours and interfere with the high rate of air traffic scheduled into SFO from mid-morning to early afternoon, and when the ceilings are below minimums at SFO, the arrival rate drops from 60 aircraft per hour to 30 per hour. The 1500Z to 1600Z time frame (0800-0900 local) is typically when the expected arrival demand is more than 30 aircraft per hour.

The Resultant ATM Impact

If the ceilings have not lifted by 1500Z to 1600Z, or are not anticipated to lift by that time, the situation is managed by issuing a GDP. In a GDP, flights estimated to arrive at an airport during a designated time period are issued delays and held on the ground at their departure airports.

These delays are assigned in a way to ensure a steady and consistent arrival flow into the airport without exceeding the arrival capacity.

TFM Decision Support

SFO Stratus Forecast System

The SFO Marine Stratus Forecast System (SSFS) was developed to provide specific forecast guidance to aid weather forecasters and traffic managers in determining the time of stratus clearing for efficient implementation and termination of GDPs. The prototype system was demonstrated from 2001 through 2004, after which responsibility for its operation and maintenance was transferred to the NWS Forecast Office in Monterey. The base station computer is located at the Oakland ARTCC, with forecast guidance made available to remotely located forecasters and decision makers via a Web-based display. The capability has become a shared resource for the daily planning conference call for SFO traffic flow strategic planning. It is often cited by users as guidance for decisions to implement GDPs, and it was referenced in the "rule of thumb" guidelines for SFO traffic planners that are provided by the ATCSCC.

The system provides a continually updated forecast of the time of stratus clearing each morning. Forecasts are initialized at 9, 11, 13, 15, 16, 17, and 18 GMT (i.e. 2 AM through 11 AM Pacific Daylight Time), with forecasts available approximately 20 minutes after the top of the hour. The forecast of stratus clearing time is presented both deterministically and probabilistically. The expected time of clearing is presented, accompanied by a binary indication of forecast confidence (either "good" or "low"). Additionally, the deterministic forecast is converted to a probability of clearing (derived empirically from historical data) by various target times during the high traffic volume period of the day, namely 17, 18, 19, and 20 GMT. The graphic representation of forecasts provided to users is shown in Figure 3-15.

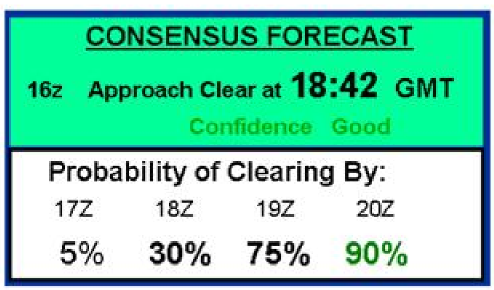

Figure 3-15: Deterministic and Probabilistic Display of Automated SFO Marine Stratus Forecast

The NWS performed a system performance evaluation in 2008 confirming that the forecast system was generating reliable forecasts, but the forecasts were not effectively translating into more efficient GDPs in terms of reducing unnecessary delay. An objective GDP Parameter Selection Model (GPSM) has been developed which provides a recommendation for selecting GDP start time, end time, AAR, and scope based on the current stratus forecast and arrival traffic demand, using an approach that weighs the benefits of the parameter selection (measured by aircraft delay reduction) versus associated risks (measured by the likelihood of a GDP ending too early and the resulting airborne queue).

SFO GPSM

Due to the uncertainty in stratus clearing, GDPs tend to be overly conservative, using a later GDP end time than is necessary. The operational cost of such a coping mechanism is that upon stratus clearing, there is a period of wasted arrival capacity while the upstream pipeline of aircraft is filled following release of ground-held planes. The research that led to the development of the SFO GPSM was conducted by Mosaic ATM under a NASA Research Announcement (NRA) contract with NASA Ames. One deliverable under this contract was to show the benefits of improved decision making by using a probabilistic forecast of stratus clearing at SFO airport. Analysis showed that despite the deployment of the SFO Stratus Forecast System in 2004, GDP practices continued as before, with no measurable benefits, particularly through 2008. (It should be noted that a more aggressive GDP strategy was observed during the recent 2009 stratus season.) The conclusion was that the probabilistic nature of the forecast capability was difficult for humans to interpret.

Today the primary forecasting responsibility for anticipating the time of stratus clearing is shared by the Center Weather Service Unit (CWSU) at the Oakland ARTCC, the aviation forecasting desk of the NWS Forecast Office in Monterey, and the operations centers of major commercial airlines with a significant market share in SFO. Their guidance is used by air traffic managers at the TMUs at Oakland Center and the ATCSCC to determine the duration and scope (number of planes impacted) by a proposed GDP (Figure 16). In an effort to reach a collaborative decision, each of these participants share information at a morning teleconference that takes place daily at 13:15 GMT (6:15 AM Pacific Daylight Time). The Command Center ultimately has authority for the final decision. Once the duration and scope of the GDP is implemented, the forecasts are monitored throughout the morning hours to ensure that the early morning stratus forecast remains intact. If the stratus dissipation does not evolve as anticipated or if the forecast changes throughout the morning, the Command Center has the opportunity to amend the GDP by changing any of its parameters, to include the scope, the arrival rate, and/or the termination time of the program.

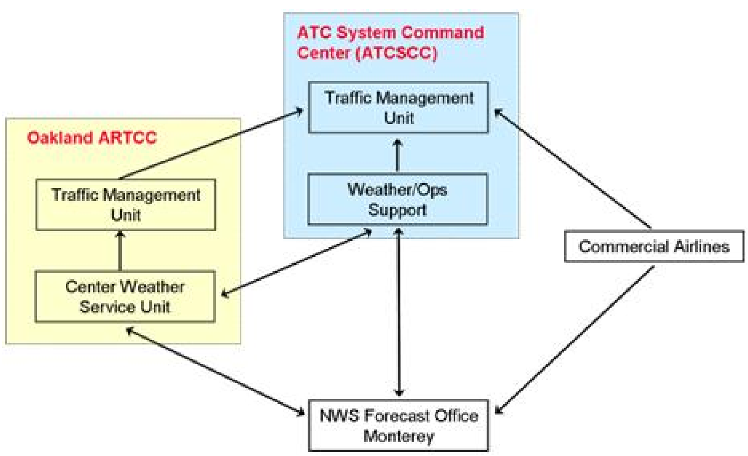

Figure 3-16 Flow of Information for Determining Scope of GDP

The SFO GPSM applies a risk model to the SFO Stratus Forecast System to enhance decision-making and provide recommendations for GDP start/end times, scope, duration, and arrival rates given the probabilistic forecast of stratus clearing.

- The SSFS display has been enhanced to provide relevant GDP parameter information provided by the GPSM. In Figure 3-17: the SFO Stratus Forecast System Display is enhanced with GDP Recommendations Table.
- Includes specific GDP parameters recommended by the GPSM, and supporting information to convey to the users an objective metric of risks and rewards associated with adopting the recommended parameters.
- The GDP Parameter Recommendations Table (Figure 18) indicates the parameters recommended by the GSPM, as well as two options that provide both a more conservative alternative (labeled "Alt-2") and a more aggressive alternative (labeled "Alt-1"). The alternatives provide a quantification of the risk and benefit of deviating from the primary recommendation, which may be the preferred course of action based on the expertise and experience of traffic managers and/or weather forecast support personnel. For each, the table will indicate the run time associated with the GDP parameter guidance, and the recommended start time, stop time, AAR, and scope of the GDP. Additionally, there is a simple relative quantification of the risk and benefit associated with selecting the recommended parameters. Risk is quantified as the probability that the recommended GDP end time occurs before the actual stratus clearing time. Benefits are presented as the reduction in total aircraft delay minutes that will result from selecting the recommended parameters in lieu of a baseline GDP (described below). For simplicity, these quantifications on the main page are also presented on a five-point scale: Very High, High, Moderate, Low, and Very Low.

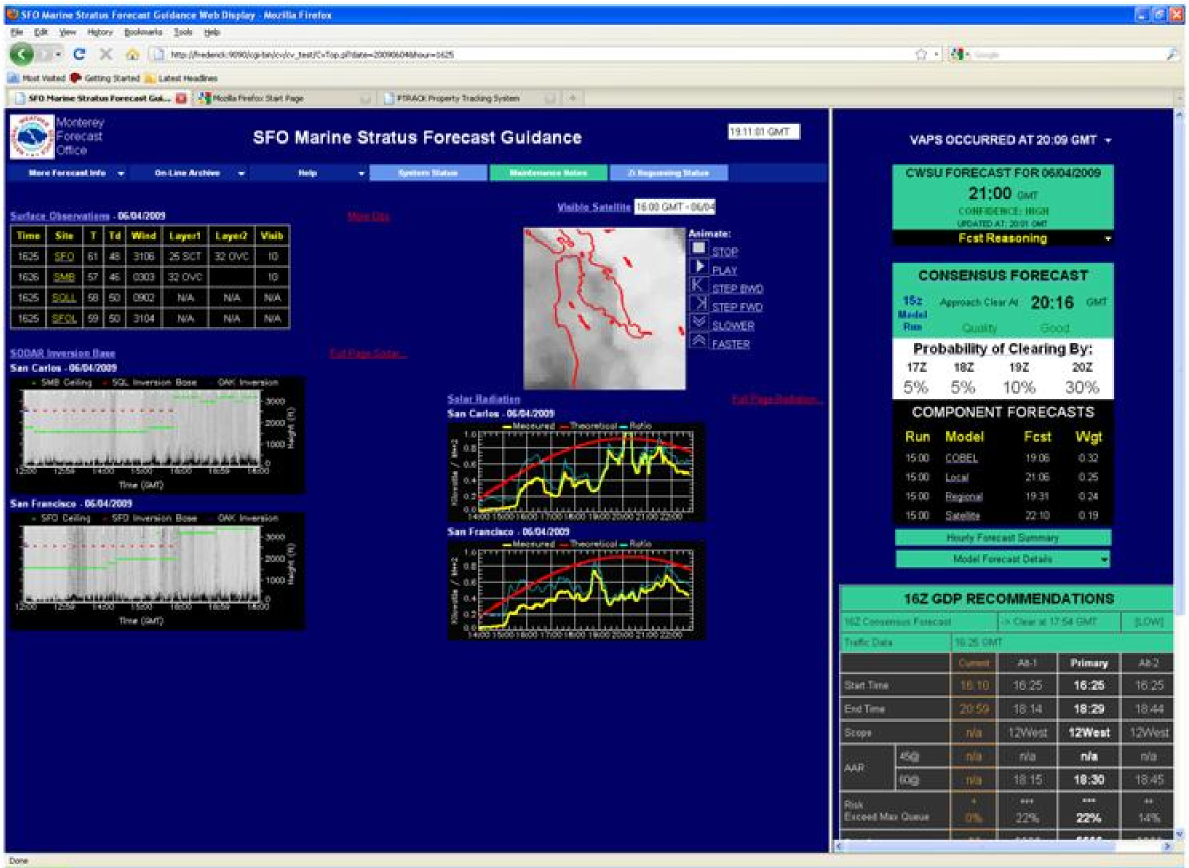

Figure 3-17: SFO Stratus Forecast System Display, Enhanced with GDP Recommendations Table

17Z GDP RECOMMENDATIONS					
17Z Consensus Forecast			-> Clear at 18:00 GMT		[GOOD]
Traffic Data		17:25 GMT			
		Current	Alt-1	Primary	Alt-2
StartTime		16:00	16:25	16:25	16:25
End Time		19:14	18:14	18:29	18:44
Scope		1200 m	1000 m	1000 m	600 m
AAR	45 @ 60 @	n/a n/a	n/a 18:15	n/a 18:30	n/a 18:45
Risk Exceed Max Queue		* 1%	*** 22%	* 6%	* 3%
Benefit Delay Reduction		$$ 37%	$$$$ 76%	$$$ 59%	$$$ 51%
Expanded statistics					

Figure 3-18: GDP Recommendations Table

Plans

During 2010 an Engineering Evaluation plan is being conducted. The purpose of this engineering field evaluation is two-fold:

- Evaluate the current version of the GPSM Software Prototype under real-time conditions over an extended period of time and to validate the functional, performance, and user interface requirements developed for the model.
- Identify new desired functionality and refine existing functionality in response to user feedback and model analysis to guide the GPSM evolution.

3.6.3 Collaborative Trajectory Options Program (C-TOP)

Background: "The Operational Problem"

Note: C-TOP was previously known as System Enhancements for Versatile Electronic Negotiation (SEVEN).

Normally the en-route airspace environment is less prone to capacity/demand imbalances than what is often seen in the terminal environment. At the airport level, it becomes challenging to manage when either less than optimum airport configurations occur or when conditions shifts from Visual Meteorological Conditions (VMC) to IMC. However, there are conditions that affect en-route airspace throughput and capacity. A common en-route constraint that affects air traffic throughput and routing efficiency during the spring and summer seasons is convective weather (thunderstorms). Due to the uncertainty of weather constraints and individual flight planning considerations, it is difficult to isolate a single solution to any given problem in the en route domain. Operational planning tasks such as; developing flight plans, flow capacity planning, and exit planning must all be considered. Rationing demand schedules, coordinating dynamic conditions and communicating agreed upon solutions are operationally resource and labor intensive.

The Decision

The decision environment is national in scope (strategic) from a traffic flow perspective and broad from a collaborative perspective with stakeholder involvement including the ATCSCC, flight operators, and regional ARTCC TFM.

The Weather Constraint

The most common en-route constraint that causes the loss of airspace capacity and system throughput is convective weather. Thunderstorms produce flight hazards due to the nature of the weather attributes that can be encountered, such as turbulence, hail, wind shear, lightning, and icing. Therefore, avoidance of the hazards is paramount and based on many factors, such as aircraft type, federal regulations, good operating practices, airline operations specification (ops specs) and flight operation manuals. Because the decisions required are of a significant lead time in the planning process, up to six or more hours before the constraining event, the uncertainty of the weather forecast must be taken into consideration. Strategy options must be applied based on a probability of occurrence, including the location, severity, area of coverage, and tops of the forecasted weather.

The Resultant NAS System Impact

System impact as a result of thunderstorm activity in the en-route environment is from sector capacity loss and throughput reduction at the service provider level. System impact is also increased fuel burn, increased flight time, flight delay, and/or flight diversions at the aircraft operator level. Severity of the impact will be relational to the geography, severity, and characteristics of the convective weather. For example, multi-center lines, solid lines, or large areas of scattered storms are determinates of impact severity. The ability and flexibility of the system to "dial" the plan up or down is also a factor in the amount of impact that will be felt on the system when the plan turns into actual conditions encountered.

Translation of Weather into ATM Constraint

The weather translation methodology applied to C-TOP is described in Appendix B, B-1.1, En - route Convective Weather Avoidance Modeling. In order to determine the impacts of convective weather on en route air traffic operations, it is necessary first to partition airspace into passable and impassable regions. As shown in Figure 3-19, en route CWAM calculates WAFs as a function of observed and/or forecast weather. WAFs are two dimensional (2D) or three dimensional (3D) grids whose grid points are assigned either a probability of deviation or a binary deviation decision value (0 or 1).

Since the pilot is responsible for weather avoidance, CWAM requires both the inference of pilot intent from an analysis of trajectory and weather data and an operational definition of deviation. Characteristics of the weather encountered along the planned trajectories and the trajectory classification are input to statistical pattern classification algorithms to identify the weather characteristics that best predict deviations.

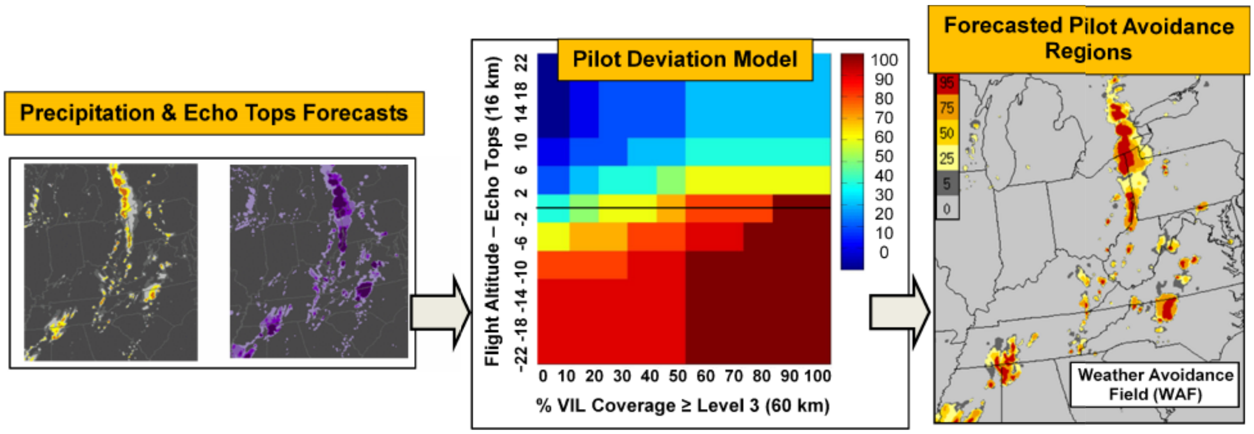

Figure 3-19: Translating weather into constraints

Translation of Weather ATM Constraint into ATM Impact

Once the weather information is translated into WAF predictions these constraints can now be applied to Flow Constrained Areas (FCAs), which is the technology used by TFM to identify and manage demand on en-route resources. Figure 3-20 depicts how WAF predictions can be applied to FCA corridors and provide the Traffic Manager with guidance on setting capacity and throughput rates.

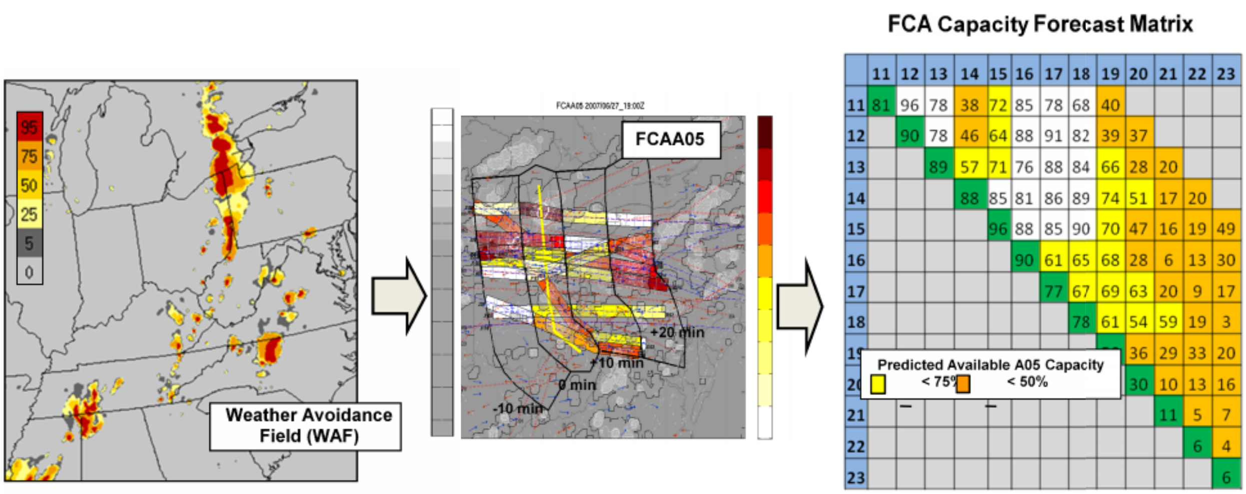

Figure 3-20: Applying WAF Predictions Across FCA's to Estimate Impact on Capacity

TFM Decision Support

C-TOP[8] is a new concept for managing en route congestion that allows NAS customers to submit alternative trajectory options for each flight along with the preferences for the alternatives. C-TOP provides traffic managers with a tool that algorithmically takes these customer preferences into consideration as it assigns reroutes and delays to flights subject to traffic flow constraints.

[8] Collaborative Decision Making (CDM) Future Concepts Team (FCT), System Requirements Document, Version 1.4, March 31, 2010

This concept has the potential to reduce the workload of traffic managers while allowing them finer control over traffic as the weather/traffic conditions change. It also provides NAS customers greater flexibility to operate their flights according to their business priorities. One of the most significant benefits is the ability to recapture system capacity that is currently lost when severe weather (or other capacity limiting factors) does not materialize as predicted.

There are two key enabling ideas at the core of C-TOP. The first is that NAS customers are able to submit cost weighted sets of multiple trajectory options called the Trajectory Options Set (TOS) to the TFMS. The TOSs in C-TOP are, in fact, four dimensional (4D) trajectory options. Each entry in the TOS consists of a 2D route, an altitude, a speed, departure time restrictions, and a cost factor. Each field is set by the customer providing the TOS. The second is the Interactive Dynamic Flight List (IDFL) that the FAA uses to manage demand on resources such as FCAs. The IDFL provides the capability to set capacities on the FCA(s) and run allocation algorithms that adjust demand to satisfy those capacities while attempting to place each flight on the lowest cost option available.

Traffic managers can respond easily to changing conditions by making adjustments to C-TOP resource capacities. C-TOP is designed to handle capacity changes quickly and smoothly, allowing uncertainty management and exit strategies not available in today's TMIs. The focus on demand management through resource capacity and the electronic exchange of customer options allow traffic managers to avoid low level traffic decisions while providing customers with tailored consideration of their individual preferences, based on their business models, in generating solutions to TFM challenges.

C-TOP is designed for resolving airspace capacity issues, modeled on the design of current delay programs such as Airspace Flow Programs (AFPs) and GDPs. C-TOP extends the benefits of these programs by incorporating the use of customer-developed routing and delay options to resolve NAS constrained areas. When demand for a NAS resource exceeds capacity, that demand must somehow be modified. Delay programs, such as GDPs, achieve this by changing the schedules of the flights involved. Reroute-based programs, such as Playbooks and AFPs, reduce demand on airspace resources by delaying flights on the ground and providing them with the option to re-route the flight out of the constrained airspace. Current reroute-based programs rely on either air traffic controllers to provide reroutes for flights or NAS customers to file reroutes in reaction to the programs. C-TOP integrates these delays and reroute-based techniques for dealing with excess demand while providing a method for accepting earlier customer input on reroute options.

GDPs and AFPs have been evolving for several years and employ sophisticated methods for allocating constrained NAS resources equitably and dealing with uncertainty. C-TOP attempts to preserve or extend these methods where possible.

Plans

Development work of the CDM Future Concepts Team (FCT) is planned to be transferred to the CDM C-TOP Deployment Work Group in 2010. Initial capability is expected in TFMS work packages for a 2011-2012 deployment

4 ATM-WEATHER CONSTRAINTS/IMPACTS AND INTEGRATION TECHNOLOGY

This section, with more detail in Appendix B, provides a survey that identifies technologies and methodologies for translating weather information into ATM constraints/impacts in the NAS. The survey includes approaches for addressing weather-related uncertainty in ATM decision making – risk management processes. The survey is organized into three parts:

- ATM-Weather Translation and Impact Models – these describe the translation of weather information into ATM constraints the use of weather constraint input in ATM impact models
- ATM-Weather Integration Techniques – these describe how ATM-weather impact models may be integrated into DSTs or in other ways to manage uncertainties in NAS decision making
- The methodology used for technology ranking and selection for further study and investment

For each part, the maturity of the state-of-the-art is determined and gaps in technology are identified. These methodologies emphasize solutions for ATM-weather integration for the NextGen.

Constraints and Impacts

The technologies in this survey address a mixture of both constraints and impacts. As described in Section 2, the weather community will only invest in the translation of weather information into constraint information. The user community will be expected to invest in any necessary technology for addressing and dealing with impacts. This Plan is intended to bridge both of those communities and be useful to each. Therefore, both constraint and impact technologies are included.

4.1 Survey of ATM-Weather Constraint/Impact Models and Related Research

In the NAS, en route TFM balances air traffic demand against available capacity, to ensure a safe and expeditious flow of aircraft. TFM resources may be expressed in terms of airspace availability. This includes fix availability, route availability, and airspace availability (e.g., grid cell, hex cell, sector, center, or FCA). For example, Figure 4-1 illustrates the transformation of weather forecast data into point-impacts (suitable for assessing fix availability), route-impacts (suitable for assessing route blockage), and sector-based impacts (suitable for TFM flow planning). TFM resources also include airport resources, including AAR, ADR, runway availability, and others. All these resources are important and are mentioned in the survey where applicable.

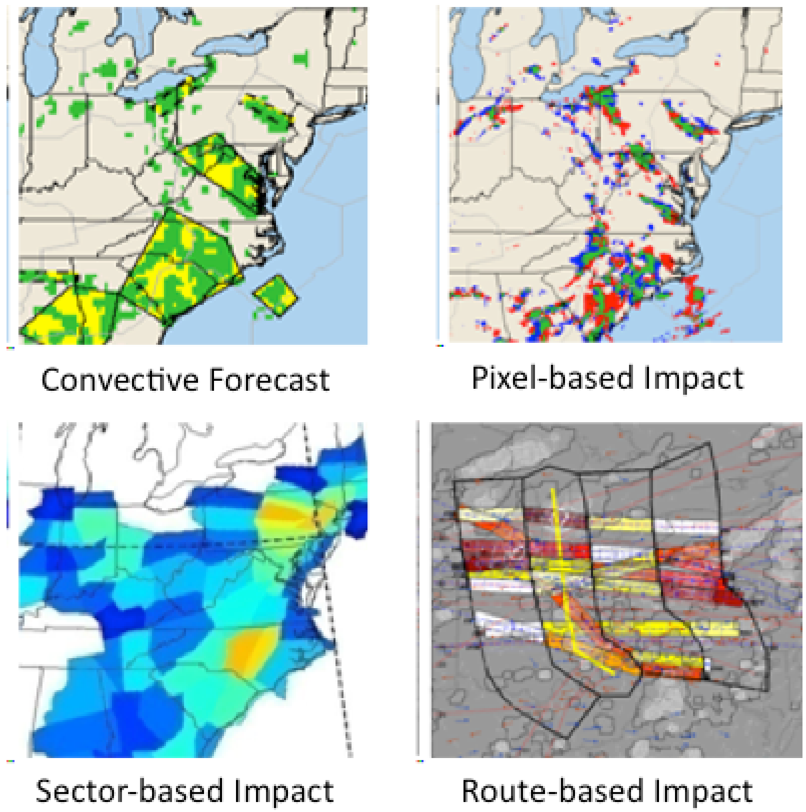

Figure 4-1 Convective Forecast Transformed into ATM Impact in Various Formats.

The majority of the ATM-impact models address airspace capacity issues. In today's NAS, there is no automation tool to predict airspace capacity, since there is no established and accepted indicator of airspace capacity. The Enhanced Traffic Management System (ETMS) [E02] provides a congestion alerting function that uses the peak one-minute aircraft count as a sector congestion alerting criterion (the Monitor Alert Parameter [MAP]). The MAP is not meant to be a measure of airspace capacity, but rather a threshold which, when exceeded by predicted demand, alerts traffic managers to examine the sector for potential congestion. The MAP value is typically designed to account for the nominal traffic structure experienced in the airspace rather than a hypothetical structure designed to maximize capacity. ATM-impact models that address the structure from nominal routing along today's jet routes as well as ATM-impact models that design new traffic flow structures that maximize capacity are included in the survey, since it is clear that airspace capacity models are needed for today's routing structures as well as NextGen's more flexible routing structures.

As demonstrated by the survey, estimating capacity has many difficulties due to the complexity of weather forecasting and demand estimation. One difficulty is that weather forecasts all have some degree of uncertainty. To address this, several of the ATM-impact methods go beyond deterministic weather forecasts and into probabilistic weather forecasts, both in terms of probability distributions as well as ensemble weather forecasts. In addition to weather forecast errors, minor differences in how weather develops, for instance, the weather organization, can lead to major differences in the impacts on the NAS. Small storms located at critical locations in the NAS can have more impact than larger storms in less critical locations. In the case of a squall line, for instance, many of the westbound flights in a sector may be blocked, while several northbound flights can make it through. One ATM-impact method specifically addresses the issue of directional capacity. Furthermore, ATM-impact models for en route airspace must be modified to address transition or terminal area airspaces. Sector capacity in particular, is a function of the traffic flow pattern, whether it is a pattern established by jet routes, a uniform distribution of flow in a standard direction (e.g., East-to-West), or random, as is the case of Free Flight (if implemented in NextGen). Capacity is not strictly independent of demand; the trajectories and altitude profiles of flights that plan to use an airspace can significantly alter how many flights can be managed. Some researchers refer to this as “demand-driven capacity.”

Next, is a summary of each of the surveyed ATM-impact models starting with models that were derived primarily for convection, and ending with a wide variety of models for several types of aviation hazards, including turbulence, icing, winter weather, and others.

Stochastic Prediction Models

Stochastic prediction models do not model capacity directly. They infer the capacity from historical traffic data and they infer the relationship between capacity reduction and weather by comparing historical traffic to weather data. This may be accomplished from a range of techniques from statistical testing to cluster analysis. Stochastic prediction models may be applied to all types of weather, such as convective weather, turbulence, icing, ceiling and visibility, and surface winds. Also, stochastic prediction models may be applied to assess the capacity of a wide variety of NAS resources, including metering fix capacity, route capacity, sector and center capacity, and even overall NAS capacity.

Deterministic Prediction Models

Deterministic prediction models model capacity directly. They deduce the capacity from traffic models, operational procedures, airspace geometry, weather models, and so forth. Some models use current-day jet routes, while others assume that the routing across the airspace can be redesigned to maximize capacity (e.g., parallel flows of traffic across FCAs) or maximize user preferences (Free Flight). The ATM-impact evaluation can be done for different parameterizations (from conservative to aggressive, with a variety of safety margins representing pilot and airline preferences), to evaluate a range of impacts of the weather on the nominal capacity. Modeling errors will result in capacity estimation errors.

En route Convective Weather Avoidance Models

An en route CWAM calculates WAFs as a function of observed and/or forecast weather. WAFs are 2D or 3D grids whose grid points are assigned either a probability of deviation or a binary deviation decision value (0 or 1). CWAM requires both the inference of pilot intent from an analysis of trajectory and weather data and an operational definition of deviation. Two approaches have been taken to model and validate weather-avoiding deviations using trajectory and weather data: trajectory classification and spatial cross-correlation.

Terminal Convective Weather Avoidance Models

In order to determine the impacts of convective weather on terminal air traffic operations, CWAM models must be modified to take into account the constraints of terminal area flight to calculate WAFs that apply specifically to terminal area operations. Each WAF grid point is assigned a probability and/or a binary value (0 or 1) that represents that likelihood that pilots will choose to avoid convective weather at a point location in the terminal area. For instance, departures and arrivals are constrained to follow ascending or descending trajectories between the surface and cruise altitude, leaving little flexibility to avoid weather by flying over it. Aircraft flying at low altitudes in the terminal area appear to penetrate weather that en route traffic generally avoids. The willingness of pilots to penetrate severe weather on arrival increases as they approach landing.

Maximum Airspace Capacity Models

Mincut Algorithms: For NextGen when jet routes can be dynamically redefined to adjust flows of traffic around weather constraints, the maximum capacity of an airspace may be determined using extensions of MaxFlow/Mincut Theorem. A continuous flow version of the network MaxFlow/Mincut Theorem is suitable for estimating the maximum throughput across an en route airspace given a traffic flow pattern, a uniform distribution of flow monotonically traversing in a standard direction (e.g., East-to-West), or random, Free Flight conditions. Given a required gap size between weather constraints (i.e., gap size to safely fly through it), an algorithm identifies the mincut bottleneck line – this mincut determines the maximum capacity in terms of the maximum number of air lanes that can pass through the gaps in the weather for a specified altitude range. Capacity is determined by analyzing mincut values from the lowest to highest altitude in a sector as a function of time given a weather forecast.

Mincut Algorithms Given Hard/Soft Constraints. The Maxflow/Mincut Theorem assumes that weather hazards are classified in a binary manner: traversable or not (hazardous or not). The assumption is that all hazards are hard constraints. However, weather hazards, including the "types" of convection, turbulence, icing, and other weather effects may more generally be classified into hard and soft constraints. Hard constraints are formed by weather hazards that no aircraft can safely fly through (e.g., severe convection, turbulence or in-flight icing). Soft constraints are formed by weather hazards that some pilots or airlines decide to fly through while others do not (e.g., moderate turbulence or icing). Define Class 1 aircraft to be those that avoid both hard and soft constraints, and Class 2 aircraft to be those that avoid hard constraints but are willing to fly through soft constraints. The problem is that of multi-commodity flow, in which the goal is to determine if there exists a set of air lanes, each with an associated class of aircraft (the "commodity"), such that each air lane satisfies all constraints from the weather types that impact the Class, and such that the air lanes yield a set of flows that satisfy the demand, or some fraction of the demand.

Sector Capacity Models

NAS sectors typically exhibit a small set of common traffic flow patterns, and different patterns represent different levels of traffic complexity. Quantifying sector capacity as a function of traffic flow pattern provides a basis for capturing weather impact on sector capacity. The future traffic flow pattern in the sector is predicted and described with flows and flow features. The available flow capacity of each flow in the predicted traffic flow pattern is determined by MaxFlow/Mincut Theory applied to a Weather Avoidance Altitude Field (WAAF) – a 3D version of the CWAM WAF. The available flow capacities are combined and translated to the available sector capacity based on the traffic on each flow and the normal sector capacity given the predicted traffic flow pattern.

Route Availability Models

Several ATM tasks, including departure and arrival flow management and the planning of weather-avoiding reroutes, require the assessment of the availability and/or capacity of individual traffic routes or flows. Thus, it is natural to extend Maxflow/Mincut, CWAM, and WAF concepts into route availability. A route is available if traffic can follow a route and stay within acceptable deviation limits around the route centerline while avoiding hazardous weather. The route capacity indicates the rate of traffic flow that an available route can support. Estimating route availability may be achieved by Maxflow/Mincut and Route Blockage techniques. Capacity estimates must account for the workload and uncertainty involved in flying the weather-avoiding trajectories that they identify.

Directional Capacity and Directional Demand Models

Since traffic flow patterns are directional, capacity is also directional. The capacity of an airspace can be estimated for a series of cardinal directions, e.g., North (N), East (E), South (S), West (W) and the diagonals NE, NW, SE, and SW. Also, directions can be quantified every Θ degrees (e.g., Θ=20 deg.), spaced around a given NAS resource, for instance, around an airport, metroplex, or fix location, or within a section of airspace. For each angular wedge of airspace, the maximum capacity for traffic arriving from a specified direction may be established. MaxFlow/Mincut techniques as well as scan line techniques have been demonstrated. The maximum capacity for a particular angular wedge of airspace will quantify the permeability of the weather with respect to traffic arriving from a specified direction. The challenge is to determine acceptable amounts of traffic that may pass through in given directions, subject to controller workload limits.

NAS Traffic Models

The WITI measures the number of flights impacted by weather. Each weather constraint is weighted by the number of flights encountering that constraint in order to measure the impact of weather on NAS traffic at a given location. Historically, WITI has focused on en route convective weather, but the approach is now applied to other weather hazard types as well. A WITI-B variation evaluates the extent to which a flight would have to reroute in order to avoid severe weather. The En route WITI (E-WITI) for a flow is the product of its hourly flight frequency and the amount of convective reports in a region of airspace. Another approach apportions all en route WITI measures to origin and destination airports. Terminal WITI (T-WITI) considers terminal area weather, ranked by severity of impact, and weights it by the departures and arrivals at an airport. The National Weather Index (NWX) implements the WITI on a NAS-wide scale.

Sector Demand Models

Traditional air traffic flow prediction models track the aircraft count in a region of the airspace based on the trajectories of proposed flights. Deterministic forecasting of sector demand is routinely done within ETMS, which relies on the computation of each aircraft's entry and exit times at each sector along the flight path. Since the accuracy of these predictions is impacted by departure time and weather uncertainties, and since weather forecast uncertainty causes errors in the sector count predictions, traditional methods can only predict the behavior of NAS for short durations of time – up to 20 minutes or so. It is difficult to make sound strategic ATM decisions with such a short prediction time. An empirical sector prediction model accounts for weather impact on both short-term (15 minutes) and mid-term (30 minutes to 2 hours) predictions. Different from traditional trajectory-based methods, Periodic Auto-Regressive (PAR) models evaluate the performance of various demand prediction models considering both the historical traffic flows to capture the mid-term trend, and flows in the near past to capture the transient response. A component is embedded in the model to reflect weather impacts on sector demand.

NAS Traffic Flow Distribution Models

Congestion Models

A stochastic congestion grid quantifies congestion (density of aircraft) in a way that accounts for the uncertainty of the aircraft demand and uncertainty of the weather forecast (convection, turbulence, or icing) for long look-ahead times, as required by strategic TFM planning processes. Each grid cell records an estimate of the probability that the expected traffic exceeds a threshold level. In NextGen, 4-D trajectories are stored in the 4-D congestion grid by projecting the 4-D trajectory onto the grid with an error model for along track error and cross track error. An increase in probability of congestion occurs where the traffic flow increase coincides with a predicted weather constraint. A probability that a weather constraint will exist is described on a grid cell instead of a binary value for a constraint versus no constraint. If the probability that traffic in any 4-D grid cell exceeds tolerable thresholds, then appropriate TFM planning is warranted.

Network Flow Models.

Weather impacts on network flows may be modeled to capture the optimal movement of traffic across a grid of triangles, squares, or hexcells. The cell to cell movement of aggregate traffic through and around weather hazards is captured in discrete time steps (e.g., 15 minutes). During each time step, aggregate flows of traffic can move from one cell to any of the adjacent cell as long as the flow does not exceed the capacity limit (e.g., as determined by capacity models based on convection, turbulence, icing, etc.). The resulting traffic counts typically go down to zero inside hazardous weather constraint regions but increase around the corners of those constraints as flows of traffic pass around constraints. These traffic counts represent optimal (least delay) adjustment of traffic flows to projected weather constraints, however, they do not account for any changes to the demand distribution due to TFM actions.

Ensemble Models

In NextGen, in order to capture the uncertainties posed by long-term weather forecasting, strategic TFM planning will rely on probabilistic ensemble weather forecast information. Ensemble forecast systems generate a series of deterministic forecasts of potential weather outcomes (i.e., members of the ensemble). Each forecast represents a possible weather scenario that may emerge later in the day. These weather forecasts, in turn, are translated into ATM impacts with relative likelihoods and Probability Density Functions (PDFs) for use by either humans-over-the-loop or computer-to-computer ATM applications. The definition of a weather hazard could be for convection, turbulence, icing, or other aviation-relevant hazards and events (e.g., major wind shifts at an airport), and any appropriate weather hazard model can be placed into the ensemble-translation process; for instance, the CWAM WAF for a given altitude range.

Deterministic Models

NextGen systems can benefit from understanding how a single deterministic forecast in a grid-based format, and some error bounds associated with the forecast, can be used to create probabilistic ATM impacts for airspace regions. Variations on a single deterministic forecast are created by considering error models that account for errors in timing, errors in coverage, translational errors, and echo top errors. A synthetic ensemble of forecasts is created that are similar (perturbations) to the input deterministic forecast. The set of erroneous forecasts represents "what if" cases: "what if the weather system arrives early (late)," "what if it is larger (smaller) than expected," etc. The underlying assumption is that the weather organization has been correctly forecasted, but the speed, growth, or decay of weather cells may be in error. The synthetic ensemble of erroneous forecasts is then input into an ATM-impact model, for instance, a Maxflow/Mincut method, route blockage method, or CWAM model, and a set of ATM-impacts is output. This probabilistic estimate may assist users or the ANSP in assessing risks associated with weather impacts.

Sensitivity of NAS-wide ATM Performance to Weather Forecasting Uncertainty

Planners need to understand sensitivity of ATM performance to the weather forecasting uncertainty in order to make research and development decisions. The ATM performance improvement (benefit) is determined by comparing the performance sensitivity and a contemplated forecasting uncertainty reduction. Simulation is typically required to model ATM performance. Such a simulation must include effects of the weather and its forecast in order to model the sensitivity to the weather forecasting uncertainty. For instance, such effects might include the modeling of vectoring, rerouting and ground hold decision-making models in response to weather forecasts. The ATM performance simulations require weather forecasts of varying accuracy in order to evaluate the sensitivity to forecasting uncertainty.

Pilot Deviation Models

The operational probabilistic weather product called the National Convective Weather Product–6 (NCWP-6) provides up to 6-hour forecasts of the probability of convection. One way to translate probabilities of convection to ATM impact is to determine a correlation between aircraft position and the National Convective Weather Forecast – 6 (NCWF-6) convective probability values, at the appropriate flight level and relative distance above the echo top. Using the correlation, a decision-maker could assess the NCWF-6 probability that aircraft are willing to traverse, and in turn, the risk associated with traveling in the vicinity of forecasted NCWF-6 probability contours. The Probability Cut-off Parameter (PCP) is the maximum NCWF-6 probability contour that correlates with a majority of aircraft positions based on historical analysis. PCP values differ with forecast times and they can be established for a local scope, at sector and center levels.

ATM Impact Assessment Models

In order to better understand the application of convective weather forecasts into the ATM planning process, convective forecast products need to be objectively evaluated at key strategic decision points throughout the day. For example, a sector-based verification approach along

ATM strategic planning decision points and a measure of weather impact across the NAS can be used to evaluate convective weather forecast quality in an operational context. The fundamental unit of measure is applied to super high sectors – the volumes that are used for strategic air traffic planning of en route air traffic. The goal is to correctly transform the forecast into sector impacts quantified by the ATM impact model that applies, for instance a directional capacity impact in the direction of flow established by the ATM flow plan. ATM impact models must be tied into the evaluation of weather forecast quality in a way that the ATM impact is accurately predicted in measures that are meaningful to the ATM application.

Conditioning ATM Impact Models into User-relevant Metrics

In order to translate weather forecasts into useful information for ATM planners, weather forecasts must be calibrated, not with respect to meteorological criteria, but with respect to operational planning criteria. Since the airlines participate in the ATM process through CDM processes, calibrated ATM-impacts must be expressed in meaningful terms to the airlines (dispatch and ATC coordinators) as well as to the ANSP. When planning and scheduling flows of air traffic to cross the NAS, one must project flight schedules and trajectories and weather forecast information into an ATM impact model to arrive at delay estimates (arrival and airborne delays), cancellation estimates, and cost estimates. In NextGen, post-process analysis can be used to adjust the bias on ATM impact models so that future ATM impacts best model actual costs. In NextGen, it will be critical that the impacts of weather information be calibrated with respect to ATM operational decisions for effective planning and automated decision support.

Ground Delay Fog Impact Models

The situation at SFO provides an opportunity to explore the integration of probabilistic weather forecasts into TFM decision making. This case involves a forecast of a single weather parameter – the marine stratus (fog) burn off time – at a fixed geographical location (the SFO approach zone). Traffic managers initiate a GDP to reduce the inflow of aircraft when fog at SFO lingers well into the morning arrival rush, thereby reducing the AAR in half (because only one runway can be used instead of two). One must rate the confidence of each of several forecasts, and use empirical errors of historical forecasts in order to create a probabilistic forecast in terms of a cumulative distribution function of clearing time. To address the ATM impact, a weather translation model must integrate SFO's probabilistic fog burn off forecast in with GDP algorithms.

Airport Winter Weather Impact Models

The accumulation of ice on aircraft prior to take off is a significant safety hazard affecting aircraft. Research indicates that the icing hazard for aircraft directly corresponds to the amount of water in the snow, rather than visibility – the traditional metric used to determine de-icing and take off decisions. Results from field tests of de-icing fluids have identified the liquid-equivalent snowfall rate as the most important factor determining the holdover time (time until a fluid fails to protect against further ice build-up). The ATM impact of decisions made regarding aircraft de-icing holdover times, de-icing fluid types, and application procedures have yet to be defined and integrated into a NextGen gate-to-gate ConOps.

Weather Impacts on Airport Capacity.

Terminal weather conditions, including C&V, surface winds, precipitation, snow, and convective activity, have significant direct (e.g., available runways) and indirect (e.g., aircraft separation requirements) impact on the available airport capacity. Approaches for estimating airport capacity as function of existing or forecast weather can be roughly divided into two groups: models predicting the impact based on trends observed in historical data and analytical airport capacity models explicitly incorporating weather parameters and their uncertainty into the modeling process.

In-Flight Icing Impact Models

In-flight icing impacts air traffic flow in complex ways. For aircraft not certified for icing conditions, all known or forecast icing is prohibited airspace. Some situations have icing severity and aircraft equipage combined to define a "soft" constraint – some properly equipped aircraft may penetrate the icing volume for limited exposure times. In-flight icing is typically a low altitude hazard, generally less than FL200. Major ATM impacts, therefore, are seen for low-end General Aviation (GA) and for all aircraft in the arrival/departure and terminal phases of flight. National ATM impact can be significant when icing affects large airport metroplexes.

ATM Impacts derived from Probabilistic Forecasts for Ceiling and Visibility and Obstructions to Visibility

The Ceiling and Visibility (C&V), and Obstructions to Visibility (OTV) impacts differ depending on the flight regime (terminal, en route, ground operations) and type of aircraft operation. The core forecast technology for OTV, plus translation to ATM impact and decision support dealing with uncertainty, are technology gaps that still need to be addressed for NextGen.

Airport Configuration Impact Models

The airport configuration is a primary factor in various airport characteristics such as arrival and departure capacities (AARs and ADRs) and terminal area traffic patterns. The wind speed and direction is essential in determining which runways are feasible. Terminal Area Forecasts (TAFs) do not currently predict wind conditions precisely enough or accurately enough to enable airport configuration prediction. NextGen weather forecast systems must correct this in order to assimilate weather into DSTs for airport surface operations as well as TFM decision making. As for modeling the ATM impact, there is also research needed to establish the relationship between the way controllers choose between viable configurations to meet the arrival and departure demands of an airport.

Wake Vortex Impact Models

Knowledge of wake vortex characteristics and behavior in near real time allows the opportunity to safely reduce existing separation standards to increase throughput, particularly within the terminal airspace. Recent efforts have focused on wind dependent solutions where a very short term wind forecast (20 minutes) is sufficient to determine when persistent transport crosswinds protect specific CSPRs from the threat of a wake vortex moving into the departure flight path, thereby safely allowing reduced separations.

Traffic Flow Compression Models

Generally, when strong winds aloft are present, the wind speed will vary considerably with altitude. This will cause large variations in groundspeeds among aircraft at different altitudes and thus in trail spacing becomes difficult to maintain. From an ATM perspective, currently, larger MIT restrictions are issued to handle this effect, which controllers refer to as compression. Generally when winds aloft impact the airspace, MIT restrictions must be increased, and there is also the possibility of impacting performance with a lower AARs with the potential of GDPs and Ground Stops (GS). The outstanding issue is how to translate this information to determine compression effects on ATM, and how the requirements relate to the weather forecast accuracy.

Oceanic/Remote Weather Integration

The NextGen ConOps envisions a seamless transition between the CONUS, terminal, and oceanic domains. Weather information for oceanic and remote areas will be integrated with ATM at the same level as for the CONUS operations. However, weather information for remote and non-littoral oceanic regions is more difficult to create than for the CONUS because data is sparse. Therefore, it requires creative use of available data from satellites and other limited sources, and is an area of active research within the DOD. Prototype algorithms have been developed for regional use, but have not been integrated with ATM procedures. For instance, studies demonstrate how wind data can be used to generate wind optimal routes, transitioning away from the fixed oceanic routes to user-preferred routes. While such routing takes advantage of the jet stream, it also must take into account turbulence that can be found near the jet stream, which is an area of future research.

Volcanic Ash Impact Models

Advanced techniques are needed in NextGen that will detect, forecast, and disseminate information on volcanic ash plume hazards and how the hazards will affect ATM resources to aviation operators and users. Airborne volcanic ash constitutes a recognized threat to aviation that can severely damage jet aircraft engines through erosion, corrosion, and congestion. As was apparent in the eruption of the Icelandic volcano Eyjafjallajökull, volcanic ash modeling efforts should be harmonized and coordinated with other Volcanic Ash Advisory Centers. Volcanic ash contamination may render large volumes of airspace unavailable, necessitating costly rerouting contingencies. The volcanic ash also degrades braking action at affected airports and may completely close contaminated airports. The weather transformation model for volcanic ash plume hazards requires further advancement of both science and operational modeling.

Environmental Impact Models

Environmental impacts will be significant constraints on the capacity and flexibility of NextGen. The major environmental effects include emissions of pollutants, greenhouse gases, aircraft noise, and water pollution via de-icing agents, spilled fuel, etc. Most environmental impacts are affected by the atmosphere and will require the integration of probabilistic weather forecast elements for proper risk management. Weather affects the strength and direction of acoustic propagation, the dispersion of mixing of air pollutants, and it effects engine performance and fuel usage. Environmental impacts are transformed into ATM impacts via several mechanisms, including:

- Mitigation measures such as specialized departure and arrival procedures and routings, as well as restricted periods of operation

- Routing and altitude assignments that seek to minimize fuel consumption (and possibly contrail formation)
- Surface and system management that seeks to minimize taxi times and delays on the ground with engines running.

Space Weather Impact Models

There is a growing threat from space weather as aviation's dependence on space and terrestrial networks vulnerable to space weather continues to grow. Specific threats exist for communication and navigation service interruptions, radiation damage to avionics, and radiation exposure to passenger and crew on high latitude flights. Even relatively minor solar storms can affect these services and cause flights to reroute, divert, or not even dispatch over polar regions. Moderate to strong solar flares can impact High Frequency (HF) service (on the order of hours to days) in the low to middle latitudes. Thus, an expected increase in polar flight activity (and increasing flight levels) will bring about an increase in NAS delays due to space weather events. Therefore, we can expect an "as-yet undefined" impact to the NAS in the CONUS, and on a global scale By integrating space weather into the NextGen infrastructure, we can lessen the impact to air traffic.

General Aviation Impact Models

While the number of studies that have been performed to build ATM impact translation models has been increasing over the years, few and possibly none of these have focused on the particular parameters that model GA aircraft in particular, or have quantified the overall impacts to GA pilots in the aggregate.

4.2 ATM-Weather Constraint/Impact Maturity and Gap Analysis

This section is to assess the maturity of the ATM-impact models presented, and to identify gaps in technologies that must be addressed for NextGen. In order to assess the maturity of each ATM-impact model, we use the following criteria:

- Low Maturity – The concept is defined, however, there is no theoretical foundation or scientific data gathered to build the mathematical model for the concept
- Medium Maturity – The concept is defined and a theoretical foundation or scientific data is gathered for a mathematical model for the concept
- High Maturity – The concept is defined, a mathematical model is established, and effort has been made to verify and refine the model for acceptable operational use, and
- Full Maturity – The concept is an acceptable method of modeling ATM-impact and is in operational use.

Note that no ATM-impact model that has been reviewed is at full maturity. For instance, there is no established and accepted indicator of airspace capacity in the NAS today. Most of the ATM-impact models fall in the low and medium maturity levels, with further research, development, and deployment needed. Table 4-1 provides an assessment of the maturity of the ATM-impact models described in this survey.

Table 4-1. Level of Maturity for ATM-impact Models.

ATM-impact Model	Low	Medium	High	Full
En Route CWAMs		x		
Terminal CWAMs		x		
Maximum Airspace Capacity Models Mincut Algorithms Mincut Algorithms Given Hard/Soft Constraints		x		
Sector Capacity Models		x		
Route Availability Methods			x	
Directional Capacity / Directional Demand Models		x		
NAS Traffic Models		x		
Sector Demand Models		x		
NAS Traffic Flow Distribution Models Congestion Models Network Flow Models		x		
Ensemble Models		x		
Deterministic Models		x		
Pilot Deviation Models		x		
ATM Impact Assessment Models		x		
Ground Delay Fog Impact Models			x	
Airport Winter Weather Impact Models		x		
Airport Capacity Models		x		
In-flight Icing Impact Models		x		
Airport Configuration Impact Models	x			
Wake Vortex Impact Models			x	
Traffic Flow Compression Models		x		
Volcanic Ash Impact Models	x			
Environmental Impact Models	x			
Space Weather Impact Models	x			
General Aviation Impact Models	x			

Gaps in ATM-impact modeling include the following:

- Human Factors (see C-5), including Human-in-the-Loop (HITL) simulations, roles and responsibilities, and culture, need be included into ATM-impact models to adequately address capacity limitations that are driven by controller, dispatcher, and pilot workload; complexity; displays; collaboration and team work between various decision makers; etc.
- The role of CDM and how it influences the demand on a weather-impacted resource, enforcement of company policy, and the coordination and collaboration of TFM solutions needs to be integrated in with future ATM integration solutions.
- Any model that observes how pilots fly in today's NAS does not represent how pilots may fly in NextGen when new technology and new procedures are likely to be in place. There is a need to transform a lot of ATM-impact models into NextGen conditions. However, it is difficult to validate such models, except in simulation environments. Similarly, as various air traffic automation tools to assist in separation of aircraft from other aircraft are introduced, it will be necessary to recalibrate the models that translate weather impacts into capacity impacts. Here again, simulations may be needed.
- Work is also required to determine how to properly combine impacts from multiple ATM-impact models to evaluate the magnitude of expected ATM impact from multiple weather types. For example a segment of airspace may be simultaneously experiencing impacts from convection, elevated haze, turbulence and volcanic ash. The impact of each environmental condition may be calculated (deterministically or stochastically) by individual impact models; yet rolling them up into an integrated impact will not likely be commutative since each of these events are not likely statistically independent. Complicating the task of integrating these various impact models into one is the fact that each model reviewed in this section is at a different level of maturity, as indicated in Table 4-1.

4-D hazard information must be integrated with winds and temperature effects on all flight profiles. Airline dispatchers and pilots using 4-D flight planning systems can then strategically plan flight profiles and, most importantly, pilots can prepare to react tactically to real-time hazard information prior to an encounter with any aviation weather hazard.This discussion on gap analysis is at a very high level because it is work that needs to be done. Performing a gap analysis is part of the foundation building called for in Paragraph 5.1.1, performed by the team identified in Paragraph 5.2.2.2 and under the oversight of the board identified in Paragraph 5.2.3

4.3 Survey of ATM-Weather Integration Technologies

Many of the ATM-impact models will eventually be integrated into DSTs in order to help users reason about the impacts of weather while solving ATM problems. The survey includes approaches for addressing weather-related uncertainty in ATM decision making for strategic look-ahead times – risk management processes – as well as approaches that wait until the tactical look-ahead times to address deterministic forecasts after the uncertainties diminish. The ATM-Weather integration techniques make reference to ATM-impact models as appropriate. An assessment of maturity of these ATM-Weather integration technologies and a gap analysis are given at the end of the section.

Sequential Congestion Management for addressing Weather Impacts

Flexibility and adaptability in the presence of severe weather is an essential NextGen characteristic. Sequential Congestion Management is a means to achieve this. There are two approaches to Sequential Congestion Management: probabilistic and adaptive. The probabilistic approach describes how to incrementally manage en route airspace congestion in the presence of uncertainties. This approach can take advantage of probabilistic weather forecasts to reduce weather impact on en route airspace. It would also provide an effective inner loop to be used in conjunction with strategic flow management initiatives, based on longer-range weather forecasts. The adaptive approach performs sequential congestion management using multiple timescales. This method may or may not employ probabilistic forecasts, but rather relies on adapting to observed weather as it develops.

Sequential Traffic Flow Optimization

A deterministic sequential optimization approach integrates a strategic departure control model with a fast-time simulation environment to reactively control flights subject to system uncertainties, such as imperfect weather and flight intent information. To reduce the computational complexity of the strategic model, only departure delays are assigned, while tactical en route flight control is accomplished through heuristic techniques.

Airspace Flow Programs

An AFP is a particular type of TMI that controls traffic flowing into an airspace where demand is predicted to exceed capacity. An FCA is defined to be the boundary of the region of airspace where demand exceeds capacity – most typically, due to convective weather constraints. Today's AFPs use fixed locations for FCA boundaries, and these regions are defined by air traffic control center and sector boundaries, not the location of the weather constraint itself. In NextGen, the FCA is likely to be a 4-D volume that describes the space-time region where weather constraints (not only convection, but severe turbulence and icing regions as well) cause significant ATM impacts. Because the AFP must reason about the effects of weather on airspace capacity for long look-ahead times, it is necessary for the AFP to reason about a probabilistic estimate of capacity.

Ground Delay Program Optimization

GDP's must be optimized in NextGen to minimize delays. Weather forecast uncertainty accounts for a great deal of the uncertainty in capacity forecasts. This poses significant challenges in planning and controlling a GDP. There are two primary decisions associated with any GDP: (1) setting the AAR, and (2) allocating landing slots to flights, and hence, to the airlines who operate those flights. Static and dynamic stochastic optimization models that account for weather forecast uncertainty are appropriate to meet this requirement in NextGen.

Contingency Flow Planning

Management of the complex interaction between potential weather outcomes and TMIs can be modeled using a collection of potential weather scenarios. These would be retained in an ensemble forecast, which would serve as input to a Probabilistic Decision Tree. Flow planners would make use of this to form a primary plan and contingency flow plans (one for each possible weather scenario) (for instance, strategic two to four hours in the future). This assists in the strategic planning of GDPs, AFPs across FCAs as well as tactical GSs, holding, metering, reroutes, and other plans.

ATM Turbulence Impact

Unexpected turbulence injures crew and passengers, and potentially can damage aircraft. The hazard results from several different atmospheric phenomena including jet stream interaction, shear, mountain wave generation, and convection. Two distinct types of turbulence are of concern: Clear Air Turbulence (CAT) and Convectively Induced Turbulence (CIT). The ATM impact results from pilots desiring to avoid or exit turbulent conditions for safety reasons. This may happen tactically or strategically. Alerting to potential turbulence is important so that the cabin can be properly secured prior to an encounter. Exiting an unplanned encounter requires information to identify an acceptable exit strategy (that is, climb or descend to airspace clear of turbulence, or avoid by changing horizontal flight path to a region clear of turbulence). The exit strategy can be determined tactically, essentially as an aircraft is experiencing turbulence, or is warned that it is about to enter it, or strategically, with sufficient planning time to enter into a region of potential turbulence or avoid it altogether.

Automated Turbulence Electronic Pilot Reports

NextGen will likely automate the process of collecting and distributing turbulence (as well as other) Pilot Report (PIREP) information. Such automated e-PIREPs will automatically and frequently report PIREPs by data link to ATC and to nearby aircraft. With a collection of e-PIREP information reported at a wide variety of flight levels (null as well as hazard reports), turbulence information can be data linked directly to nearby aircraft or collected and distributed via a centralized database. Thus, hazardous airspace as well as airspace clear of turbulence can be communicated to nearby aircraft that are soon to pass into such airspace. Since turbulence is a transient hazard, this process needs to be automated, a data link needs to quickly communicate information to nearby aircraft, and the process must repeat throughout the day for detecting CIT and CAT hazards.

Probabilistic Traffic Flow Management

The strategic TFM problem is inherently stochastic since both the traffic loadings and system capacities are difficult to forecast precisely over such long time horizons. Strategic TFM solutions need to account for forecasting uncertainties, forecasted traffic loadings, and estimated system capacities. The specific solution method can take several forms. One is a resource allocation solution involving a combination of rerouting and ground delay. This probabilistic TFM concept has a high maturity level, as it has been defined, analyzed and verified at various levels.

Adaptive Search for Resolution Actions

Uncertainties present in demand, weather, and capacity, create a need to resolve congestion in an efficient and flexible manner. In both the strategic and tactical time frames, the methods utilized to resolve congestion should provide metrics to measure the quality of the proposed solutions. A Generalized Random Adaptive Search Procedure (GRASP) can address this problem through a computationally-efficient heuristic optimization approach. GRASP finds feasible solutions quickly and evaluates proposed solutions against defined metrics to determine the set of resolution maneuvers that best satisfies the objectives.

Integrated Departure Route Planning

NextGen will require an IDRP capability in order to handle departure traffic efficiently and safely. The IDRP capability must integrate departure route and en route sector congestion information, especially when weather constraints are present and traffic demand must dynamically adjust to predicted downstream capacity fluctuations. This concept also applies to downstream weather constraints such as convection, turbulence, or icing. The IDRP capability reduces the time needed to coordinate and implement TMIs and supporting departure management plans.

Tactical Flow-Based Rerouting

Controllers now tactically reroute air traffic flows around severe weather. This task can be optimized with an ATM-Impact model for route blockage. In the tactical timeframe (0 to 2 hours), weather predictions are relatively good, so the reroutes can be closer to the weather than strategic reroutes and thread through smaller gaps between weather cells. Automated solutions can make tactical rerouting easier and reduce workloads associated with rerouting. Also, moving this activity from controllers to traffic managers will reduce controller workload, thereby safely increasing airspace capacity during severe weather. This is because airspace capacity is a function of not only weather but of controller workload.

Tactical On-Demand Coded Departure Routes

Today, air traffic flows are tactically (0 to 2 hours) rerouted around severe weather using a static Coded Departure Route (CDR) framework. NextGen will change the CDR framework to a dynamically defined "On Demand" CDR framework for tactically routing 4-D trajectories. To facilitate this framework, an ATM-impact model is needed to identify route blockage ahead of time as well as to design space-time reroutes between city pairs with a 1-2 hour look-ahead time. On-Demand CDRs will move the rerouting decision as close as possible to the tactical time horizon to reduce the uncertainty in rerouting that results from weather forecast uncertainty.

4.4 ATM-Weather Integration Maturity and Gap Analysis

This section is to assesses the maturity of the ATM-weather integration technologies, and identifies gaps in technologies that must be addressed for NextGen. In order to assess the maturity of each ATM-weather integration technology, we used the following criteria:

- Low Maturity – The concept is defined (e.g., in the form of an operational concept), however, there is no theoretical foundation or scientific data gathered to explore the ATM-impact models and performance of the ATM-weather integration technology.
- Medium Maturity – The concept is defined and a theoretical foundation and/or scientific data is gathered for a mathematical model for ATM-impact components, components of the technology have been assembled in a prototype system, and some evaluation of performance has been demonstrated.
- High Maturity – The concept is defined, a models have been established, and effort has been made to verify and refine the models and prepare the technology for acceptable operational use.
- Full Maturity – The integrated technology is an acceptable technology in operational use integrating an ATM-impact model with a deployed DST in the NAS.

Note that no ATM-integration technology that has been reviewed is at full maturity. Most of the ATM-impact models fall in the low and medium maturity levels, with further research, development, and deployment needed. Table 4-2 provides an assessment of the maturity of the ATM-weather integration technologies described in this survey.

Table 4-2. Level of Maturity for ATM-Weather Integration Technologies

ATM-Weather Integration Technology	Low	Medium	High	Full
Sequential Congestion Management		x		
Sequential Traffic Flow Optimization		x		
Airspace Flow Programs	x			
Ground Delay Program Optimization		x		
Contingency Flow Planning		x		
ATM Turbulence Impact		x		
Automated Turbulence Electronic Pilot Reports		x		
Probabilistic Traffic Flow Management		x		
Adaptive Search for Resolution Actions		x		
Integrated Departure Route Planning		x		
Tactical Flow-Based Rerouting		x		
Tactical On-Demand Coded Departure Routes		x		

Gaps in ATM-weather integration technologies include the following:

- As was the case in ATM-impact models, human factors (see C-5) is absent in many of the ATM-weather integration technologies.
- Many of the ATM-weather integration technologies are tied to how pilots may fly in the NAS today, using jet routes, current day sector definitions, and current day traffic demand loads. In NextGen when new technology and new procedures are likely to be in place, and when new concepts allow for more flexible routing strategies (no longer tied to Navaids and jet routes), some technologies may have to change to address such conditions. There is a need to transform ATM-impact models into NextGen conditions, and a need to transform ATM-weather integration technologies to NextGen conditions.
- Work is required for NextGen to determine how to combine impacts from multiple ATM-impact models to ensure the DSTs receive proper magnitude of expected ATM impact from multiple weather types. Not only may an airspace be simultaneously experiencing multiple types of weather impacts, but also the effects from these impacts in one part of the NAS may affect ATM in other parts of the NAS with upstream and downstream propagation. The ATM-integration effort should not be limited in spatial or temporal scope nor or in the breadth of weather phenomena.

This discussion on gap analysis is at a very high level because it is work that needs to be done. Performing a gap analysis is part of the foundation building called for in Paragraph 5.1.1, performed by the team identified in Paragraph 5.2.2.2 and under the oversight of the board identified in Paragraph 5.2.3

4.5 Technology Ranking and Selection

This section describes the methodology used for ranking and selection of technologies for potential investment and use. Appendix B contains the full table of technologies and rankings. Following the discussion on ranking methodology, a discussion of the preliminary selection of technologies is provided.

4.5.1 Technology Ranking Methodology

During the initial phase of the process for evaluating weather integration technologies as described in Appendix B of Version 1.0 of this Plan, the following process was used to determine top candidate technologies for further near-term investment.

These criteria are grouped into four major categories:

- Criteria for evaluating technology utility
- Criteria for evaluating technology maturity
- Criteria for evaluating technology cost
- Criteria for evaluating technology dependencies

Each technology listed in Appendix B is scored against each criterion. Each score is determined using a combination of analysis of existing literature describing the technology and its applications, SME opinion, and engineering judgment. Next, each criterion's score is assigned a weight that reflects its relative importance. Scores that are more important from the perspective of the value of the technology to ATM and its near-term applicability (two to five years) are assigned higher weights than other evaluation criteria. Once the weights are assigned to all scores, an overall utility of each technology is computed, and the top three technologies are selected.

During the initial phase of the process for evaluating weather integration technologies described in Appendix B of the JPDO-ATM Weather Integration Plan, Version 1.0, September 17, 2009, selection was criteria grouped into four categories as follows:

4.5.1.1 Utility

- *Time horizon:* Defines if the technology provides tactical (TAC) decision support, strategic (STR) decision support, or both.
- *Airspace Domain:* Defines airspace domain in which the technology can be applied, including arrivals (ARR), departures (DEP), en route (ENR), and oceanic (OCE).
- *ATM application:* Defines if the technology is applicable to ATC, TFM, or both.
- *Decision support:* Defines the type of decision support provided by the technology: predictive (PRE) or post-analysis (ANA).

- *Supported weather events:* Defines types of weather events supported by the technology, including convective, turbulence, ceiling, visibility, snow, icing, wind, lightning, space weather (radiation), and volcanic ash.
- *Weather events frequency:* Defines how often weather events supported by the technology occur in the NAS operations.
- *Weather events duration:* Defines typical duration of weather events supported by the technology.
- *Weather events scale:* Defines typical spatial scales of weather events supported by the technology, including local, regional, NAS, or global.
- *Weather inputs:* Defines types of weather inputs (weather analysis and forecast products) used by the technology, including deterministic (DET) inputs, probabilistic (PROB) inputs, and weather ensembles (ENS).
- *Captured disruption-Impact on traffic:* Defines the rough order of magnitude of the total disruption/impact of weather events supported by the technology on NAS operations. The disruption is expressed in terms of estimated annual costs to NAS stakeholders caused by these weather events. Note that this criterion does not estimate the actual benefits provided by the technology but rather the total impact of all weather events supported by this technology.
- *Output dimensionality:* Defines the dimensionality of the outputs produced by the technology, including 2D (one spatial dimension and time), 3D (two spatial dimensions and time), and 4D (three spatial dimensions and time).
- *Output spatial resolution:* Defines the spatial resolution of the technology outputs expressed in km. If the resolution of a technology's outputs is dependent on the resolution of weather input data, this is noted by "weather-input dependent" value.
- *Output temporal resolution:* Defines the temporal resolution of the output produced by the technology. The temporal resolution is defined as static if the technology is not iterative and produces outputs for a given set of inputs; it is classified as dynamic if the technology accepts periodically updated input data (e.g., updated weather nowcasts and forecasts) and produces revised outputs. In the latter case, the frequency of output updates expressed in minutes is also utilized as a selection criterion.
- *Output accuracy:* Defines the accuracy of technology outputs as reported in validation and verification studies for this technology.
- *Reliability (Type I error, Type II error):* Defines the reliability of the technology expressed in terms of Type I and Type II error probabilities. These probabilities are obtained from validation and verification studies for the technology, if such were performed.
- *Portability:* Defines to what degree the technology can be applied to different location in the NAS, e.g., different sectors, centers, or airports.

- *Output versatility:* Defines the technology's potential applicability to other types of weather events requiring possibly only minor modifications to its mathematical model.
- *Real-time support:* Defines the degree to which the technology has sufficient computational speed to support real-time decision making. Sufficient computational speed depends on the technology's ATM applicability, i.e., if it is used for tactical or strategic purposes.

4.5.1.2 Maturity

- *Stage of development:* Defines the current status of the technology's development as problem statement (STAT) (least developed), concept (CONC), implementation (IMPL), or deployed (DEPL) (most developed).
- *Theoretically valid?:* Defines if the technology has a theoretical foundation or scientific data gathered to build the mathematical model of the concept.
- *Empirically valid?:* Defines if the technology has been verified with empirical data to determine its feasibility for acceptable operational use.
- *Operationally valid?:* Defines if the technology has been validated operationally to ascertain its acceptable use in ATM.
- *Benefit studies conducted?:* Defines if benefit studies were conducted for technology.
- *Estimated benefits:* Defines the technology's estimated benefits as obtained from studies, if such were conducted.
- *Number of publications:* Defines the number of reports and publications describing the technology and its applications.

4.5.1.3 Cost

- *Cost of finishing technology:* Defines an estimated total cost of completing the technology's development to support its operational use.
- *Cost of completing mathematical model:* Defines an estimated cost of completing development of the scientific foundation and algorithms.
- *Cost of infrastructure for the supplier:* Defines the cost of infrastructure to the supplier of the technology.
- *Cost of implementation for the government:* Defines the government's cost to implement the technology for operational use.
- *Cost of implementation for airlines/users:* Defines the cost incurred by airlines and other NAS users to implement the technology.

4.5.1.4 Dependency

- *Required NAS adaptation:* Defines if the technology requires any changes in the current NAS operations, and lists the needed NAS adaptations as necessary.

- *Dependencies and interdependencies:* Defines if the technology has any dependencies and/or interdependencies, and lists these dependencies as required.
- *Dependence on obsolete technology:* Defines if the technology depends on any other technology which will become obsolete in the Near-Term NextGen (two to five year timeframe).

4.5.1.5 Weather Integration Technology Classification

- *Weather translation (TRA):* This technology is comprised of one or more functions that ingest weather observations, analyses, and forecasts of meteorological parameters and automatically produce relevant, standardized threshold events or characterizations of weather-related NAS constraints.
- *ATM impact (IMP):* This technology takes information from the weather translation function, combines it with known ATM demand/capacity information, and converts it into potential NAS state changes (in the case of threshold events) or capacity impact (in the case of characterized weather-related constraints).
- *Decision support tool (DST):* This technology uses the NAS impact analysis results from the ATM impact functionality in developing traffic management plans, strategic through tactical, that suggest the best operating strategies to deal with forecast changes of the state of NAS components or that best mitigate the effects of the forecast set of constraints

4.5.2 Preliminary Technical Evaluation of Weather Integration Technologies

Due to the very short timeframe for completing the preliminary technology evaluations, not all data required for defined selection criteria were available to compute the ranking. Hence, the selection process was modified such that the most important criteria were identified in terms of potential utility of the technology, sufficientmaturity for Near-Term implementation, and existence of dependencies prohibiting its operational deployment within the next two to five years. Once these criteria were identified, a team of six aviation weather researchers and SMEs (including an air traffic controller, a dispatcher, and a pilot) developed a preliminary ranking of top candidate technologies for Near-Term investment.

This simplified selection process is suitable for conducting preliminary technical evaluations of weather integration technologies. The full version of the formal selection process described in Section 4.5.1 will be utilized during the subsequent phase of the project focused on developing a refined ranking of these technologies.

The preliminary ranking of weather integration technologies is presented below, with the most promising technology assigned Rank 1.

4.5.2.1 Initial Technology Ranking

Rank 1: B-1.1 En Route Convective Weather Avoidance Modeling

En route CWAM calculates WAFs through observed and forecast weather. They define 4D (three spatial dimensions and time) en route constraints applicable for both tactical and strategic look-ahead times, and offer advantages for ATC and for TFM, including identification of expected constraints in the NAS using state-of-the-art convective forecast data and building common situational awareness of weather impact between traffic managers and NAS users. CWAM is fairly mature weather integration technology at the implementation stage, and has been empirically validated.

En route convective weather presents a danger to aviation, and is a very significant contributor to delay in the NAS. Any improvement in prediction of limitation to or closure of airspace due to this type of constraint will produce very significant benefits, including increased predictability for ATC, TFM and NAS users; more accurate prediction of constraint areas; added margin of flight safety; and more efficient routing around convective constraints.

There are no requirements for NAS adaptation in order to deploy this technology, which means that the technology is applicable to Near-Term operational deployment. There are some identified weaknesses to the methodology, and additional research is needed to determine if the inclusion of other data will increase the accuracy of CWAM.

Rank 2: B-1.5 Route Availability in Convective Weather

Route Availability in Convective Weather (RACW) seeks to predict accurate and timely access to departure, en route, and arrival airspace during convective weather. Such predictions promise to enhance safety, reduce encounters with severe turbulence and hail, and increase throughput at impacted airports—all of which will be a tactical and strategic asset to ATC, TFM, and the users of the NAS. From the two types of route availability technologies discussed in Appendix B, the technology based on Route Blockage algorithms is applicable to Near-Term deployment, whereas the technology based on the Mincut/Maxflow algorithm will most likely require longer deployment timeframe due to identified dependencies. The latter, however, offers much more flexibility than the former, which should provide additional benefits in NextGen.

The most critical need for improved route availability management during convective events is in the highly congested Northeast area. The RAPT prototype implements a Route Blockage approach, one of the two components of RAPT, is already used by EWR, LGA, JFK, TEB, N90, ZNY, ZDC, ZOB, ZBW, ATCSCC, as well as airline dispatchers at Continental, JetBlue and Delta Air Lines. The RAPT Evaluation and Post-Event Analysis Tool (REPEAT) supports post-event analysis of New York-area departure operations, which indicates its level of operational maturity. Research into improving the model is ongoing.

Rank 3: B-1.2 Terminal Convective Weather Avoidance Modeling

Terminal CWAM addresses arrivals and departures in the vicinity of airports which can be affected differently by convective weather compared with flights en route. In particular, departures may simply wait until the weather hazard is clear, and arrivals may engage in maneuvering (holding, vectoring, etc.) to avoid the constraint before landing. Given that, in terminal airspace, the ability to laterally or vertically deviate from a convective constraint is more limited compared with en route airspace, a separate CWAM is necessary for the terminal airspace domain.

The ability to provide better capacity estimation in terminal airspace, especially in the vicinity of the busiest airports in the NAS, will not only reduce delay, but their propagation effects that ripple through the system. Terminal CWAM is currently in the early stages of development; however, the realization of this model will further the IDRP concept.

4.5.2.2 Other Promising Weather Integration Technologies

NAS Impact Model: B-1.6 Directional Capacity and Demand

Directional Capacity and Demand is an example of a recent NAS impact model focused on predicting available capacity of airspace resources impacted by weather. This approach assesses the capacity of an airspace constrained by convective weather by placing scan lines, in 20-degree rotational increments, through the airspace and evaluating the maximum intensity of convection encountered on each of the scan lines. The numbers of scan lines clear, partially blocked or blocked, divided by the total number of scan lines, represents the availability of the airspace.

This approach also evaluates the directional demand of the airspace. The directional capacity and directional demand are convolved on a wind-rose chart; capacity and demand imbalances are identified by direction. This provides information that can later be used for resource reallocations, or rerouting, to angular wedges of airspace that have excess capacity. This model can be centered on a fix, airport, group of airports, or any NAS resource. This type of model, centered on an airport or group of airports, can be a tool that helps alleviate constrained terminal airspace in and around the airports.

Contrary to other existing NAS impact models for predicting airspace and terminal capacity, the Directional Capacity and Demand approach recognizes that the capacity of an airspace resource may depend on the direction of expected demand. As such, the technology may offer additional benefits of improved airspace utilization.

NAS Impact Model: B-1.8 Weather-Weighted Periodic Auto Regressive Models for Sector Demand Prediction

Traditional air traffic flow prediction models track the aircraft count in a region of the airspace based on the trajectories of the proposed flights. Deterministic forecasting of sector demand is routinely done within TFMS, which relies on the computation of each aircraft's entry and exit times at each sector along the path of flight. This method, however, does not account for many uncertainties, such as departure delay due to weather, which can cause a great amount of performance lag.

These uncertainties may cause demand prediction problems, especially for longer strategic look-ahead times. As a result, an empirical sector prediction model accounts for weather impact on both short term (15 minutes) and mid-term (30 minutes – 2 hours) predictions. The PAR model and its variants evaluate the performance of various demand prediction models, considering both the historical traffic flows to capture the Mid-Term trend, and flows in the near past to capture the transient response. In other words, this model predicts the sector demand based on historical traffic data and recent past actual flight flows data, andcompensates for the weather present in that sector.

The PAR model supports terminal and en route airspace domains at local, regional, and NAS-wide scales. This technology requires no NAS adaptation, but its dependencies include 3D weather information with echo tops and storm location information, TFMS data feed, and historical traffic flow data. There have been a few validation and verification studies for this technology, and the results show significant improvements in demand prediction as compared to existing methods.

5 WEATHER INTEGRATION PLAN EXECUTION

The purpose of this section of the Plan is to describe 1) how the plan will be executed, 2) organizational issues and the Weather Integration Methodologies Management Team, and 3) the relationship between weather integration, ATM tool developers and the major AWG programs: RWI, NextGen Network Enabled Weather (NNEW), Weather Technology in the Cockpit (WTIC), and Aviation Weather Research Program (AWRP).

5.1 Plan Execution

The execution of this Plan will occur in four steps. The steps will be executed more or less in sequential order from the start for any given ATM tool, but the steps will be repeated many times as new weather technologies and ATM tools are developed and may be occurring simultaneously at some point in the future. Note that the term "tool" may refer to an automation system for decision support or to a human decision process. The execution steps are:

First, to align teams with each solution set and analyze weather integration requirements for a service and performance-based approach for weather integration as associated with operational relevance. This step will require a mix of operations, programmatic, and meteorological personnel.

Second, to identify the specific weather integration need and insertion points, including performance criteria and value, into ATM tool or decision platform functionality. This step will be highly dependent upon collaboration with the ATM user community and decision tool developers. This step will require a mix of system engineering, tool/design, operations, and meteorological personnel.

Third, to identify and recommend the specific weather integration technologies and technologies that best fit the requirements of a particular TFM tool under development and particularly the insertion points identified in the previous step. This step will require a combination of meteorological, system engineering, and programmatic personnel.

Fourth, to serve as the subject matter expert for the ATM Tool development team to assist in interpretation and integration of the weather constraints and methodologies and to evaluate test results. This step will require meteorological and system engineering personnel.

Prior to proceeding with full-scale integration, it is essential that the weather community develop the foundation of data, products and methodologies that will make integration possible.

5.1.1 Foundation for Integration

In order for weather integration to be successful, a robust set of weather methodologies must be available. The methodologies may deal with the translation of weather into constraints or may center more on decision processes, such as dealing with uncertainty in weather forecasts. Appendix B to this plan shows the Methodology set. Members of the set are at varying levels of maturity. Before they are ready for implementation, they will be winnowed down to the most applicable methodologies, brought to a high level of maturity, prototyped in a generic application, and classified according to their proper use and their Technology Readiness Level (TRL).

The following are being accomplished in establishing the foundation for integration:

- Conduct preliminary selection of the most promising methodologies based on potential skill, applicability to NextGen needs, cost, and schedule
- Continue engineering development of selected methodologies
- Establish and apply a test bed
- Perform TRL assessments of selected methodologies
- Characterize appropriate applications for each selected methodology
- Perform gap analysis to identify un-met user needs
- Demonstrate the methodologies with sample NextGen applications
- Establish a network service for generating multiple-use translated products and supplying them to user systems
- For unique applications, provide user systems with documentation

5.1.2 Integration Process

The following sections describe the four steps for weather integration. These steps are executed sequentially; however, while later steps are being executed, the process can be started at Step 1 when new tools or methodologies are developed that support additional integration possibilities.

5.1.2.1 Step 1: Team Alignment and Analysis

There will be teams aligned with the six non-weather solution sets: TBO, CATM, FlexTerm, HiDensity, SSE, and Facilities. Some teams may support more than one solution set. Using the identified assumptions and determination for weather integration for decision support in Section 5, each team is to identify the set of operational tools, processes and initiatives which will support their solution set capabilities. (Note: Details about the teams are contained in Section 5.2.)

The each team is to be comprised of a broad cross-section of operational users, planners, and engineers, who are intimately familiar with the use and relative value of each identified tool. Additional team members include those who can describe Near-Term functional migration of these tools (operational functions) and who could verify/validate further functional migration into Mid-Term and Far-Term timeframes. If there is no migration path, then team members must be capable of joining with the Solution Set Coordinators in making appropriate assumptions in regard to what tools and what functions will support the capabilities.

There is a need for team members who can identify, either through previous documentation or perception, which of the entire operational tool list qualifies as a potential candidate for weather integration need. This will be a subset of the entire tool set.

The team is to contain operational users that can describe various levels of real or perceived tool improvement (first based on current operational practices and use and then via assumptions on how functionality from tool migration may work). Many tools for the Mid-Term and Far-Term do not yet exist, and the team is to apply their judgment in combination with that of the tool creators and owners. By understanding the kinds of output changes a tool must demonstrate for value to be perceived, the relative value of weather, including the relative success of the integration, can be more easily measured against tool improved value from the perspective of the end user.

The user team members would verify/validate the assumptions used in Section 3 and Appendix A of this plan for the need for and use of weather. They would also validate the methodology described there. Programmatic team members would verify migration and/or functionality evolution plan within the EA, office coordination, and funding.

Information developed in Step 1 will be documented as an update to Appendix A of this Plan.

5.1.2.2 Step 2: Weather Integration Insertion Determination

Step 2 addresses user needs and tool requirements for weather integration and specifically where weather integration should focus (i.e., weather insertion points within the tools or processes as identified in Step 1).

Together with the user tool developers, during this step the weather integration team members consider the decision processes and tool functionality that would be affected when weather occurs. For example:

- The presence of convective weather would reduce the capacity of a route and alter use of that route; that would be noted as a weather constraint point.
- C&V conditions may determine whether an airport should be operating under IMC or VMC, thereby impacting airport capacity.
- Cross winds and turbulence paired with lateral runway separation may impact the decision of whether an airport should run dependent or independent runway operations.
- Space weather introducing errors into GPS position information may impact the landing categories.

The weather phenomena will be prioritized according to the severity and likelihood of occurrence of their impacts (exactly how to perform this prioritization is a topic for future research). If it is not practical to address all possible weather impacts, the prioritization will be a basis for choosing among them.

The combined weather and ATM team will consider the time scale of the impact and whether probabilistic information can be applied as a risk management technique. On very short time scales, especially with regard to an individual flight, the single best deterministic weather constraint information may be called for. For strategic decisions over a multi-hour period or when a number of aircraft may be affected, a probabilistic forecast is usually the appropriate way to deal with uncertainty.

This analysis identifies (with assumptions) where weather needs to be integrated into tools and processes that can affect decisions, the types of weather information needed, and may provide a preliminary indication of the performance requirements for the weather constraint information. Weather informational gaps can be identified (weather information available today versus what is needed) to satisfy the need for weather integration within each application at the identified insertion points.

Information developed in Step 2 will be documented as an update to Appendix A of this Plan.

5.1.2.3 Step 3: Identification of Specific Weather Technologies

Step 3 is the crucial matching of user needs and weather technology support. The weather team will support users in considering the decision, tool, and process characteristics from Step 2, and compare those to available weather translation and decision methodologies documented in Appendix B of this Plan to identify the best concept to apply. It is incumbent upon the weather community to supply needed weather information. In this step, performance needs (e.g. resolution in time and space of the weather information) will be determined and related to the weather provider teams.

As outlined in Chapter 2, the role of the weather community is primarily to provide weather information translated into aviation constraints. Decisions on the relationship between constraints and operational impacts are in the purview of the user community. In application, often the technologies are intertwined. In addition, the weather integration community will of necessity develop an awareness of technologies associated with impacts and how various NextGen systems have decided to bridge the gap between constraints and impacts. The weather team will work with the user program to assist the ATM users in coming to conclusions to how to address the impacts. The weather team must be ever mindful that the ATM tool owners have the ultimate authority as to what goes into their tool.

A key technique for making the technology selection is the use of a demonstration or prototype. Weather methodologies can be demonstrated in a generic sense as a means of showing their benefits and application possibilities. If needed, the ATM tool owners together with weather team members can view the methodology in prototype action in an integration laboratory. This will help them to envision how the methodology applies to their own ATM tool.

Intersections are a consideration when choosing a methodology. In this use, “intersections” refers to decisions with more than one tool involved or even more than one solution set. The weather team representatives must coordinate with their counterparts on related decision tool teams to ensure that the concept is consistent with team doctrine and a collaborative and coherent NAS.

In the text of this plan, weather methodologies and user capabilities were kept separate in order to facilitate the use of any given methodology with multiple user capabilities. In actual practice, during Step 3, the two may overlap. Tailoring of a methodology to the needs of a particular user capability can occur. Furthermore, a developmental effort can occur in which user capabilities and weather methodologies can be matured together. The developments can cross over lines among tools, solution sets, near-mid-far-term, strategic versus tactical, and agency roles. Flexibility, focus, discipline, and creativity will all be hallmarks of successful integration. Human factors are a key ingredient in the integration process and human factors experts must be considered in this step of the process.

Key decisions in the process are; which specific weather constraint and impact parameters are needed for decision support; and whether the constraints and impacts could be taken from a common use network service or are sufficiently unique that the translation should occur within the ATM tool itself.

Information developed in Step 3 will be documented as an update to Appendix A of this Plan and also to Appendix B if applicable.

5.1.2.4 Step 4: Integration of Weather Technology into TFM Tool

Step 4 takes the selections made in Step 3 and turns them into reality in the context of an ATM tool or decision process. The weather team representative continues to work with the tool owners, providing advice, interpretation, and assistance throughout the development cycle. This extends even into the development of user training. It is absolutely essential that human factors be considered and documented in this step.

Information developed in Step 4 will be documented as an update to Appendix A of this Plan. Roadmaps and other baseline documents will also be updated if that has not already occurred.

5.2 Organization

5.2.1 Weather Integration Leadership Team

The Weather Integration Leadership Team is the senior management level for weather integration into ATM operations. It consists of the weather integration manager, the FAA Reduce Weather Impact Solution Set Coordinator, representatives from other stakeholder agencies (NASA, DOD, and NOAA), representatives from implementing organizations (such as Systems Operations, Technical Operations, Terminal Services, En Route and Oceanic Service), leaders of all sub-teams, and others as needed.

The Weather Leadership Team has the following functions and responsibilities

- Carrying out the tasks in the Integration Plan
- Track TRL of target programs
- Provide basis for business decisions, including benefits, cost, risk, schedule
- Track and project integration level (1 to 4) for target programs, with benefits being derived from each level increase
- Manage the various integration laboratory activities and infrastructure for testing and prototyping and objective inputs to the Weather Integration Technology Evaluation Board on TRL levels
- Track progress
- Make commitments on progress

5.2.2 Weather Integration Sub-Teams

Weather integration sub-teams will carry out the actual work of the integration effort by working with inside ATM program offices to provide support and to suggest weather integration solutions to implementing programs. They will be comprised of systems engineers with an operations background/understanding, programmatic personnel, and meteorologists. The team will execute the steps described in Section 5.1.

5.2.2.1 ATM Weather Analysis Team

The ATM Weather Analysis Team is predominately a team of operations personnel and ATM tool developers with knowledge and training in tool operation and weather methodologies. This team will interface directly with members of the target ATM tool and process owners and developers. They will be the weather team representatives whose work is described in Steps 1 through 4 of Section 5.1 of this plan. They will serve as SMEs, assisting tool development experts in the best methodologies for insertion of weather into ATM tools. The ATM Weather Analysis Team will include individuals schooled in the human factors discipline who will ensure compliance with human factors principels as the team works with decision makers and ATM tool developers.

Members of the ATM Weather Analysis Team will be trained on all current weather integration methodologies, ATM operations, NextGen plans and priorities.

There is a need for operator involvement in the development of NextGen DSTs and systems. Tool developers by themselves may not be fully aware of the operational implications of their products. It is not within the power of the ATM Weather Analysis Team to direct that users be part of the DST developers' programs. However, whenever weather impact decisions are being addressed, the ATM Weather Analysis Team will attempt to bring users into the process to ensure that their weather decision perspectives are voiced.

5.2.2.2 Weather Translation Team

The Weather Integration Techniques Team is composed of FAA, NASA, NOAA, and DOD representatives with knowledge of weather integration research and ATM decision processes. This team's work is described in Section 5.1 of this Plan. This sub-team will conduct weather integration laboratory activities. Roles include the following:

- Estimate the time needed to advance to the next TRL
- Track and manage methodology developments
- Document what problems are being solved by each developer
- Give users (e.g. DST developers) insight into integration technologies described in Appendix B of this Plan
- Recommend developmental priorities
- Recommend developmental funding
- Establish and maintain a prototype and demonstration capability for use in refining weather methodologies and in conjunction with users, for assessing and choosing methodologies for a specific integration opportunity
- Provide feedback to NOAA regarding NextGen weather data requirements and impacts so that NOAA can clearly understand, interpret, and offer guidance on these requirements
- Determine meteorological and IT performance requirements of weather information needed for each technology. Evaluate sensitivity of the system to varying performance levels to guide weather data production and dissemination system design

5.2.2.3 Weather Integration Program Team

The Weather Integration Program Team will support programmatic elements of the integration effort, including budget, schedule, benefits assessments, and other tasks needed by the integration manager.

5.2.3 Weather Integration Technology Evaluation Board

The role of the Weather Integration Technology Evaluation Board is to provide objective evaluation and grading of the methodologies presented by the Weather Translation Team. Specifically they will:

- Oversee development of methodologies
- Evaluate and assign TRLs
- Recommend developmental priorities
- State deliverables for each developmental project and evaluate their completion
- Bring focus, discipline, and creativity to the methodology engineering process
- Sponsor development of new weather methodologies to meet needs expressed by the ATM community for which current methodologies do not meet the need on a resolution, accuracy, or timeliness basis
- When appropriate, partner with a "Strategic Planning Advisory Review Cadre" (SPARC) to help with TRL assessments

5.3 Risk Assessment

The following risk factors have been identified but not yet fully assessed or mitigated. Dealing with risk issues is a task to be addressed in FY11.

1. External program managers may be unwilling to cooperate in the Integration process.
2. The incremental cost to a DST tool developer for integrating weather constraint and impact information may not be budgeted for and therefore will not be available in a timely manner.
3. The incremental cost to a DST tool developer for integrating weather constraint and impact information may be so large that the target program manager can not demonstrate sufficient benefits from integration to make it cost beneficial.
4. The translation technologies may not be sufficiently accurate and efficient when they are needed, thereby jeopardizing target systems which have been designed around the translation information.
5. Underlying weather information from the 4-D Wx Data Cube may not be sufficiently accurate, sufficiently timely, or of sufficiently high resolution in space and time in order for it to support constraint translations needed by the user.
6. NNEW or SWIM may suffer technical or programmatic setbacks which prevent planned dissemination of information from the 4-D Wx Data Cube to the constraints translator or from the constraints translator to the user.
7. The translation technologies may be rejected by regulatory organizations.
8. The NWS or other supporting organization may not adequately support needed operations.
9. A user may not be identified in time for integration to occur.
10. The translation function may not be allocated to an appropriate FAA system.

5.4 Human Factors Considerations

Weather brings unique human factors considerations. The weather community will enlist the help of the human factors community in the development of new weather products and weather translation products that will be directly used by the user community. Where weather information is used in the calculation of weather constraints and impacts or is used directly by decision support systems, the weather community will engage the human factors community to assist in determining how human factors considerations will be handled.

5.5 Cost and Schedule

A weather integration program plan and a weather integration budget document are available for internal FAA users if needed. These documents may be requested from AJP-681, Attn: Dave Pace.

5.6 Training

The JPDO is developing plans to address the adoption of new technologies and procedures to enable NextGen objectives. These objectives must be turned into training objectives, and the targeted audiences for training must be identified. For the topic of weather integration, the audience will include the staff members and support contractors of the NextGen Weather Integration Team that executes the Plan. This section suggests the training goals and objectives for the integration of new NextGen weather technologies and procedures.

5.6.1 Identifying Training Needs

In order to effectively identify the NextGen weather integration training needs, the goals and objectives of the JPDO Weather Integration Plan and ConOps must be addressed. The training objectives will be based upon these goals and objectives as well as the technologies and procedures that are envisioned to accomplish them.

5.6.2 Training Adoption

Based upon the system's needs, NextGen innovations and procedures must be addressed in training objectives, in order for them to be implemented in a seamless transition, while augmenting current operational practices. Because of this, guidance concerning the adoption of the new training must be provided to the integration team executing the plan, so that standardization will be ensured. Care must be taken to demonstrate the necessity and inevitability of each change that will be implemented. Training must also demonstrate how airspace users will be capable of adaptation to these changes, in order to encourage understanding, acceptance and motivation within team executing the integration plan.

5.6.3 Weather Integration Plan Goals, Objectives and Training Objectives

The Weather Integration Plan goals and objectives will drive the training the necessary training objectives for the personnel charged with the Plan's implementation. Based on this assumption, the training objectives are:

- **Training Objective 1:** Weather Integration Plan implementation personnel will ensure that weather data/graphics are integrated into DST applications according to the decision-making situations (temporal and spatial accuracy) that they satisfy.

- **Training Objective 2:** Weather Integration Plan implementation personnel will ensure that weather constraints on and impacts to air traffic operations are implemented into DST applications, such as Probabilistic NAS Platform (PNP) and ProbTFM, (both developmental options from the private sector), in a manner that only represents operational impacts in spatial/temporal significance through the use of nowcast and forecast, and net-enabled distribution through SWIM.

Note: Further development of training objectives will occur in FY11.

5.7 Relationship of Integration with Aviation Weather Programs

DSTs essentially remain outside the purview of aviation weather. While weather information drawn from the 4-D Wx SAS must be consistent—i.e., the same published forecast value for a given time and place—the uses to which that information can be put is potentially limitless. The weather may be the same, but its impact is highly variable. The AWG communicates with the weather data user community ensuring that the 4-D Wx Data Cube and especially the 4-D Wx SAS contains current and forecast weather data in the form and at the temporal and spatial resolution required to meet all user requirements.

The AWG operates the followingfour key programs that play a critical role in the integration of weather into DSTs:

5.7.1 Aviation Weather Research Program (AWRP)

The program develops new technologies to provide weather observations, warnings, and forecasts that are accurate, accessible, and efficient. It works to enable flight deck weather information technologies that allow pilots and aircrews to engage in shared situational awareness and shared responsibilities with controllers, dispatchers, Flight Service Station specialists, and others, pertaining to safe and efficient preflight, en route, and post-flight aviation safety decisions involving weather. As the integration effort works with NextGen decision process designers, it will uncover more information about specific user weather requirements. AWRP is addressing those requirements that were identified in preliminary analyses. If additional weather capabilities are identified through the integration process as new or refined requirements, they will be forwarded through RWI for AWRP to address. One AWRP development of particular interest is the NEVS. NEVS is a quality assessment and weather verification capability that will support the translation of weather information into aviation constraints.

5.7.2 Reduce Weather Impact (RWI)

RWI is the primary funding and implementation program for integration activities. It addresses the need to enable better weather decision making and use of weather information in the transformed NAS. User requirements for weather observations and forecasts identified by the integration process will be relayed to RWI to ensure that the weather infrastructure can support them. RWI addresses providing improved forecasts and observations, and providing weather forecast information tailored for integration into traffic management decision support systems. RWI will conduct planning, prototyping, demonstrations, engineering evaluation and investment readiness activities leading to an implementation of operational capabilities throughout NextGen Near-, Mid- and Far-Terms.

5.7.3 Weather Technology in the Cockpit (WTIC)

WTIC is a research and development program that seeks to ensure the adoption of cockpit, ground, and communication technologies, practices, and procedures that will do the following:

- Provide pilots with shared and consistent weather information to enhance common situational awareness
- Provide airborne tools to exploit the common weather picture
- Utilize the "aircraft as a node", functions to autonomously exchange weather information with surrounding aircraft and ground systems
- Facilitate integration of weather information into cockpit NextGen capabilities (e.g., TBO)
- Result from WTIC R&D supporting certification and operational approvals.

WTIC is essentially an Integration effort--one dimension of the overall Integration Plan. WTIC efforts will be applied to cockpit weather integration. Note that it is not the role of this document to specify the role of the pilot. Rather, the document shows that the role of the pilot as determined by other authorities will result in the pilot having needs for weather information or decision support tools that incorporate weather information, constraints, and impacts. The integration process in intended to identify those needs and facilitate their satisfaction.

5.7.4 NextGen Network Enabled Weather (NNEW)

NNEW develops the standards necessary to support universal user access to needed weather information. It enables the seamless access to standard weather data sets by all NextGen users by establishing the 4-D Wx Data Cube. There will be demonstration efforts to resolve key technical questions and reduce implementation risk of a network-enabled weather environment to the FAA and external system users. This will include assurance that NNEW is fully compatible and consistent with the evolved SWIM infrastructure. This will also serve to define open standards and requirements necessary for overall NextGen weather dissemination compatibility. NNEW is the delivery mechanism by which weather information will be provided from weather sources to decision makers. The Integration Team will ensure that the user systems are informed about applicable network-centric standards so that they can obtain and apply the weather information from NNEW capabilities.

5.7.5 Aviation Weather Programs Summary

The AWRP will fill the technology gap when observing and forecast technologies are not sufficient either in time/space resolution or quality to enable TFM DSTs to have the weather information required to make automated decisions. The RWI program provides a programmatic platform for the AWG to test prototype applications of weather technologies in order to demonstrate that they offer the accuracy and quality for direct application into DSTs. NNEW will provide the means for direct access by DSTs to appropriate weather data.

The key interaction for success in weather integration will be the relationships established between the AWG and the ATM tool development community. The AWG role is to ensure proper use and application of weather data and technologies in development of specific DSTs. During development, the AWG will fund demonstrations for specific technologies in order to demonstrate both the quality and usability of weather information in the decision process. As DST development proceeds, weather data for specific DSTs will transition from a testing scenario to inclusion of production data directly from the 4-D Wx Data Cube.

5.8 Quality Assessment

The core quality assurance capability for NextGen weather resides in the NEVS. Two integration-oriented functions of NEVS are described below: the NEVS Synthesis and NEVS Alert functions.

5.8.1 NEVS Synthesis Function

The weather translation algorithms will use criteria specific to a particular planning scenario to produce translated constraint information. Each forecast weather variable needed as input to the weather translation algorithm will be provided by the SAS, using the criteria specific to the planning scenario. For each variable, its SAS forecast is determined by synthesizing or choosing from candidate forecasts in a manner specified by the 4-D Wx Data Cube Domain Authority, using performance information of the forecasts as an input. NEVS provides performance information for these candidate forecasts according to the criteria specific to the weather translation scenario. The SAS synthesis algorithms use this performance information to synthesize forecast candidates into final forecasts that will serve as input to the translation algorithms. (For more information on the SAS process, see the NextGen Weather Plan.) NEVS also ingests the SAS forecast variables to compute and store their corresponding performance metrics. These metrics can be provided as input to the translation algorithms and their synthesis of the different variables into final aviation constraints or threshold events. The final weather translation information is provided as input to the downstream ATM Impact Conversion.

Just as the weather translation algorithms are applied to the SAS forecasts, they may also be applied to the individual forecast candidates and observations, and ingested by NEVS. The operationally-used weather translation output will be ingested by NEVS as well. NEVS will apply translation-specific verification methods to these translated fields, and accumulate their performance information.

Quality information of the operationally-used translation information can be fed to the ATM Impact Conversion as needed by the conversion algorithm. This quality information can also be used as feedback for the development of later versions of the weather translation algorithms.

NEVS will have quality information both for the raw weather forecasts as well as their translation output, which will facilitate an understanding of the relationship between the quality of weather and the quality of its translation. This can be used to provide feedback into the raw forecast performance information that is provided to the SAS synthesis, enabling optimization of the forecast synthesis toward this particular weather translation algorithm.

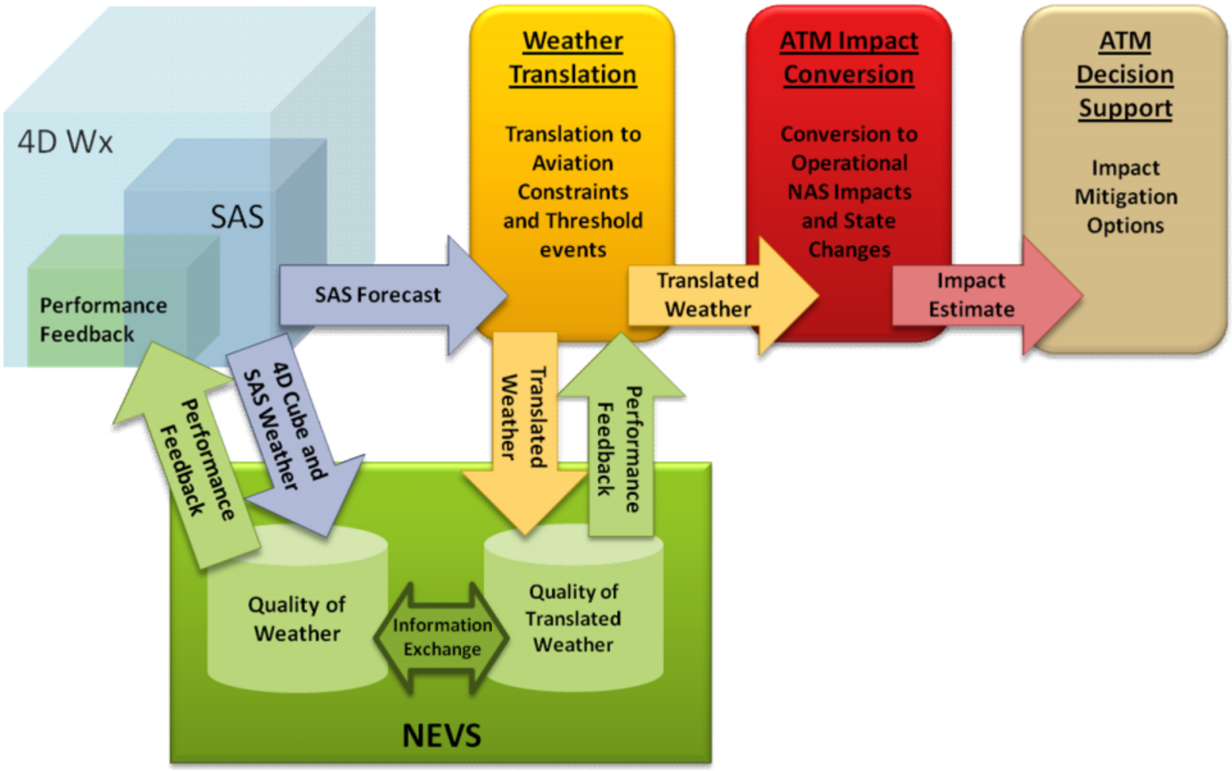

Figure 5-1 NEVS Synthesis Input

5.8.2 NEVS Alert Function

A traffic management plan is based upon a prediction of the state of the atmosphere at a certain point in time and its potential aviation impact. A deviation of the actual weather from the predicted state could warrant a change to the original plan. As the use of weather becomes more automated in the decision-making process and transparent to the decision maker, some automated monitoring of the weather will be necessary to recognize deviations in the expected weather as soon as possible and notify downstream elements of the decision-making process (Figure 5-2)

A planner will have some idea of tolerances in the current forecasted constraint within which the plan will still hold. It is when the constraint exceeds these tolerances that the plan may need to be re-evaluated. These constraint tolerances can be mapped to tolerances or criteria in the original weather attributes that were used to compute the constraint. When the attributes begin to exceed their associated criteria, this should trigger an alert that would begin a re-evaluation of an updated constraint to determine if modification to the plan is needed.

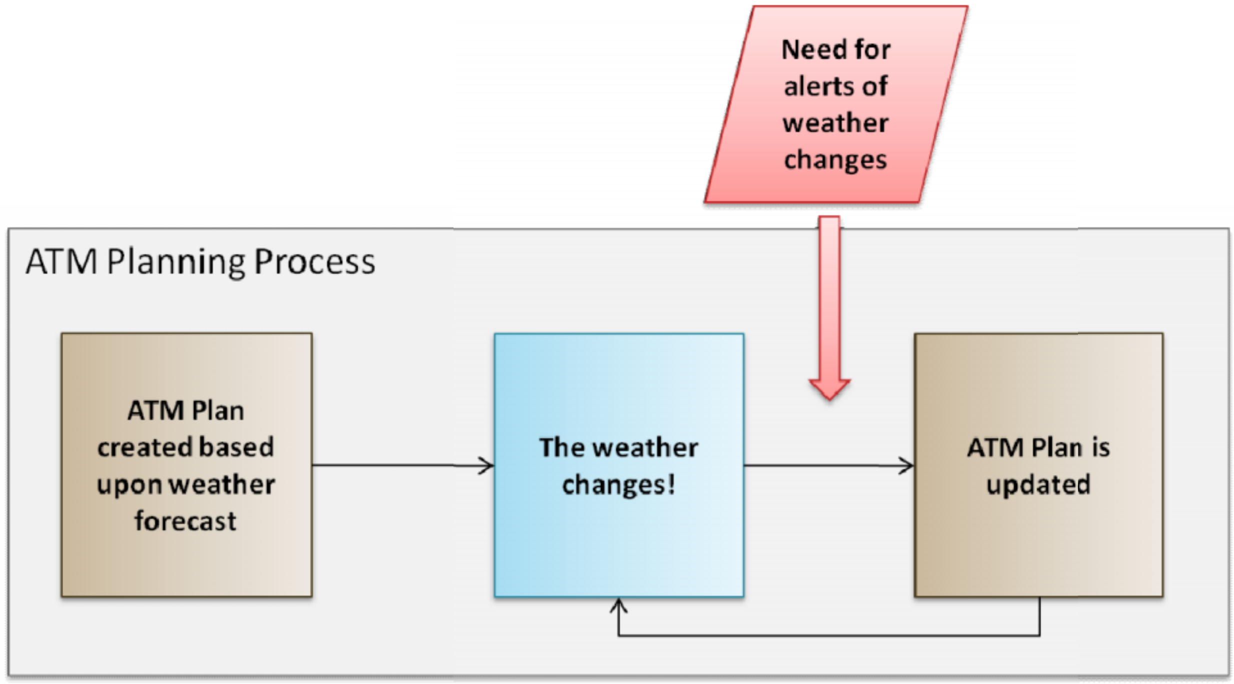

Figure 5-2 The Need for an Alert Function

Architecturally speaking, NEVS is an ideal place for the allocation of this alert functionality. Monitoring of the current state of the weather as described above requires a real-time ingest of relevant observations, combined with an ongoing evaluation of these observations against the specified weather criteria to determine if the criteria still hold. The nature of this processing is akin to what NEVS does for verification of a forecast, where observations are ingested in real time and are evaluated against forecast values to produce a performance metric. NEVS will already be ingesting the relevant observations as part of the verification process for the weather data and its translation output that went into the original plan. Evaluating these observations against another form of criteria is a variation on the standard NEVS measure of quality. Given the criteria that the weather should be expected to meet to support the plan, NEVS will monitor observations and alert a downstream process when these criteria are exceeded. This will trigger an evaluation to see if the plan should be modified (Figure 5-3).

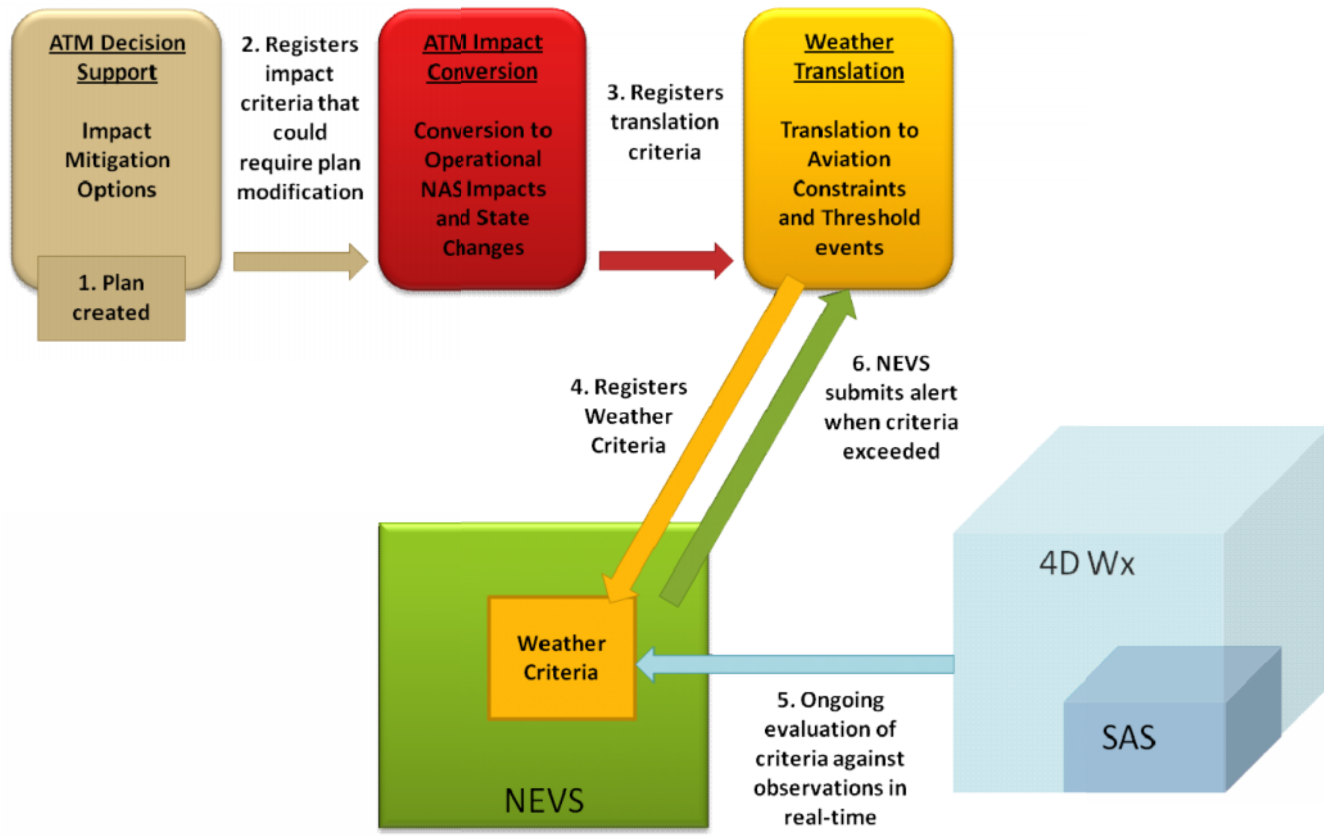

Figure 5-3 NEVS Alert Capability

5.9 Intellectual Property Rights Considerations

This area will be addressed on a case-by-case basis as specific technologies and DSTs are identified as weather integration targets.

6 ALIGNING THE WEATHER INTEGRATION PLAN WITH PREVIOUS FINDINGS AND RECOMMENDATIONS

There is a need for a multi-agency, synchronized plan to achieve solutions to the problem of weather integration into ATM operations and decisions. As articulated in the NextGen vision, the solution must enable decision makers to identify areas where and when aircraft can fly safely with weather assimilated into the decision making process in order to optimize the entire NAS. The NextGen Weather Integration Plan provides the initial requirements, scope and implementation roadmap to achieve the NextGen vision. It also addresses agency roles and responsibilities and includes resource requirements.

6.1 Weather – ATM Integration Working Group (WAIWG) of the National Airspace System Operations Subcommittee of the FAA's Research, Engineering and Development Advisory Committee (REDAC)

The WAIWG of the National Airspace System Operations Subcommittee of the FAA's REDAC conducted a twelve-month study to examine the potential benefits of integrating weather and air traffic management.

The group, with members from airlines, general aviation, NASA, the NWS, national research centers and academia, gathered information during visits to airline operations centers terminals and en route air traffic facilities and research centers. The following key findings and recommendation were reported back to the FAA:

- Few instances of integrated tools exist: time-of-flight estimates incorporating winds aloft; storm free departure times at one airport, and winter deicing timing. All other NAS decision tools use weather manually, as traffic display overlays or on separate displays.
- Aviation weather forecasts have much more accuracy in 0-2 hour, tactical time frame, than the 2-10 hour, strategic time frame. However, the size and shape of the 0-2 hour solution space is much smaller and with increasing congestion, more decisions will have to be made in the latter. Conversely the more the tactical solution space can be expanded, the more decisions can be delayed adaptively and traffic optimized to meet business objectives.
- A risk management approach with adaptive, incremental decision making, based on automatically translating weather forecasts into air traffic impacts, presents a major new opportunity for reducing weather related delays in the future NAS.
- The key recommendation is that a cross cutting research program, involving public and private sector ATM and aviation weather experts, is needed to exploit these key findings.

6.2 NextGen Conference on Integrating Weather, Airports, and Air Navigation Services

Over 200 aviation professionals – user, agency and industry stakeholders – converged on Washington, DC for two days in February 2008 to discuss the challenges of meeting NextGen with regards to weather and weather integration. Several of the plenary speakers urged participants to "think outside the current ways of doing business" - be novel and non-traditional. The group broke into relatively small working groups to address the issues of policy, research, planning, simulations, demonstrations and metrics with regard to weather integration within each of the four major pillars of NextGen: Trajectory Based Operations, Super Density Operations, Surface Airport Operations, and Net-Centric availability and access to common weather information.

A common theme that prevailed across the working groups was that while the language in the NextGen ConOps has been embraced by all NAS stakeholders, there are several considerations towards the reduction of weather impact that must be taken into account before many of the envisioned operational (non-weather) benefits are realized. These involve operational constructs and nuances as perceived by the intended user of the information. Such considerations go beyond any specific scientific improvements in weather understanding and behavior, airborne or ground-based weather sensor density, weather forecast skill or modeling and ultimate weather integration. These considerations include how and when the information is presented, the consistency of the information among differing operators, common interpretation of the information in terms that are relevant to the operation, and the risks or consequences (real or perceived) of the use of the information. There was general agreement that the most important considerations of all will be the policies that facilitate change, the regulations that dictate change, and the transitional stages in operations that will enable operational evolution (e.g., continuity of services/conservation of functionality) while providing perceived benefits and safety. The general consensus of the participants in the NextGen Weather work group determined that while network enabled digital data is a key to success, there was a lack of clarity and messaging (outside the JPDO) regarding government and industry roles for populating and operating the weather 4-D Wx Data Cube. Weather dissemination to, and access by, aircraft is also vital to satisfying the "aircraft as nodes on the net" concept. The private sector is prepared to join the government in identifying options to make NextGen Weather a reality.

6.3 Integration Teams Approach to Tracking the Status on the Previous Findings and Recommendations

The Weather Integration Team has developed a spread sheet to track the status of the major findings and recommendations from these two groups. The spreadsheet is contained in Appendix D.

6.4 Agency Approaches to Implementing the Findings and Recommendations

In the NextGen concept, weather information used by ATM decision-makers will come from a net-centric, virtual, data repository of aviation weather data, (4-D Wx Data Cube). This concept allows each federal agency to leverage and merge their existing agency-specific efforts and aviation-weather requirements into a mutually supportable national and eventually global, construct. This federal effort addresses a way to combine public and private sector aviation weather needs into the ATM process as well as allow each agency to maintain various independent capabilities consistent with their own weather needs. The weather communities within NOAA, FAA, DoD have developed a plan to ensure accessible, network-enabled weather information will be available to meet integration/operation needs.

Currently, the FAA is the lead agency charged with developing integration tools. The FAA's NIP includes the RWI Program. Activities in the Near Term will focus on: developing a ConUse and initial requirements for weather dissemination; preparing for and conducting a weather dissemination interoperability demonstration; developing a concept of use and requirements for weather information needed by manual and automated traffic management and cockpit decision-support tools; assessing gaps and redundancies in the current aviation weather observation networks; development of a pre-prototype multifunction phased array radar; and development of improved forecasts (e.g., convection, turbulence, icing).

APPENDICES

A. NEXTGEN SOLUTION SET-ORIENTED WEATHER INTEGRATION ANALYSES

A-1. Introduction

A-1.1 Description and Differences

Version 1.0 of the ATM-Weather Integration Plan was published in September, 2009. In Appendix A of that document, the vast majority of the material consisted of analyses of ATM-weather integration from the perspective of the one of the relevant NextGen Solution Sets. That strategy continues to be used in this, Appendix A of Version 2.0 of the ATM-Weather Integration Plan, with the formats of the analyses now made consistent throughout. New to this year's version is the adoption of the FAA program viewpoint as a lens through which ATM-weather integration requirements are analyzed, gaps identified and results reported. That material makes up Chapter Three of this document. The capabilities that have been, or are required to be, associated with each FAA program found in Chapter Three are derived from the analyses found here in Appendix A.

A-1.2 Format

A-1.2.1 Solution Set

The Solution Set-Oriented Analysis begins with the name of the solution set and a brief description taken primarily from the associated FAA Solution Set Smart Sheet and/or FAA NAS EA Portal.

A-1.2.1.1 Operational Improvement

Each Mid-Term OI within the solution set is identified and described, often using the wording from the associated FAA Solution Set Smart Sheet and/or FAA NAS EA Portal.

A-1.2.1.1.1 High Level Mid-term Capabilities

For each OI, associated high level Mid-Term planned capabilities are described using the wording from the associated FAA Solution Set Smart Sheet and/or FAA NAS EA Portal. In some cases, the capabilities are further clarified.

A-1.2.1.1.2 Mid-Term Operational Scenarios

Brief Mid-Term operational scenarios are included in some of the analyses for the purpose of better understanding the capabilities associated with the OI, the role that weather might play in the OI and potential weather integration points.

A-1.2.1.1.3 Mid-Term Weather Integration and Needs Analysis

Following an optional description of Mid-Term weather integration possibilities, weather needs associated with the high level Mid-Term planned capabilities are listed in a table. The first column of the table identifies the weather integration need. The second column attempts to identify the functional weather information needs of that DST, and the third column identifies the weather information that will, according to current plans, be available in the mid-term. The last column identifies Mid-Term planning gaps.

It is expected that the identification of Mid-Term functional and performance weather information needs will be an ongoing process that will mature as concepts are further detailed and analyses and research are conducted.

A-2. Solution Set-Oriented Analyses (SSOAs)

A-2.1 HiDensity

The HiDensity Solution Set involves airports (and the airspace used to access those airports) in which the density of traffic is relatively high. Several common characteristic of these airports are:

- The demand for runway capacity is high.
- There are multiple runways with both airspace and taxiing interactions.
- There are close-proximity airports with the potential for airspace or approach interference.

In order for these airports to successfully handle the high volume of traffic, all of the operational capabilities associated with the Flex Term Solution Set must be present, along with integrated tactical and strategic flow capabilities. HiDensity may require higher performance, navigation and communications capabilities for ANSPs and aircraft to support these additional operational requirements.

The Mid-Term OIs of interest are listed here in the order in which they appear as brick red-colored timelines in the HiDensity Figure A-1:

- Improved Parallel Runway Operations
- Initial Surface Traffic Management
- RNAV and RNP Route Assignments
- IASDF
- Enhance Departure Flow Operations
- Time-Based Metering in the Terminal Environment
- Integrated Arrival/Departure Airspace Management

Over time, Far-Term OIs (represented by the light blue shaded timelines in the figure) may be added to this analysis.

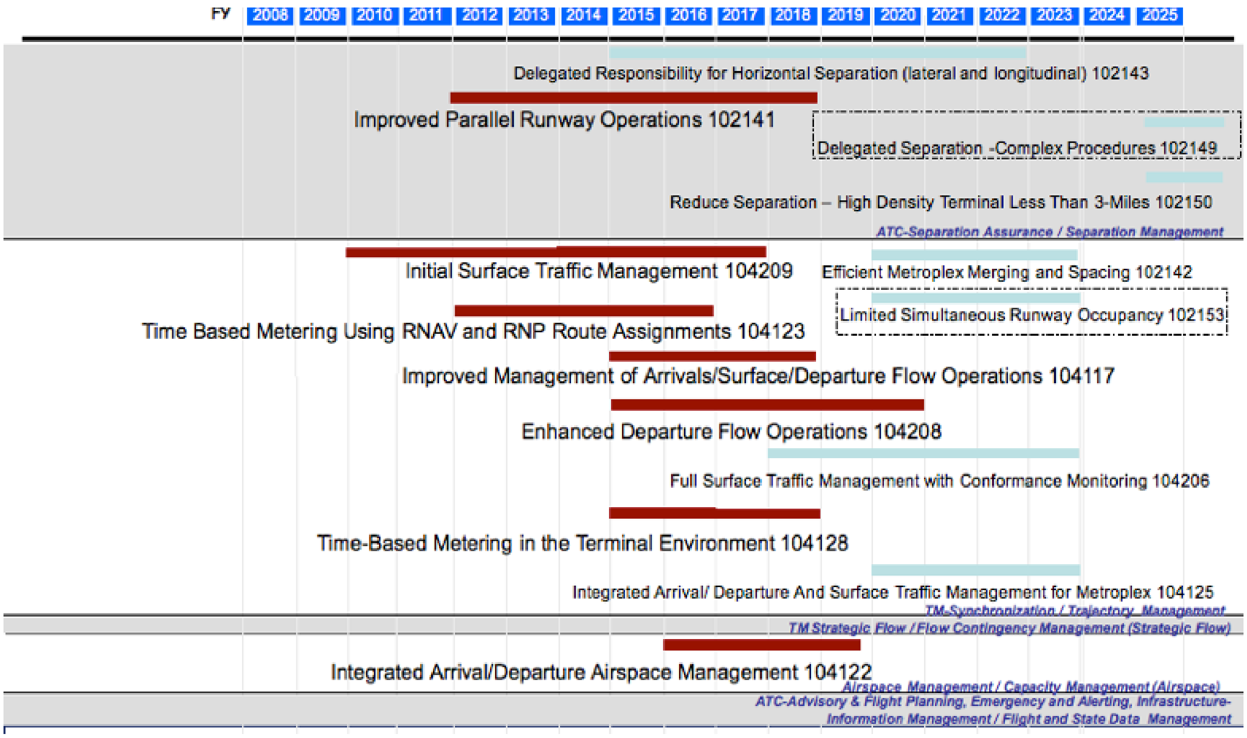

Figure A-1 Increase Arrivals/Departures at High Density Airports Timeline

A-2.1.1 OI - Improved Parallel Runway Operations (102141)

The improvement will explore concepts to recover lost capacity through reduced separation standards, increased applications of dependent and independent operations, enabled operations in lower visibility conditions, and changes in separation responsibility between the ATC and the flight deck.

This improvement will develop improved procedures that enable operations for closely spaced parallel runways (runways spaced less than 4300 feet laterally) in reduced visibility weather conditions. This OI promotes a coordinated implementation of policies, technologies, standards and procedures to meet the requirement for increased capacity while meeting safety, security, and environmental goals.

Intermediate concepts for maintaining access to parallel runways continue to be explored (e.g., use of RNP approaches to define parallel approaches with adequate spacing; RNP transition to an ILS final approach course; RNP/LAAS/WAAS; Wake Program Office initiatives).

Research will be initiated and continued to support Far-Term capacity requirements. Research will be focused on finding ways to recover lost capacity due to IMC events by providing a monitoring capability that mimics or replaces visual separation. This improvement allows additional reduction of lateral spacing for arrivals. VMC-like capacity may be achieved by integrating new aircraft technologies such as ADS-B in, precision navigation, data communications and cockpit displays. Additionally, research will be focused on finding ways to recover lost capacity due to IMC events by updating standards and terminal instrument procedures by taking advantage of systems with advanced navigation accuracy such as WAAS and LAAS and advanced surveillance capabilities such as multilateration Precision Runway Monitor-Alternate (PRM-A) and eventually ADS-B.

A-2.1.1.1 High Level Mid-Term Capabilities

This OI is fundamentally about aircraft-to-aircraft separation capabilities. It primarily addresses lateral position relative to paired parallel traffic (see Figure A-2). By comparison, wake vortex-related capabilities found in the FlexTerm Solution Set are concerned with longitudinal separation. However, references to wake vortex research are made in the OI description found in the FAA Service Roadmap: Increase Arrivals/Departures at High Density Airports. Additionally, it is assumed that this OI encompasses all Instrument Flight Rules (IFR) parallel runway operations, ranging from a lateral runway separation of 4300 feet down to as little as 750 feet or possibly even less. Operationally, the pilot will be advised of the type of operation in effect and will maintain the required lateral position relative to paired parallel traffic that is specified for that type of operation. The aircraft may be operating under ground-managed time-based spacing or airborne merging and spacing. Current thinking is that both types of operations will be supported and may even co-exist within a single arrival stream.

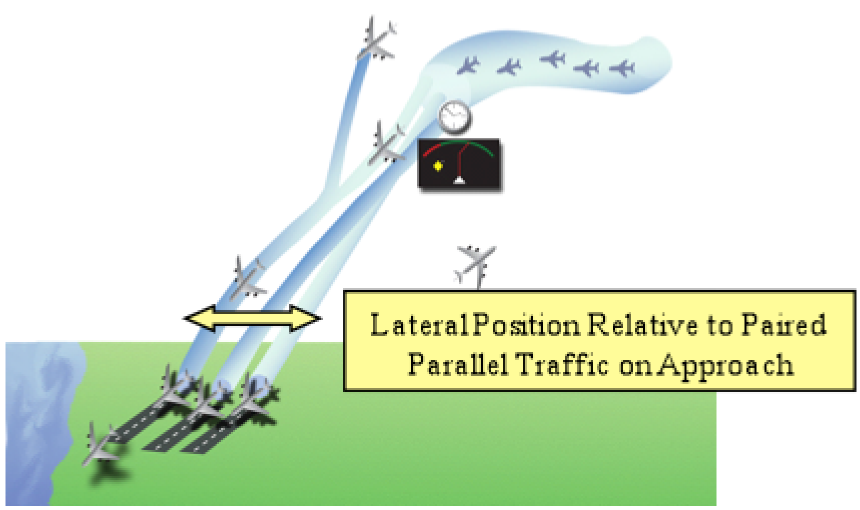

Figure A-2 Lateral Position Relative to Paired Parallel Traffic on Approach

A-2.1.1.2 Mid-Term Operational Scenario

A-2.1.1.2.1 Determine Runway Operations, Given Existing Weather Conditions

The point of this scenario is to examine the process for determining how and when to initiate/terminate a runway operation, so as to identify the associated weather information needs. Therefore the scenario does not include steps for the actual conduct of the operation after initiation.

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. The TMC consults with weather displays to acquire weather situational awareness.

Step 1: TMC uses C&V conditions to determine whether parallel runway offset procedures can be used and whether the airport is operating under IFR or VFR conditions. TMC may look at cross winds and turbulence conditions paired with lateral runway separation to determine dependent vs. independent runway operations, or the TMC may access space weather to determine whether certain procedures are prohibited due to the impact of solar conditions on GPS.

Step 2: The controller advises the pilot of whether airport operations are IFR or VFR, dependent or independent, and whether parallel runway offset procedures are in effect.

A-2.1.1.3 Mid-Term Weather Integration and Needs analysis

Weather information is needed to determine whether a set of parallel runways should be:

a) Operating under IFR or VFR conditions, and

b) Using parallel offset procedures.

Weather thresholds are established for these determinations. Reliable and accurate predictions of the transition from visual to IMC procedures would help to decrease the unnecessary loss of airport capacity due to a drop in ceiling or visibility. However, there are probably no Mid-Term needs for integrating weather into DST rules based algorithms and no “new” weather information needs have yet been identified. Possibly, cross winds and turbulence conditions paired with lateral runway separation are used to determine dependent vs. independent runway operations. Additionally, the TMC may access space weather to determine whether certain procedures are prohibited due to the impact of solar conditions on GPS. These “potential” weather information needs may be examined further in future versions of this document.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-1.

Table A-1 Improved Parallel Runway Operations – Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Displays make weather information available to the TMC, who determines the operations in effect (i.e., parallel runway offset procedures, IFR/VFR) based on established rules for the runway pair	Current weather conditions: •Airport C&V Forecasts 0-30 minute out •Crosswinds at the surface and along final approach *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	Airport Ceiling/Visibility •Meteorological Aviation Report (METAR) •TAF •SIGMET •AIRMET •G-AIRMET •ITWS)Terminal Winds Diagnostic a) 10 km horizontal, 50 mb vertical, 30 min update, sfc-50,000 ft b) 2 km horizontal, 50 mb vertical, 5 min update, sfc-18,000 ft	No “new” weather information needs have yet been identified, so no Mid-Term gaps have been identified

		• HRRR a) 3 km horizontal, hourly update, 15 min resolution, Continental United States (CONUS) •RUC a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS •Weather Research and Forecasting (WRF) - Rapid Refresh (RR)	

A-2.1.2 OI – Initial Surface Traffic Management (102141)

Today, when air traffic demand exceeds NAS resources, traffic flow managers and air traffic controllers employ a variety of techniques to manage departure runways at high-density airports. Most of these techniques rely on the skill and capability of the individual traffic flow managers and controllers. Managing surface traffic to enable aircraft to depart or land at airport runways within tightly scheduled time windows is a daunting task. There is an increasing demand for DSTs to assist controllers in completing this assignment.

Through this OI, departures are sequenced and staged to maintain throughput. The ANSP uses automation to integrate surface movement operations with departure sequencing to ensure departing aircraft meet departure schedule times while optimizing the physical queue in the movement area. ANSP automation also provides surface sequencing and staging lists for departures and average departure delay (current and predicted). These functions will incorporate TMIs, separation requirements, weather data, and user preferences, as appropriate.

ANSP automated DSTs integrate surveillance data, weather data, departure queues, aircraft flight plan information, runway configuration, expected departure times, and gate assignments. Local collaboration between ANSP and airport stakeholders improves information flow to decision support as well as the ability for aircraft operators to meet their operational and business objectives.

This OI is responsible to make airport configuration recommendations.

Appropriate surface data, when developed, will be shared with flight planners and FOCs, as well as airport authorities.

A-2.1.2.1 High Level Mid-Term Planned Capabilities

Given the need for accurate, time-controlled aircraft movements that would seem to be inferred by concepts such as TBO and TBFM, it seems reasonable to conclude that this OI, while concerned overall with the optimal management of aircraft operations on the surface of high density airports, is primarily focused on the departure side of the equation.

The Mid-Term ConOps for TFDM, dated September 2009, suggests that the following capabilities are associated with this OI in the near- and Mid-Term:

- A significant expansion in inter-domain data exchange.

- DSTs that will assist traffic flow managers and air traffic controllers in the management of runway configuration and departure queues, runway assignment, and departure sequencing.
- DST enhancements that develop recommendations for optimized airport configuration and runway assignment.
- Collaboration with flight operators in surface scheduling.
- The introduction of 2D taxi routing and surface conformance monitoring capabilities

Among the questions still to be resolved are the following:

- How will Initial Surface Traffic Management use RVR or other visibility information to address surface movement, so as not to constrain FlexTerm improvements for arrivals involving lowered RVR minima?

A-2.1.2.2 Mid-Term Operational Scenarios

A-2.1.2.2.1 Baseline (Strategic) Airport Configuration Plan for the Flight Day, Using Weather Forecasts

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to plan the airport configuration for the flight day.

Step 1: DST assists with the development of or recommends an airport configuration. DST may base this recommendation on comparisons of existing weather conditions with historical ASPM data analysis, which empirically identifies weather-parameter thresholds (e.g., winds) that are associated with actual runway configuration usage, or the DST may use other methodologies to make its recommendation.

Step 2: The baseline airport configuration is coordinated within the facility and with Integrated Arrival/Departure Airspace Management, which is responsible for the corresponding baseline arrival/departure configuration.

A-2.1.2.2.2 Proactive Change in Airport Configuration Due to Forecast Wind Shift

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to identify and plan for airport configuration changes.

Step 1: DST monitors wind shift timing information to better predict when changes to airport configuration is required.

Step 2: As a wind shift approaches (i.e., far enough in advance to efficiently move traffic to a new arrival/departure configuration), DST assists with the development of or recommends an airport configuration change. DST may base this recommendation on comparisons of existing weather conditions with historical ASPM data analysis, which empirically identifies weather-parameter thresholds (e.g., winds) that are associated with actual runway configuration usage, or the DST may use other methodologies to make its recommendation. DST also takes current traffic demand into consideration when recommending an airport configuration change. If the wind shift is subtle and there is no urgency in changing the configuration, ANSP may wait for a lull in the operations to make the actual turn around. This becomes more of an issue in large metroplex areas where multiple airports may have to change their configuration simultaneously. A lot of efficiency can be lost by ceasing operations at one or more airports prematurely. Additionally, thunderstorm outflow (as cells decay) are extremely unpredictable and often prompt what turns out to be an unnecessary airport configuration change. Better understanding and identification of the life-cycle of outflow winds would be helpful in determining the need for an airport reconfiguration.

Step 3: The airport configuration change is coordinated within the facility and with Integrated Arrival/Departure Airspace Management, which is responsible for the corresponding arrival/departure configuration changes.

Step 4: The tower controller, determines which aircraft will be the last in sequence to use the current runway configuration and coordinates this information with the TRACON.

Step 5: The TRACON starts sequencing other aircraft to the new airport and arrival/departure configuration.

A-2.1.2.2.3 Departure Staging of Surface Traffic Flow

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to manage surface traffic.

Step 1: DST integrates weather information, current departure queues, aircraft flight plans, runway configuration, expected departure times, and departure gate to determine sequencing and staging lists and average departure delays.

A-2.1.2.2.4 Severe Weather Surface Departure Operations

This scenario is sourced from the Mid-Term Concept of Operations for a TFDM, dated September 2009.

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to manage surface traffic. This scenario deals with a system-wide bad weather day characterized by localized severe thunderstorms and highlights the integration of TFM initiatives and Collaborative Surface Management. Given the magnitude of the severe weather impact, the primary users of the surface departure schedule in this scenario are the TS, TMC, and Ground Controller (GC). Additional users are the TRACON and ARTCC TMUs, and the ATCSCC, which are coordinating all of the bad weather day initiatives. All time references are in Coordinated Universal Time (UTC) also referred to as Zulu (Z) time.

Step 1: Flight Operators and TFM are coordinating system level strategies (e.g., CDM) using the TFM automation to provide Expected Departure Clearance Time (EDCT) and updates regarding the route-related flight information to the surface automation. This collaboration includes pre-coordinated departure routes provided by the Departure Routing functionality for the departure airport, which provide alternate routes that are acceptable to the flight operators should the need arise for reroutes due to the weather conditions. A departure routing strategy is currently in effect for the departure airport and surrounding airspace.

Step 2: The surface automation receives the airport situation awareness data and flight specific data. Additionally, due to the weather, TFM automation provides the automation system with any specific NAS constraints (including GDP, TFM re-routing, and En Route Metering) as well as updated flight plan information as it become available. This information is shared with surface automation users, as applicable.

Step 3: As an example, Flight ABC312 files an initial flight plan departing Runway 9R with an RNAV departure procedure over the local fix FIX03 (shown in Figure A-3), then onto the remaining portion of the filed plan to its destination. This flight's Proposed Departure Time (PDT) is 1505Z, 60 minutes from the current time. Due to the severe weather conditions, the tower supervisor, along with the TRACON TMC, ARTCC TMU, and ATCSCC, reviews the existing demand/capacity conditions and local weather forecasts, and then enters local route restrictions into surface automation. The Scheduling and Sequencing capability generates a planned surface sequence showing the airport demand and capacity balance.

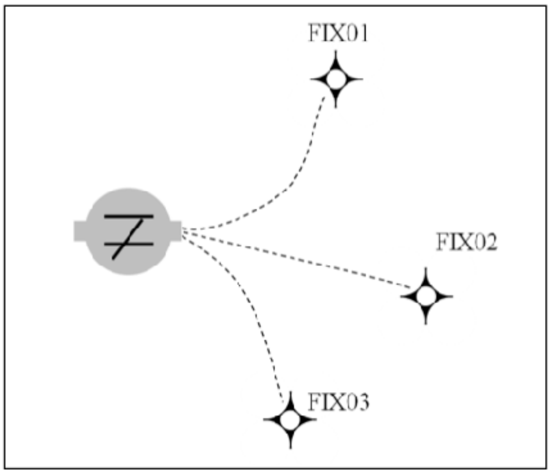

Figure A-3 Standard Instrument Departures for Severe Weather Operations Scenario

Step 4: Encroaching thunderstorms require that departure fix FIX03 be closed for 45 minutes starting at 1430Z. Based upon guidance from the Runway Assignment and Departure Routing capabilities (and in coordination with traffic managers), ABC312's initial runway assignment and routing is adjusted to now depart on 9L to initial fix FIX01 (Figure A-3 and Figure A-4).

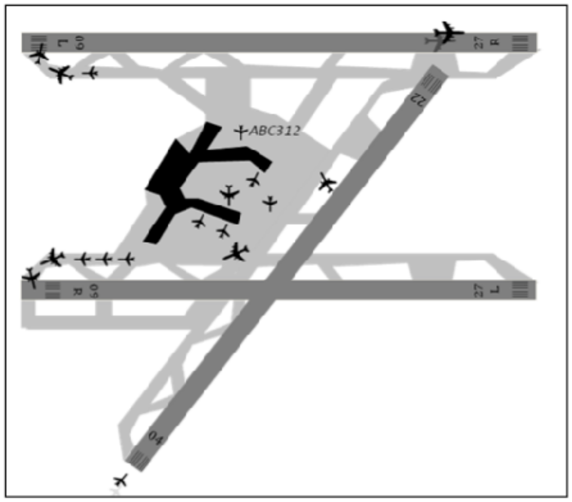

Figure A-4 Airport Diagram for Severe Weather Operations Scenario

Step 5: The tower controller uses tower automation[9] to update this flight's revised route, using the pre-coordinated departure alternative, and to reassign the flight to Runway 9L. The revised route is forwarded to en route automation for processing and then shared with other domains. Based on the new route information, TFM automation assigns a controlled departure time. TFM considers this flight's revised route and assigns an EDCT of 1535Z. Using the Scheduling and Sequencing capability, the updated route, and the updated departure time information, the surface automation updates the runway sequences and schedules and provides them to the tower TM/supervisor. Surface automation also accounts for arrivals to the same or conflicting (e.g., crossing) runways when assigning departure slots, and revises the time at the spot to 1525Z for flight ABC312.

Step 6: All other planned departures through FIX03 also require a similar reroute. The new route is applied to other affected departures by the ARTCC TM, using TFM automation.[10] Based upon the new runway assignments, the Airport Configuration function indicates a significant imbalance in the departure runway loading to the Tower Supervisor, who subsequently modifies the airport runway configuration due to the upcoming departure fix closure, to start in 25 minutes. The surface automation system re-evaluates the current demands and modifies runway assignments to balance the departure loads and then provides this updated information to the TFM automation.

Step 7: The GC is notified of the recommended revised schedule. It is also shared internally among other FAA facilities (TRACON, ARTCC, and ATCSCC) and additional coordination occurs as needed. The tower supervisor coordinates with GC to ensure the surface departure schedule is consistent with tactical tower operations and updates restrictions. At this point

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[9] The reroute may be entered by either the tower controller or the ARTCC TMC, based on local procedures and specific workload conditions. In this scenario, it is assumed that this is a tactical, pre-coordinated reroute and will be entered in tower automation for flights close to the runway. Data exchange capabilities will ensure that the updates are shared by both automation systems.

[10] In this case, the reroute for later flights is entered by ARTCC traffic managers.

(approximately 45 minutes prior to departure and 15 minutes prior to closing fix FIX03), the severe weather forecast continues as predicted and there is no need to further revise the schedule.

Step 8: The revised surface departure schedule is now distributed to flight operators, ramp towers, and non-FAA users. The flight crew for ABC312 is assigned a spot time and is provided the current sequence and taxi queue lengths/delays information.

Step 9: The ramp tower reviews the assigned slot times and determines to hold Flight ABC312 at the gate for an additional three minutes. In addition, the flight operator swaps the spot slot times for two other flights in order to satisfy business goals, in this case, freeing up one of the gates to accommodate an arrival. This updated data is provided to surface automation.

Step 10: Prior to 1430Z, the TS/CIC notes that the weather is moving more rapidly than originally predicted and departure fix FIX02 has to be closed also, further affecting the departures from Runway 9R. The TS/CIC or TMC updates this revised fix information in the surface automation, and it is shared with both internal and external users. As was done earlier, flights are re-routed away from the closed departure fix as necessary, and the surface automation receives the re-route information. The system updates the surface departure schedule and the Airport Configuration system reassigns flights affected by the new departure fix closure to a different runway to balance the runway load and optimize the departure schedule.

Step 11: The pushback and spot times for Flight ABC312 are unaffected by this; however, the automation system determines that the departure runways, 9L and 9R, are once again out of balance and allocation assignments require updating. The surface automation updates ABC flight dispatch, who notifies the flight crew of ABC312, with the additional runway queue time. However, due to late arrivals and other business case decisions, several other users are unable to meet the revised slot times, but ABC airlines has additional aircraft that can be ready to pushback and can be substituted. This information is sent to the surface automation from the flight operators' automation system via data-sharing. The TS/CIC or TMC reviews the surface departure schedule. Unaffected by the substitutions, Flight ABC312 will not need to absorb any additional runway queue delays. The surface automation then updates the TFM automation for downstream coordination and planning.

Step 12: Flight ABC312's clearance delivery, pushback, taxi and take-off then occur as would take place under nominal departure conditions.

A-2.1.2.2.5 Operation under a Severe Weather Avoidance Procedure (SWAP)

This scenario is sourced from the STBO Mid-Term Concept of Operations Overview and Scenarios, dated September 2009.

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to manage surface traffic. This scenario begins as a normal day of operations where the DSTs within TFDM receive the flight and flow management data from the en route and TFM domains and generates an initial runway assignment for the flight XY123 and develops the related runway sequence.

Step 1: An hour or so before the expected pushback, the TMU at the ARTCC responsible for the airspace looks at the weather forecasts and prepares a SWAP Statement for presentation to the ATCSCC. The statement includes the details of the expected weather event, its potential impact on traffic flows, and possible alternatives for mitigating the expected event; it proposes to close the departure fix XYZ for 45 minutes beginning in 60 minutes. The ATCSCC then consults the same weather information for the affected airspace and prepares and distributes a SWAP Advisory to all facilities. The Advisory includes a description of the impending weather event, the routes affected (i.e., weather information is translated into route blockage), the potential impact on the traffic flows (i.e., weather-related route blockage and any other constraints are assessed for their impact on traffic flow), and the TMI (the closing of the departure fix XYZ for 45 minutes beginning in 30 minutes) initiated to mitigate the impact of the weather event. Appropriate information related to the advisory is also posted onto the National Traffic Management Log (NTML). The ARTCC then informs all the affected facilities within their area of responsibility when and how the SWAP will be implemented.

Step 2: The TRACON TMU or the Tower TMC (hereafter TMC refers to TMC, TS, or CIC) reviews the existing demand/capacity conditions and enters the above SWAP Advisory restriction into TFDM DST for Airport Configuration Management. The TMC uses the tool to get its recommendations on an optimum airport configuration for accommodating the XYZ closure. TMC considers all the operational conditions, accepts the DST recommendation, and initiates a change in the airport configuration beginning in 25 minutes.

Step 3: All of the TFDM DSTs now consider the impending change in the airport configuration and evaluate the potential impact of this change. TMC now obtains from Flight Data Manager (FDM) the lists of flights that must be rerouted in response to the fix closure and reroutes those flights as necessary. The en route automation processes these revised flight routes and calculates the associated trajectories. TFDM receives the revised flight data from en route; in response, the DSTs develop revised runway assignments and runway sequences. These sequences also accommodate all other applicable TMIs such as GS and EDCTs. The flight XY123 gets a new runway assignment and a new runway sequence. TFDM now publishes all the revised operational data for distribution via SWIM.

Step 4: The departure routing tools will work as usual with the en route arrival metering automation. They will take the arrival times at Arrival Fixes provided by en route metering and project the arrival interval, landing times, and gate arrival times for flights. The arrival interval data will then be used to define available departure slots. Airport CDM procedures will be used to collaboratively assign specific flights to the departure slots.

Step 5: During SWAP operations, the weather may change rapidly and the landing times, pushback times, taxi times, and departure times may be highly unpredictable. De-icing operations may also introduce additional uncertainty. As a result, there may be a need for highly dynamic adjustments to the schedules resulting in unused departure slots due to the inability of aircraft to meet the assigned slots. This may require an increased level of manual intervention and manipulation of the sequencing and scheduling of flights in TFDM.

Step 6: As the SWAP operations come to an end, the TMC changes the airport configuration back to the pre-SWAP conditions and TFDM and all its DSTs now implement this change in the configuration. The DSTs revise the runway assignments and runway sequences and resume nominal operations.

A-2.1.2.2.6 Collaborative Configuration Change Coordination

This scenario is sourced from the STBO Mid-Term Concept of Operations Overview and Scenarios, dated September 2009.

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to manage surface traffic. This scenario highlights the coordination required for airport configuration changes and the impact of surface operations on arrival metering. It describes operations at Central Airport which is currently operating in an east configuration, landing Runways 12 and 8R. Departures are primarily using Runway 8L with an occasional Runway 12 departure. A rapidly approaching cold front has generated a line of thunderstorms west and northwest of the airport and is expected to cause a rapid wind shift as it passes the airport within the next hour. Arrival metering is in effect for the airport with simultaneous arrivals to converging runways. NextGen weather includes a forecast, expressed in time (plus or minus a time interval) when a sustained wind shift of a stated magnitude and direction will occur at the airport.

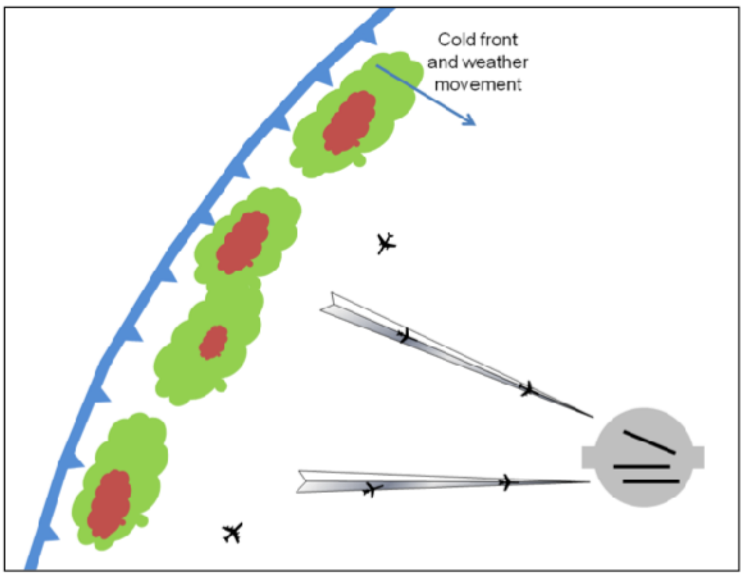


Figure A-5 Central Airport with Approaching Cold Front

Step 1: The tower and TRACON supervisor have collaborated with the airport operator and plan on departing Runways 30 and 26R after the wind shift. Arrivals will use Runways 26L and 26R. Due to the convective activity associated with the front the TRACON will dynamically manage arrivals to avoid the weather and land east as long as ILS approaches are feasible. Weather reports west of Central Airport indicate clear skies behind the front so they anticipate that visual approaches landing west will be feasible shortly after frontal passage.

Step 2: To manage the anticipated arrival restrictions, the ARTCC TMU has issued a ground stop to adjacent ARTCCs for airports within its airspace. Due to timely collaboration between the tower, TRACON, and ARTCC TMU, it is anticipated that there will be minimal airborne holding during the weather impact period and runway transition.

Step 3: When the front is within 10 minutes of the airport, the ILS final approach courses are unusable due to convective activity. Arrivals have been terminated and arrival aircraft are in holding in TRACON and ARTCC airspace. Traffic managers in the ARTCC and TRACON coordinate an arrival metering program to manage the demand on the TRACON and the airborne holding. The departure demand has increased to the point that the Scheduling and Sequencing capability indicates that departure routing should be implemented. The TMC is also using initial impact analysis capabilities within the surface automation system to determine the best departure runway configuration. This capability also factors in arrival volume and recommends that all west, north, and east departures be assigned Runway 30 and south departures use Runway 26R for the next hour. It recommends that after one hour west departures move to 26R to maintain appropriate departure runway balancing. A preliminary notification of the new airport configuration and expected time of implementation are broadcast to the ramp towers, airline operators, and airport operations personnel, through the external data exchange interface. TFM is also notified of the new runway configuration and the expected time of implementation and adjusts the arrival metering schedule accordingly. Flights taking delay in the ARTCC may have their controlled arrival times adjusted to account for the new arrival configuration and any modifications to the runway arrival rates. The system does not recommend any form of MIT restrictions.

Step 4: To minimize taxi queue lengths and prevent surface congestion, the ramp tower has been advised to hold all aircraft at the gate, or on the ramp, and to expect the resumption of departures in 15 minutes. The tower supervisor overrides the surface automation Taxi Routing default with a command to recalculate taxi routes for future departure aircraft. This assigns new departure runways and a taxi route based upon the new runway configuration, and transmits the information to appropriately equipped aircraft.

Step 5: East operation departures continue until the TDWR and LLWAS sensors on the west side of the airport indicate the wind has shifted abruptly and the wind shift line will impact the airport within the next two minutes. At this time the tower supervisor instructs the TMC to select the new airport configuration in the Airport Configuration tool. The ramp towers and airline operators receive notifications.

Step 6: After departures have been stopped, the Local Controller (LC) taxies all departure aircraft holding at the end of Runways 8L and 12 to the opposite end of the runway to accommodate the new runway configuration. Once this is complete GC begins to taxi departures from the ramp area based upon the airport configuration determined by the Airport Configuration function.

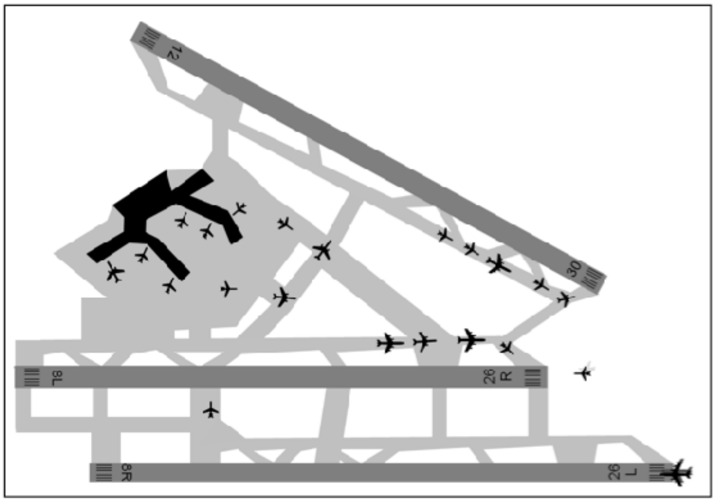


Figure A-6 Central Airport Configuration After Wind Shift

Step 7: Based upon the guidance of the Arrival Scheduling capability, the ARTCC has resumed arrivals into the TRACON airspace. The weather is clearing rapidly and arrivals are able to see the airport from 10 miles east so visual approaches are conducted initially to Runway 26L. The TRACON TMC updates the anticipated AAR in the Arrival Scheduling function. The TRACON transitions into simultaneous visual approaches to Runways 26L and 26R as the weather continues to move east.

Step 8: Departures have resumed (see Figure A-6) per the plan derived earlier from the Scheduling and Sequencing capability. All other events occur as described in the nominal arrival and departure scenario.

A-2.1.2.3 Mid-Term Weather Integration and Needs Analysis

Initial Surface Traffic Management is assumed to provide the following capabilities:

- Support/recommend a stable, baseline airport configuration plan for the flight day integrating weather forecast information including airport surface winds, convection, and ceiling/visibility.
- Proactively support/recommend airport configuration modifications, far enough in advance of predicted weather (e.g., wind shift), to efficiently move traffic to new airport and arrival/departure configurations.
- Support/recommend runway assignment, 2-D taxi routes, departure routing, and surface sequencing and scheduling, based on an analysis of traffic density, performance capabilities of the aircraft, environmental considerations in effect, plus numerous weather factors at various points around the airport including terminal area winds, convective weather (e.g., pop-up thunderstorms on departure routes), ceiling/visibility, precipitation, and temperature.
  - For surface sequencing and staging lists, taxi speed will be affected by visibility and surface conditions (i.e., braking effectiveness). Braking effectiveness is translated directly from weather impacting surface conditions (i.e., precipitation

and temperature). For the Mid-Term, taxi speed is mostly an aggregate issue, impacting the average taxi speed.

- Coordination with the Solution Set Coordinator for HiDensity has revealed that this initial Mid-Term surface traffic management capability will not involve the integration of winter weather. Although winter weather is essential to surface traffic management, its integration will occur in a follow-on OI capability (see Table 5-2). For the Mid-Term, winter weather will be a data point available for decision making, but will not be integrated in DSTs.

- Support surface operations modeling (i.e., demand, capacity, and imbalances), utilizing airport winds, visibility, temperature, and precipitation.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-2.

Table A-2 Initial Surface Traffic Management— Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Support /recommend a stable, baseline airport configuration plan for flight day	Forecasts out ~8 hrs: •Airport surface winds •High density terminal airspace winds (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) to support the increased number of closer separated departure RNP/ RNAV routes in the expanded big airspace concept •High density terminal airspace convection (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) •Airport ceiling/ visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	High Density Terminal Airspace Winds • ITWS Terminal Winds Diagnostic a) 10 km horizontal, 50 mb vertical, 30 min update, sfc-50,000 ft b) 2 km horizontal, 50 mb vertical, 5 min update, sfc-18,000 ft • HRRR 3 km horizontal, hourly update, 15 min resolution, CONUS • RUC a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • WRF-RR High Density Terminal Airspace Convection • CIWS (0-2 hr) • CoSPA (2-8 hr) Airport Ceiling/Visibility • TAF • SIGMET • AIRMET • G-AIRMET	TBD

Proactively support/recommend an airport configuration change, far enough in advance of predicted weather (e.g., wind shift), to efficiently move traffic to the new airport and arrival/departure configuration	Forecasts out ~1 hr: • Airport wind shift timing • High density terminal airspace winds (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) to support the increased number of closer separated departure routes in the expanded big airspace concept • High density terminal airspace convection • Airport ceiling/ visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	*Airport Wind Shift observation* • Derivable from ITWS Terminal Winds Diagnostic *High Density Terminal Airspace Winds* • ITWS Terminal Winds Diagnostic a) 10 km horizontal, 50 mb vertical, 30 min update, sfc-50,000 ft b) 2 km horizontal, 50 mb vertical, 5 min update, sfc-18,000 ft • HRRR a) 3 km horizontal, hourly update, 15 min resolution, CONUS • RUC a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • WRF -RR *High Density Terminal Airspace Convection* • CIWS (0-2 hr) *Airport Ceiling/Visibility* • METAR • TAF • SIGMET • AIRMET • G-AIRMET	*Airport Wind Shift timing forecast* This information is not currently planned for the 4-D Wx Data Cube IOC
Supports/recommends runway assignment, 2-D taxi routes, departure routing, and surface sequencing and scheduling	Forecasts out ~2-4 hrs: • High density terminal airspace winds because of their impact on aircraft speed • High density terminal airspace convection, which may block departure or en route routes • Airport ceiling/ visibility • Airport Temperature • Airport Precipitation *Accuracy TBD*	*High Density Terminal Airspace Winds* • ITWS Terminal Winds Diagnostic a) 10 km horizontal, 50 mb vertical, 30 min update, sfc-50,000 ft b) 2 km horizontal, 50 mb vertical, 5 min update, sfc-18,000 ft • HRRR a) 3 km horizontal, hourly update, 15 min resolution, CONUS • RUC a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • WRF-RR	TBD

	Resolution TBD *Forecast Update Rate TBD* *Latency TBD*	*High Density Terminal Airspace Convection* • CIWS (0-2 hr) *Airport Winds, Temperature, Precipitation, and Ceiling/Visibility* • TAFs • SIGMET • AIRMET • G-AIRMET	
Support surface operations modeling (i.e., demand, capacity, and imbalances)	Forecasts out ~1 hrs: • Airport winds • Airport visibility • Airport precipitation • Airport Temperature *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	*Airport Winds, Temperature, Precipitation, and Ceiling/Visibility* • TAFs • SIGMET • AIRMET • G-AIRMET	TBD

A-2.1.3 OI – Time-Based Metering Using RNP and RNAV Route Assignments (104123)

The goal of TBM Using RNP and RNAV Route Assignments is the orderly metering of aircraft flows in and out of the extended terminal area of high-density airports to maximize capacity and support user-efficient operations. Arrival flows are managed via assignment of CTAs to arrival points, which set up streams of aircraft, sequenced and appropriately spaced to efficiently conduct a variety of processes such as airborne merging and spacing, optimal profile descents, parallel runway operations and wake-based spacing. Departure routing is improved by increasing the accuracy of predicted trajectories.

The current airport environment requires additional capacity. In addition, orderly arrival-spacing of traffic is necessary if congestion, delays, and risky terminal area maneuvering are to be avoided. Currently, spacing is monitored though a series of vectors and speed changes, based on existing fixes.

A-2.1.3.1 High Level Mid-Term Planned Capabilities

RNAV, RNP, and TBM provide efficient use of runways and airspace in high-density airport environments. RNAV and RNP provide users with more efficient and consistent arrival and departure routings and fuel-efficient operations. Metering automation will manage the flow of aircraft to meter fixes, thus permitting efficient use of runways and airspace.

Building on increased capacity in terminal separation procedures, TBM will facilitate efficient arrival and departure flows. This will be accomplished using RNAV and RNP routings, coupled with meter fix crossing times. These will be issued to the flight crew via voice or data communications for input into the Flight Management System (FMS). Arrivals will be issued a RNAV routing to link arrival procedures to designated runways. Aircraft will navigate from en route to approach and landing phases with minimal adjustments (i.e., speed adjustments) or changes to flight trajectories by ANSP.

Departures will be issued clearances that specify departure routings linked from RNAV routes into the en route phase of flight. This will reduce ANSP and flight crew workload, providing flexibility as well as maximizing arrival and departure throughput at high-density airports.

CATM and TBM replace MIT restrictions. This OI provides consistent delivery of aircraft into the terminal area to match runway acceptance rates, enabling efficient and high-throughput operations. Where practical, this OI enables the application of OPD operations with RNP approaches under moderate traffic conditions, with ground-based automation providing conflict-free, time-based metering solutions for En Route and transition airspace segments. OPD is also known as CDA.

It is assumed that Time-Based Metering Using RNP and RNAV Route Assignments will set up an arrival stream by providing a set of CTAs to a metering point. This includes assigning aircraft to a runway and arrival stream and sequencing the aircraft to maximize runway capacity based on aircraft performance (e.g., speed and descent profile) and aircraft performance level (e.g., RNP, parallel runway capability, airborne merging, and spacing capability). This also includes establishing the aircraft's 4-D trajectory to the runway. TBM Using RNP and RNAV Route Assignments will also improve departure routing, by increasing the accuracy of predicted trajectories. Same route/direction departing aircraft will be provided CTAs to a departure metering point for appropriate spacing and this should require the same weather information used to calculate CTAs to an arrival metering point.

Discussions with the Solution Set Coordinator for HiDensity have established that metering in the Mid-Term is intended to be an end-to-end capability, applied to the departure, en route, and arrival phases of flight (also see the TBO OI: Point-in-Space Metering). This end-to-end metering capability permits efficient use of NAS assets, such as runways and high density departure, en route, and arrival flows. The Solution Set Coordinator also indicated TBO will be applied selectively, so MIT will still have applications at some locations and under certain conditions. It is assumed that TBM Using RNP and RNAV Route Assignments will not replace MIT in the Mid-Term, but rather reduce the need to employ MIT.

A-2.1.3.2 Operational Scenarios

TBD

A-2.1.3.3 Mid-Term Weather Integration and Needs Analysis

A CTA to an arrival metering point needs to reflect all aspects of the operation from that metering point to the runway threshold including, for example, pairing for closely spaced parallel runway operations and longitudinal spacing to enable optimal profile descents. The CTA must also reflect what an aircraft can and is likely to actually fly, given the forecast weather conditions along its intended trajectory.

Discussion with the Solution Set Coordinator for HiDensity has revealed that, despite its obvious impact on the accurate calculation of aircraft trajectories, convective weather will not be integrated into this Mid-Term OI. However, the integration of convective weather is being considered for future metering OI capabilities.

Similar to convection, turbulence and icing constraints impact aircraft performance, and therefore CTA forecasts, in the following ways:

- In some cases, aircraft operate at a reduced, turbulence-penetration speed while flying through rough air.
- An aircraft's idle thrust speed, and therefore its OPD performance, changes when icing systems are turned on.

It is possible that turbulence and icing forecasts will be integrated into this OI in the Mid-Term. If not, their integration will need to be accomplished into a future metering OI.

It can be assumed that the weather information needed for this capability is the same as is needed for calculating CTAs to an arrival metering point. Departure routings are improved by increasing the accuracy of predicted trajectories. Winds affect the speed of an aircraft, temperature and barometric pressure profiles are needed to calculate geometric altitude, and dew point is required for kinematic modeling. All of these weather parameters will be integrated and used in trajectory modeling done in the Mid-Term in support of this OI.

In order for TBM to work effectively in high density airspace, it is important for the FMS of participating aircraft to have a complete and accurate set of wind data so that both the air and ground can have an accurate estimate of arrival time over a downstream metering point. The NextGen concept to provide a common weather picture to all stakeholders is essential to achieving this requirement.

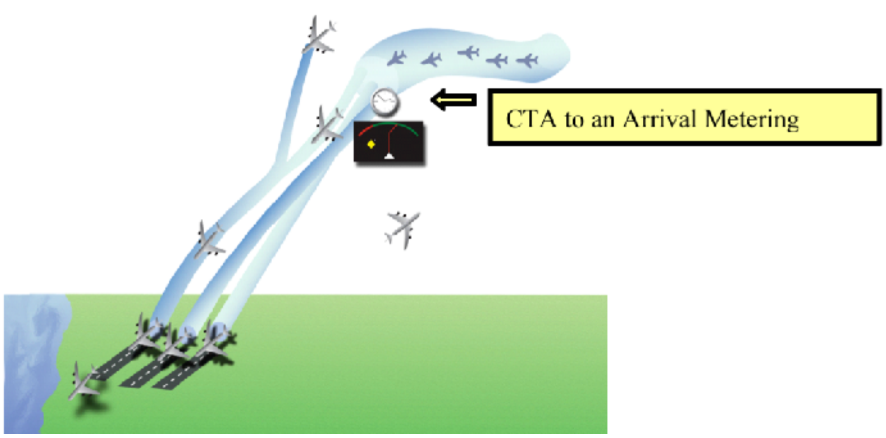


Figure A-7 CTA to an Arrival Metering Point

In summary, TBM Using RNP and RNAV Route Assignments is assumed to provide the calculation of a set of "attainable" CTAs to an arrival metering point, taking weather's impact on aircraft speed and performance into account (includes terminal winds, winds aloft, temperature, turbulence, and in-flight icing). Additionally, departure routing is improved by increasing the accuracy of predicted trajectories, which can be assumed to require the same weather information needed for calculating CTAs to an arrival metering point.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-3.

Table A-3 TBM Using RNP and RNAV Route Assignments— Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Calculation of a set of 'attainable' CTAs to an arrival metering point, taking weather's impact on aircraft speed and performance into account	Forecasts out ~1 hr: • High density terminal airspace winds because of their impact on aircraft speed (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) winds aloft need to cover trajectory prior to top of descent, with detail particularly near merge points and areas of hard to predict winds near the jet stream's edge • High density terminal airspace temperature and barometric pressure profiles to calculate geometric altitude • High density terminal airspace dew point for kinematic modeling • High density terminal airspace in-flight icing and turbulence because of their impact on aircraft performance *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	*High Density Terminal Airspace Winds* • ITWS Terminal Winds Diagnostic a) 10 km horizontal, 50 mb vertical, 30 min update, sfc-50,000 ft b) 2 km horizontal, 50 mb vertical, 5 min update, sfc-18,000 ft • HRRR a) 3 km horizontal, hourly update, 15 min resolution, CONUS • RUC a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • WRF-RR *High Density Terminal Airspace Temperatures* • HRRR a) 3 km horizontal, hourly update, 15 min resolution, CONUS • RUC a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • WRF-RR *High Density Terminal Airspace Barometric Pressure* • RUC *High Density Terminal Airspace In-flight Icing* • Current Icing Products (CIP) and 1-9hr Forecast Icing Products (FIP) (Severity,	TBD

		probability, super-cooled large droplets) *High Density Terminal Airspace Turbulence* • GTG Analysis and 1-12hr forecast	
Improve departure routing, by increasing the accuracy of predicted trajectories	Forecasts out ~1 hr: • High density terminal airspace winds because of their impact on aircraft speed (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) winds aloft need to cover trajectory prior to top of descent, with detail particularly near merge points and areas of hard to predict winds near the jet stream's edge • High density terminal airspace temperature and barometric pressure profiles to calculate geometric altitude • High density terminal airspace dew point for kinematic modeling • High density terminal airspace in-flight icing and turbulence because of their impact on aircraft performance *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	*High Density Terminal Airspace Winds* • ITWS Terminal Winds Diagnostic a) 10 km horizontal, 50 mb vertical, 30 min update, sfc-50,000 ft b) 2 km horizontal, 50 mb vertical, 5 min update, sfc-18,000 ft • HRRR a) 3 km horizontal, hourly update, 15 min resolution, CONUS • RUC a) 13 km horizontal, 50 vertical levels, hourly update,0-12 hr forecasts, CONUS • WRF-RR *High Density Terminal Airspace Temperatures* • HRRR a) 3 km horizontal, hourly update, 15 min resolution, CONUS • RUC a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • WRF-RR *High Density Terminal Airspace Barometric Pressure* • RUC *High Density Terminal Airspace In-flight Icing* • CIP and 1-9hr FIP (Severity, probability, super-cooled large droplets) *High Density Terminal Airspace Turbulence* • GTG Analysis and 1-12hr forecasts	TBD

A-2.1.4 OI – Improved Management of Arrival/Surface/Departure Flow Operations (IASDF) (104117)

This OI is intended to knit together a wide range of capabilities in a choreographed fashion in order to enable cohesive, coordinated end-to-end ATM processes and solutions. Some of those capabilities would appear to be associated with other OIs, primarily from within the HiDensity Solution Set. It leverages advanced communications and automation technologies as the primary means of accomplishing its goals.

A-2.1.4.1 High Level Mid-Term Planned Capabilities

This OI integrates advanced Arrival/Departure flow management with advanced Surface operation functions to improve overall airport capacity and efficiency. ANSP automation uses arrival and departure-scheduling tools and 4-D Trajectory (4-DT) agreements to flow traffic at high-density airports. This includes the integration of departure scheduling from multiple airports into the overhead stream, the assignment of arrival and departure runways to maximize the use of available runways at an airport, and runway configuration management with airspace configuration management to optimize the use of surface and airspace capacity when changing a runway configuration. Automation incorporates TMIs, current and forecast conditions (e.g., weather), airport configuration, user provided gate assignments, requested runway, aircraft wake characteristics, and flight performance profiles. ANSP, flight planners, and airport operators monitor airport operational efficiency and make collaborative real-time adjustments to schedules and sequencing of aircraft to optimize throughput.

Arrival and departure flows and surface operations are more effectively planned and managed through the integration of current flight plans as well as real-time airborne and surface trajectory information into ANSP decision support automation tools. These DSTs enable ANSP flow managers to work collaboratively with flight operators and with ANSP controllers to effectively manage high-capacity arrival and departure flows in the presence of various weather conditions. Automation provides optimal departure scheduling and staging and arrival sequencing based on aircraft wake and airborne performance characteristics.

The IASDF OI is enabled through the following generic operational functions:

- Integrated Departure Scheduling - Integrate the scheduling of departures from multiple airports into the overhead stream. This function will enable ATCT personnel to schedule departing aircraft into integrated departure flows, reducing the need for verbal coordination between ATCT and ARTCC personnel during Approval Request (APREQ) procedures.
- Integrated Runway Scheduling - Integrate the assignment of arrival and departure runways to maximize the use of available runways at an airport. Where appropriate, this function includes assigning arrival and departure runways to maximize the use of available runways within a multi-airport or metroplex environment.
- Integrated Runway and Airspace Configuration - Integrate runway configuration management with airspace configuration management to optimize the use of surface and airspace assets when changing a runway configuration. Where appropriate, this function includes changing a runway and airspace configuration to maximize the use of available runways and airspace within a multi-airport or metroplex environment.

All of the preceding functions incorporate TMIs, separation requirements, weather data, and user preferences, as appropriate.

A-2.1.4.2 Operational Scenarios

TBD

A-2.1.4.3 Mid-Term Weather Integration and Needs

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-4.

Table A-4 Improved Arrival, Surface, and Departure Flow Operations— Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.1.5 OI – Enhanced Departure Flow Operations (104123)

This new Mid-Term OI would appear to be complementary to the previously discussed OI entitled Initial Surface Traffic Management (NAS OI-102141). Both would seem to be intended to lay the foundation for the far-term OI entitled Full Surface Traffic Management for Conformance Monitoring (NAS OI-104206).

Among the enhancements associated with this OI, surface traffic management systems are upgraded to incorporate taxi instructions, surface movement information, and aircraft wake category. Clearances are developed, delivered, monitored and provided in digital data or textual format that is used by the flight deck display to support taxi, takeoff and departure flows in all conditions. At high-density airports clearances and amendments, requests, NAS status, airport flows, weather information, and surface movement instructions are issued via data communications.

A-2.1.5.1 High Level Mid-Term Planned Capabilities

The capabilities attributed to this OI are remarkably similar to those being discussed as part of the work of the CDM Surface CDT Team. Many of them are described in the following paragraphs.

Surface decision support and management systems use ground and airborne surveillance and a scheduling and sequencing system to develop and maintain schedules of departing aircraft within a defined time horizontal. Information is sent to participating aircraft and the air navigation service provider via data communications or voice and adjustments are made to push back times, taxi instructions, etc. to maintain schedules. Schedules are built to optimize runway utilization and incorporate information such as gate assignments, wake category, and slots for departing aircraft.

Surface movement and management systems forecast when an aircraft will be ready to push back and takeoff using various airline operations center inputs (e.g., wake category, mechanical condition, percentage loaded, etc.). Surface surveillance detects the actual block-out event and monitors the aircraft's movement. DSTs provide forecast take-off times to surface movement and flow management systems to schedule slots in the departure stream and manage/control take-off times to achieve efficient flows.

A-2.1.5.2 Operational Scenarios

TBD

A-2.1.5.3 Mid-Term Weather Integration and Needs

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-5.

Table A-5 Enhanced Departure Flow Operations— Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.1.6 OI – Time-Based Metering in the Terminal Environment (104128)

This new Mid-Term OI expands on the current, limited use of TBM.

Aircraft are time-based metered inside the terminal environment, enhancing efficiency through the optimal use of terminal airspace and surface capacity. ANSP automation develops trajectories and allocates time-based slots for various points (as needed) within the terminal environment, applying RNAV route data and leveraging enhanced surveillance, data communications, and closely spaced parallel, converging, and intersecting runway capabilities (where applicable).

A-2.1.6.1 High Level Mid-Term Planned Capabilities

This OI extends current metering capabilities into the terminal environment and furthers the pursuit of end-to-end metering and TBO. It also supports capabilities designed to expand the use of terminal separation standards in transition airspace, and solidifies the foundation for future advanced airborne-based applications that will depend upon ground-based automation to maintain the complete sequence of aircraft into and out of high density terminal locations.

A-2.1.6.2 Operational Scenarios

TBD

A-2.1.6.3 Mid-Term Weather Integration and Needs

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-6.

Table A-6 Time-Based Metering in the Terminal Environment— Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather

			Information Gap
TBD	TBD	TBD	TBD

A-2.1.7 OI – Integrated Arrival/Departure Airspace Management (104122)

This OI supports optimal terminal area configuration management by tailoring capacity to meet demand, managing delay, giving consideration to environmental factors, and better addressing metroplex interdependencies.

Current airspace structure in high-density terminal areas is complex and inefficient and does not provide the structure to support the demands for increased capacity. Complexity is created by the closeness and interaction between arrival/departure flow of several major airports, satellite airports, and over flight flow.

A-2.1.7.1 High Level Mid-Term Planned Capabilities

New airspace design takes advantage of expanded use of terminal procedures and separation standards. This is particularly applicable in major metropolitan areas supporting multiple high-volume airports. This increases aircraft flow and introduces additional routes and flexibility to reduce delays. ANSP DSTs are instrumental in scheduling and staging arrivals and departures based on airport demand, aircraft capabilities, gate assignments and improved weather data products.

This capability expands the use of terminal separation standards and procedures (e.g., 3 nm, degrees divergence) within the newly defined transition airspace. It extends further into current en route airspace (horizontally and vertically). A redesign of the airspace will permit a greater number of RNAV and RNP procedures within the transition airspace to allow for increased throughput. Extended application of terminal procedures and separation standards allows greater flexibility for traffic to be re-routed during severe weather and other disruptions to normal flows. Certain routes can be bi-directional and are used for either arrival or departure, depending on the traffic situation and the location of the severe weather.

Departure performance will be improved by implementing multiple precise departure paths from each runway end. This will allow each departing aircraft to be placed on its own, separate path, keeping the aircraft safely separated from other aircraft and wake vortices. These multiple paths also will be an important aid to circumnavigating thunderstorms and other severe weather in the airport vicinity. Precise departure paths will optimize system operations for entire metropolitan areas, reducing delays by allowing each airport to operate more independently. This will provide for better balance of arrivals and departure flow to airports within close proximity. These precise departures can also be designed to support airports that are now limited by terrain and other obstacles or during periods of reduced visibility. Precise paths will reduce flight time, fuel burn and emissions. They may also decrease the impact of aircraft noise to surrounding communities.

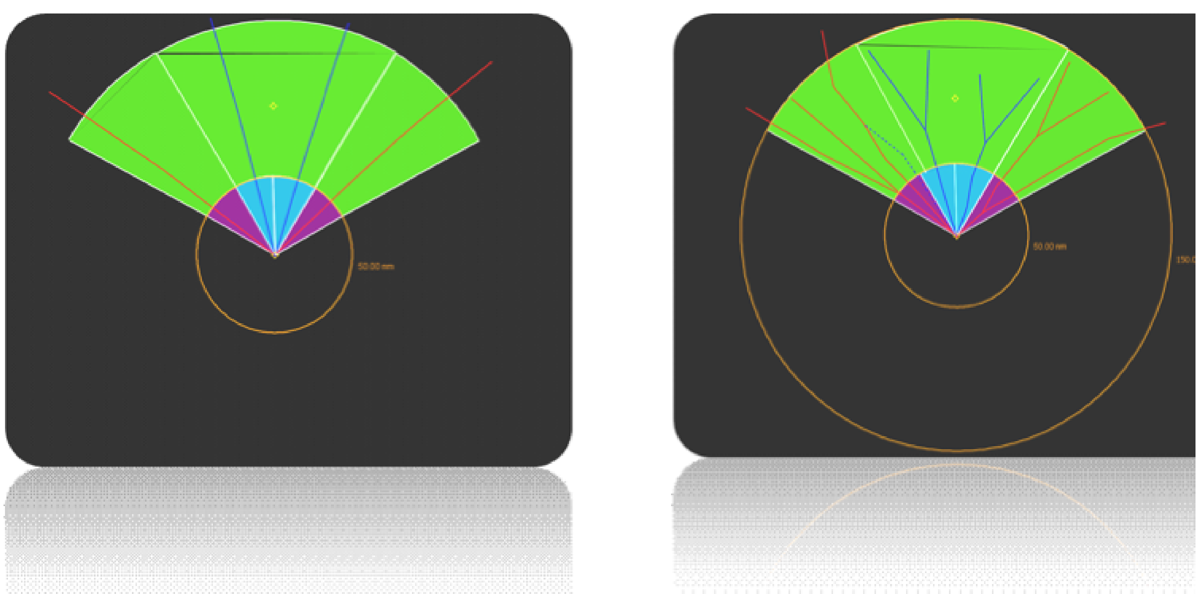
Enhanced traffic management tools will analyze flights approaching an airport from hundreds of miles away, across the facility boundaries that limit the capability today, and will calculate scheduled arrival times to maximize arrival capacity. This will provide controllers with automated information on airport arrival demand and available capacity to improve sequencing and better balance arrival and departure rates. With the improved precision of NextGen systems, separation between aircraft can be safely reduced. This will allow for more efficient transitions to the approach phase of flight to high density airports because controllers will have access to more usable airspace. Therefore, descending aircraft can be managed as a unified operation and the airspace can be structured to have multiple precision paths that maintain individual flows to each runway.

Today, the structure of arrival and departure routes does not allow for the most efficient use of the airspace. By redesigning airspace, precision 3-D paths can be used in combination to provide integrated arrival and departure operations. More important, this more flexible airspace will give controllers better options to safely manage departure and arrival operations during adverse weather, restoring capacity that is currently lost in inclement conditions. Poor visibility conditions dramatically reduce capacity for closely spaced runways. These capacity losses ripple as delays throughout the system. NextGen capabilities will allow us to continue using those runways safely by providing precise path assignments and appropriate safe separation between aircraft assigned on parallel paths, restoring capacity and reducing delays throughout the NAS.

Mid-Term capabilities for Integrated Arrival/Departure Airspace Management operations may include the following:

- An increased number and complexity of static arrival and departure configurations supported by DSTs (see Figure A-8) including more diverse configurations, RNP routes closer to one another allowing additional static arrival and departure routes, more complex merging and bi-directional routes (180 degree switching of routes between configurations).
- Timelier arrival/departure configuration changes, using weather information to better predict the timing of such changes.

Today | Mid-Term



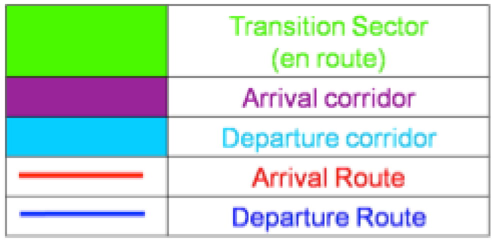


Figure A-8. Increased Number and Complexity of Static Arrival and Departure Configurations

- Extension, further into today's en route airspace (i.e., Big Airspace [BA]), of terminal procedures and separation standards (e.g., 3 nautical mile separation, visual separation), allowing for more efficient use of airspace to support higher capacity flows of traffic into high-density airports.

A graphical representation of the previous bullet is shown in Figure A-9, which depicts the airspace volume feature of the BA concept. The three nautical mile spacing reference may involve separation between aircraft merging into one or more streams before they reach the merge point or separation between streams of aircraft. This would require sophisticated DSTs and use of Required Time of Arrival (RTAs)/CTAs, rather than vectoring for spacing. The visual separation reference relates to the NextGen goal to augment/replace visual separation with airborne separation maneuvers (based on ADS-B mode signals), including CDTI Assisted Visual Separation (CAVS) that enable aircraft briefly passing through a thin cloud layer to maintain visual separation augmented by CDTI.

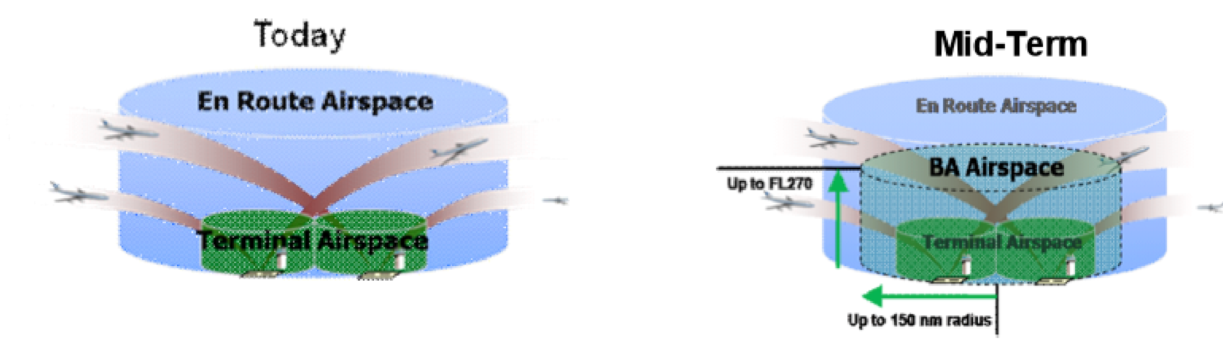


Figure A-9 Airspace Volume Feature of Big Airspace Concept

A-2.1.7.2 Operational Scenarios

A-2.1.7.2.1 Baseline (Strategic) Arrival/Departure Configuration Plan for the Flight Day, Using Weather Forecasts

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to plan the arrival/departure configuration for the flight day. DST also obtains information concerning traffic density, the performance capabilities of associated aircraft types, as well as environmental considerations in effect. Initial Surface Traffic Management has already supported the determination of the airport configuration for the flight day.

Step 1: DST assists with the development of or recommends an optimal arrival/departure configuration, plus one or two alternates, from among the increased number and complexity of predefined arrival/departure configurations. DST bases this recommendation on an analysis of traffic density, the performance capabilities of associated aircraft types, environmental considerations in effect, plus numerous weather factors at various points around the airport, including terminal area winds, winds aloft, convection, and ceiling/visibility.

Step 2: The arrival/departure configurations are coordinated within the facility, with NAS users, and with adjacent facilities, as necessary.

Step 3: The TMC, collaborating with the facility supervisor and guided by the DST and the coordination in Step 2, evaluates the options and selects an arrival/departure configuration for the flight day.

Step 4: The TMC notifies stakeholders of the arrival/departure configuration plan for the flight day and starts system-wide implementation.

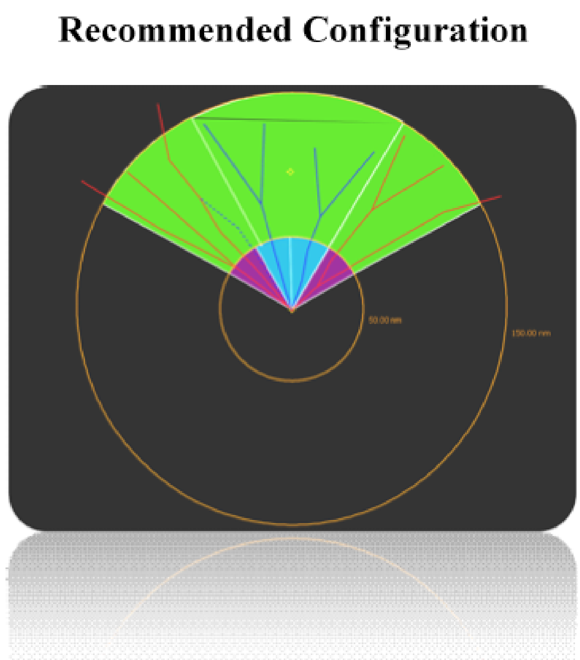


Figure A-10 Baseline (Strategic) Arrival/Departure Configuration Plan for the Flight Day, Using Weather Forecasts

A-2.1.7.2.2 Proactive Change in Arrival/Departure Configuration Due to Forecast Wind Shift

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to identify and plan for arrival/departure configuration changes. Initial Surface Traffic Management has already supported the determination of an airport configuration change for a wind shift predicted to occur at the airport in 15 minutes.

Step 1: DST monitors Initial Surface Traffic Management communications to know when arrival/departure configuration changes would be required.

Step 2: As a wind shift approaches (i.e., far enough in advance to efficiently move traffic to a new arrival/departure configuration), DST assists with the development of or recommends an optimal arrival/departure configuration with two or more alternates. In addition to an arrival/departure configuration change, DST assists with the development or recommendation of a set of interim changes to facilitate this major arrival/departure configuration change, such as switching some subset of the arrival/departure routes before doing the major swap, so the configuration change happens in steps and has a less drastic impact on capacity.

Step 3: The arrival/departure configurations are coordinated within the facility, with NAS users, and with adjacent facilities, as necessary.

Step 4: The TMC, collaborating with the facility supervisor and guided by the DST and the coordination in the Step 3, evaluates the options and selects the new arrival/departure configuration (as well as any interim arrival/departure configuration changes).

Step 5: The TMC notifies stakeholders of the arrival/departure configuration change and starts a proactive system-wide implementation.

Step 6: Flight plan amendments will be automatically updated and coordinated by automation and the amended flight plans made available to all entities (e.g., affected users, ANSP).

Step 7: Upstream controllers are notified of the configuration change and the first aircraft in the new arrival flow; and begin directing traffic accordingly. Initially, this process may be unaided by automation, but later DSTs may help to identify this first aircraft and provide controller with trajectory resolution advisories.

Step 8: The controller maintains responsibility for aircraft separation and monitoring flight conformance to the RNAV procedures.

A-2.1.7.2.3 Reactive Arrival/Departure Configuration Changes Due to Pop-Up Weather

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DST subscribes to the weather information needed to identify and plan for dynamic changes to arrival/departure configurations. DST also obtains information concerning traffic density, the performance capabilities of associated aircraft types, and environmental considerations in effect.

Step 1: DST, responding to rapidly changing and highly localized weather conditions (e.g., pop-up thunderstorm blocking a departure/arrival route), assists with the development or recommendation of a minor arrival/departure configuration change, plus one or two alternates, to deal with a temporary blockage of a departure/arrival route. DST bases this recommendation on an analysis of traffic density, performance capabilities of associated aircraft types, environmental considerations in effect, and numerous weather factors at various points around the airport, including terminal area winds, winds aloft, convection, ceiling/ visibility, as well as rapidly changing and highly localized weather conditions. For example, a pop-up thunderstorm blocking a departure route may result in the DST recommending that an arrival route be closed and opened as a departure route (see example in Figure A-11). This option is made possible because of the Mid-Term capability to recommend 180 degree switching of routes between configurations.

Step 2: The arrival/departure configuration change is coordinated within the facility, with NAS users, and with adjacent facilities, as necessary.

Step 3: The TMC, collaborating with the facility supervisor and guided by the DST and the coordination in the Step 2, evaluates options and determines whether or not to perform the recommended change, for example a 180 degree switching of an arrival route to a departure route.

Step 4: The ANSP identifies which upstream arrival aircraft will be last to use the arrival route before it is deactivated and which aircraft is first to be routed to the alternate Standard Terminal Arrival (STAR).

Step 5: Flights allocated to use the arrival route before it is deactivated are allowed to clear the airspace. ANSP manually deactivates the arrival route, activates the departure route, and performs the predefined configuration.

Step 6: Flight plan amendments will be automatically updated and coordinated by automation and the amended flight plans made available to all entities (e.g., affected users, ANSP).

Step 7: Flights in en route airspace are rerouted to alternate STARs by upstream facility. The tower controller issues clearance of the alternate Standard Instrument Departures (SID) via uplink (or voice when necessary) to surface traffic in the terminal airspace.

Step 8: The controller maintains responsibility for aircraft separation and monitoring flight conformance to the RNAV procedures.

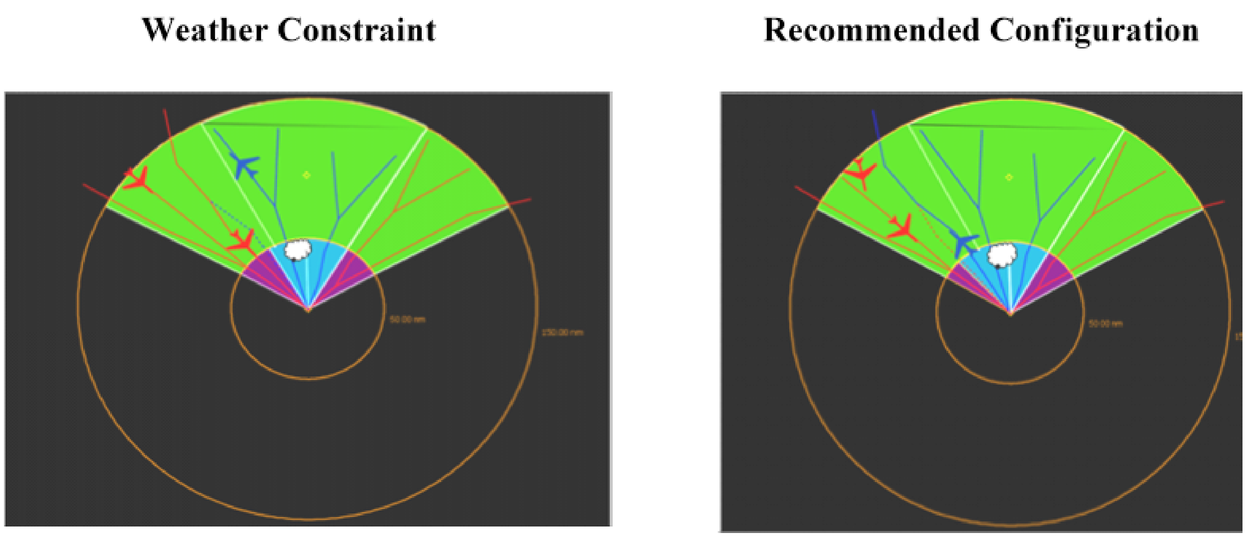


Figure A-11 Reactive Arrival/Departure Configuration Changes Due to Pop-Up Weather

A-2.1.7.3 Mid-Term Weather Integration and Needs

Integrated Arrival/Departure Airspace Management retrieves/subscribes to updates of weather information from the 4-D Wx Data Cube to support planning/re-planning. In particular, the 4-D Wx Data Cube's 4-D Wx SAS supports enhanced volumetric extractions of weather information, by time frame of interest, to enable impact analysis of the region of interest. Subscriptions provide regularly scheduled weather information updates, along with the added flexibility of additional updates, when Integrated Arrival/Departure Airspace Management provided weather parameter thresholds are met.

Integration of weather information into Integrated Arrival/Departure Airspace Management may be both tactical and strategic. From a strategic standpoint, Integrated Arrival/Departure Airspace Management may support/recommend an optimal airport configuration plan for the flight day plus one or two alternates, from among the increased number and complexity of Mid-Term arrival/departure configurations, based on an analysis of traffic density, performance capabilities of the aircraft types involved, environmental considerations in effect, plus numerous weather factors at various points around the airport, including airport winds, winds aloft, convection, and ceiling/visibility.

Weather conditions, whether they are adverse or routine, always are a major factor in the selection of an optimal arrival/departure configuration. From a tactical perspective, Integrated Arrival/Departure Airspace Management receives weather information updates, from the 4-D Wx Data Cube when weather parameter thresholds are reached, so it can continually evaluate the timing of upcoming meteorological conditions (e.g., wind shifts, C&V changes) to better predict when a change in arrival/departure configuration would be required. Integrated Arrival/Departure Airspace Management works closely with Initial Surface Traffic Management, which is responsible for airport configuration changes. Similarly, Integrated Arrival/Departure Airspace Management may also monitor rapidly changing and highly localized weather conditions (e.g., pop-up thunderstorms on arrival/departure routes) to determine when an arrival/departure configuration needs to be dynamically altered (e.g., routing an arrival route around a weather cell).

Figure A-12 represents the difference between today's and the Mid-Term's arrival/departure configurations. The rings represent the Mid-Term's expansion of terminal separation standards and procedures usage into today's en route airspace (e.g., from 50 nm today, out to 150 nm in the Mid-Term). Figure A-12 demonstrates that today there is limited maneuverability and route flexibility due to airspace constraints, requiring significant coordination when airport arrival/departure configuration or tactical maneuvers occur (e.g., maneuvering into adjacent terminal areas of control to avoid a pop-up thunderstorm). Figure A-12 also demonstrates the improved Mid-Term flexibility of airspace, resulting from expansion of terminal separation standards and procedures farther into today's en route airspace and an increased number and complexity of arrival/departure configurations (including 180 degree switching of predefined bidirectional routes).

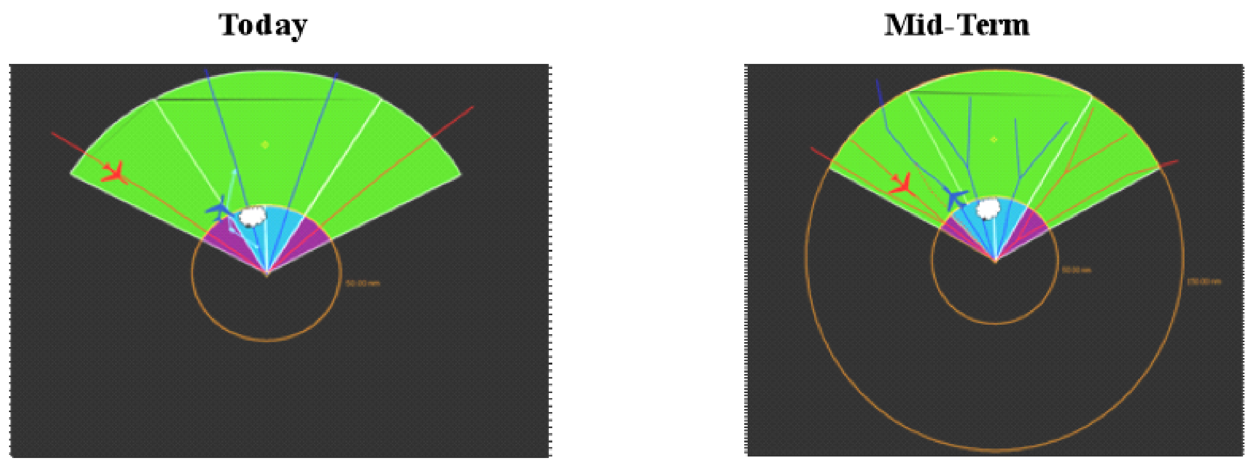


Figure A-12 Comparison of Today's and the Mid-term's Arrival/Departure Configurations

Based on the associated described capabilities, an understanding of the target objectives and information gleaned from operational scenarios, weather needs are analyzed in Table A-7.

Table A-7 Integrated Arrival/Departure Airspace Management— Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Support/recommend a stable, baseline arrival/departure configuration plan for flight day	Forecasts out ~8 hrs: • High density terminal airspace winds (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) to support the increased number of closer separated RNP/RNAV routes in the expanded big airspace concept • High density terminal airspace convection • Airport ceiling/ visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD*	*High Density Terminal Airspace Winds* • Integrated Terminal Weather System (ITWS) Terminal Winds Diagnostic a) 10 km horizontal, 50 mb vertical, 30 min update, sfc-50,000 ft b) 2 km horizontal, 50 mb vertical, 5 min update, sfc-18,000 ft • Hi-Res Rapid Refresh (HRRR) a) 3 km horizontal, hourly update, 15 min resolution, Continental United States (CONUS) • Rapid Update Cycle (RUC) a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • Weather Research and Forecasting - Rapid Refresh (WRF -RR) *High Density Terminal Airspace*	TBD

	Latency TBD	*Convection* • Corridor Integrated Weather System (CIWS) (0-2 hr) • Consolidated Storm Prediction for Aviation (CoSPA) (2-8 hr) Airport Ceiling/Visibility • TAF • SIGMET • AIRMET • G-AIRMET	
Proactively support/recommend an arrival/departure configuration change, far enough in advance of predicted weather (e.g., wind shift), to efficiently move traffic to the new arrival/departure configuration	Forecasts out ~1 hr: • Airport wind shift timing forecast • High density terminal airspace winds (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) to support the increased number of closer separated RNP/RNAV routes in the expanded big airspace concept • High density terminal airspace convection • Airport ceiling/ visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	*Airport Wind Shift observation* • Derivable information from ITWS Terminal Winds Diagnostic High Density Terminal Airspace winds • ITWS Terminal Winds Diagnostic a) 10 km horizontal, 50 mb vertical, 30 min update, sfc-50,000 ft b) 2 km horizontal, 50 mb vertical, 5 min update, sfc-18,000 ft • HRRR a) 3 km horizontal, hourly update, 15 min resolution, CONUS • RUC a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • Weather Research and Forecasting - Rapid Refresh (WRF-RR) *High Density Terminal Airspace Convection* • CIWS (0-2 hr) *Airport Ceiling/Visibility* • Meteorological Aviation Report (METAR) • TAF • SIGMET • AIRMET • G-AIRMET	*Airport Wind Shift Timing Forecast* This information is not currently planned for the 4-D Wx Data Cube IOC
Reactively support/recommend	High density terminal airspace convection	*High Density Terminal Airspace Convection*	TBD

arrival/departure configuration modifications in response to rapidly changing and highly localized weather conditions (e.g., pop-up thunderstorms on arrival/departure routes)	forecasts out ~1 hr: • High spatial and temporal resolution (to identify pop-up thunderstorms blocking individual arrival/ departure routes) • Initiation, growth, decay, and movement of individual storms *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	• CIWS (0-2 hr)	

A-2.2 Initiate Trajectory Based Operations (TBO)

The TBO Solution Set is dependent on a major paradigm shift as the control of air traffic changes from clearance-based to trajectory-based methods. Aircraft will fly negotiated trajectories as ATC moves to trajectory management. The traditional responsibilities and practices of pilots/controllers will evolve due to the increase in automation, support, and integration inherent in management by trajectory. This solution set focuses primarily on en route cruise operations, although the effects of the TBO will be felt in all phases of flight.

The Mid-Term OIs of interest are listed here in the order in which they appear as brick red-colored timelines in the TBO Timeline Figures A-13 and A-14:

- Delegated Responsibility for In-Trail Separation
- Oceanic In-trail Climb and Descent
- Automation Support for Separation Management
- Initial Conflict Resolution Advisories
- Flexible Entry Times for Oceanic Tracks
- Point-in-Space Metering
- Flexible Airspace Management
- Increase Capacity and Efficiency Using RNAV and RNP

Over time, Far-Term OIs (represented by the light blue shaded timelines in the figures) may be added to this analysis.

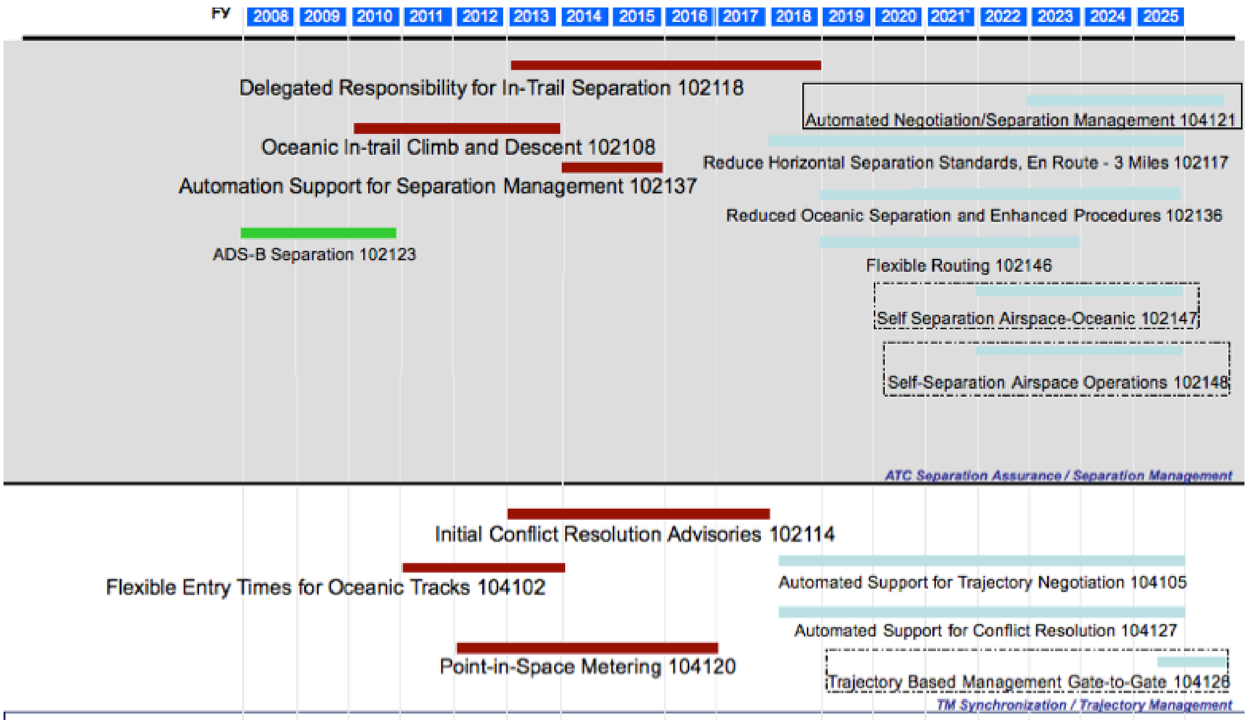


Figure A-13 Initiate Trajectory Based Operations Timeline (1 of 2)

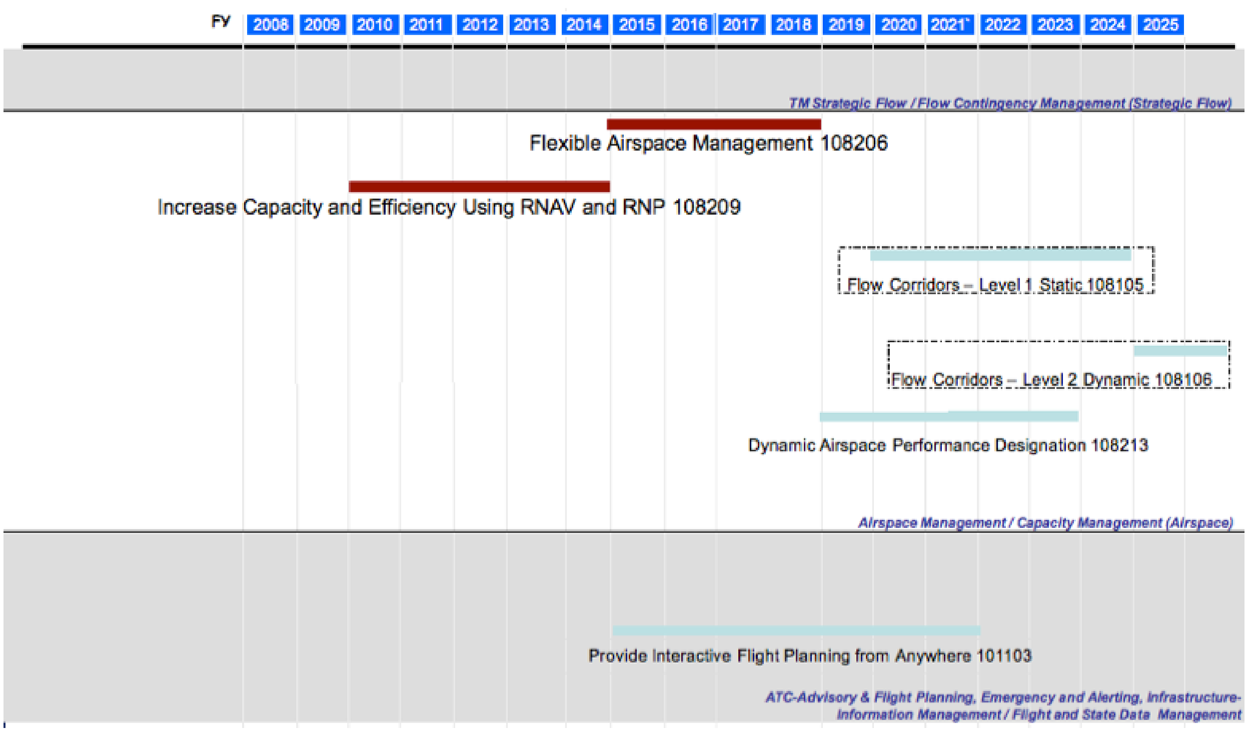


Figure A-14 Initiate Trajectory Based Operations Timeline (2 of 2)

A-2.2.1 OI – Delegated Responsibility for In-Trail Separation (102118)

The goal of Delegated Responsibility for In-Trail Separation is to extend today's visual flight rules capabilities for clear weather, pair-wise, in sight delegated longitudinal separation to operations conducted in IMC leveraging ADS-B, CDTI, and improved avionics.

Controllers are responsible for maintaining radar separation of aircraft based on established standards. Delegating separation responsibility may increase capacity through the use of more precise surveillance and shorter reaction times.

A-2.2.1.1 High Level Mid-Term Capabilities

Enhanced surveillance and new procedures enable the ANSP to delegate aircraft-to-aircraft separation. Improved display avionics and broadcast positional data provide detailed traffic situational awareness to the flight deck. When authorized by the controller, pilots will implement delegated separation between equipped aircraft using established procedures.

Broadcast surveillance sources and improved avionics capabilities provide ANSP and the flight deck with accurate position and trajectory data. Aircraft that are equipped to receive the broadcasts and have the associated displays, avionics, and crew training are authorized to perform delegated separation when assigned by the controller.

ANSP will be provided with a new set of (voice or datalink) procedures directing, for example, the flight crews to establish and to maintain a given time or distance from a designated aircraft, including separations equivalent to, but not less than current wake turbulence separations. This interval may be an absolute value, or a relative designation to remain no closer than or no further than. The flight crews will perform these new tasks along paths, including RNAV paths with turns, using new aircraft functionality.

It is assumed that this Mid-Term OI is a first step towards NextGen delegated separation responsibility and is limited to pair-wise separation. The controller will be responsible for determining when to delegate, and there are a limited number of geometries for which they may do so. The pilot may decline delegated separation responsibility.

Today, in clear weather, once an aircraft has a target aircraft in sight, a controller may delegate pair-wise separation to that aircraft during the performance of a single maneuver, such as station-keeping or passing, or conducting a visual approach, etc.

It is assumed this Mid-Term OI would allow an aircraft in IMC, either on approach or en route, to be in sight on the CDTI instead of out the window. However, Delegated Responsibility for Separation is still in the concept definition phase, so the scope of this capability is not known precisely.

Some stakeholders advocate taking advantage of onboard weather radar, such as having a "pathfinder" aircraft pick a route through a line of thunderstorms and then delegate separation responsibility to another aircraft following the "pathfinder". The potential application of this capability would be limited to pair-wise separation for limited periods of time. For this scenario, onboard weather radar becomes an enabler. A common weather picture between the aircraft and the ANSP, provided by the 4-D Wx SAS, could enhance weather situational awareness and therefore assist the delegated separation process to proceed more smoothly.

A-2.2.1.2 Mid-Term Operational Scenarios

A-2.2.1.2.1 Delegated Responsibility for Pair-Wise Separation in Cloud

Step 0: Pilot files a flight plan, which includes parameters related to aircraft performance levels and operational capabilities (e.g., aircraft certification, crew training and currency, ADS-B, CDTI, avionics)

Step 1: Controller delegates responsibility for separation to the appropriately equipped aircraft (as determined from its flight plan) to perform a specific pair-wise delegated separation maneuver (aircraft is in cloud and does not have a visual on the other pair-wise aircraft)

Step 2: Pilot of the "delegated separation" aircraft accepts responsibility for separation

Step 3: Pilot of the "other pair-wise" aircraft flies its cleared flight plan

Step 4: Pilot of the "delegated separation" aircraft maintains separation from the "other pair-wise" aircraft using aircraft systems (ADS-B, CDTI, avionics) until maneuver is complete

Step 5: Controller monitors both pair-wise flights to separate them from all other traffic during the maneuver and to determine when the maneuver is complete

Step 6: When the maneuver is complete, Controller terminates the pilot delegated separation responsibility and assumes separation responsibility

A-2.2.1.2.2 Delegated Responsibility for Pair-Wise Separation in Airspace Impacted by Convective Weather

Step 0: Pilot files a flight plan, which includes parameters related to aircraft performance levels and operational capabilities (e.g., aircraft certification, crew training and currency, ADS-B, CDTI, avionics).

Step 1: Controller delegates separation responsibility to the appropriately equipped aircraft (as determined from its flight plan) to perform a specific pair-wise delegated separation maneuver (i.e., follow a "pathfinder" aircraft through a convective weather area).

Step 2: Pilot of the "delegated separation" aircraft accepts responsibility for separation.

Step 3: Pilot of "pathfinder" aircraft finds a path through the convective weather with the aid of his onboard radar and a Common Weather Picture shared with the ANSP.

Step 4: Pilot of the "delegated separation" aircraft maintains separation from the "pathfinder" aircraft using aircraft systems (ADS-B, CDTI, avionics) and monitors the convective weather using his onboard weather radar and a Common Weather Picture shared with the ANSP and the "pathfinder" aircraft.

Step 5: Controller monitors both pair-wise flights to separate them from all other traffic during the maneuver and to determine when the maneuver is complete.

Step 6: Controller, after the paired aircraft emerge from the convective weather area, terminates the pilot delegated separation responsibility and assumes separation responsibility.

A-2.2.1.3 Mid-Term Weather Integration and Needs Analysis

It is thought that Delegated Responsibility for Separation will not include any direct weather integration. However, in the case of delegated separation for an aircraft following a "pathfinder" through an area of convective weather, providing the flight deck and ANSP with a common weather picture (i.e., the 4-D Wx SAS) would be a useful, although perhaps not essential, enabler.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-8.

Table A-8 Delegated Responsibility for In-Trail Separation—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
None	4-D Wx SAS disseminated to pathfinder, following aircraft, and controller (desired), including current convective weather conditions and forecasts out 20 minutes *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	4-D Wx SAS Initial Operating Capability (IOC), including current convective weather conditions and deterministic forecasts out 20 minutes	None

A-2.2.2 OI - Oceanic In-trail Climb and Descent (102108)

The goal of Oceanic In-trail Climb and Descent is to take advantage of improved communication, navigation, and surveillance coverage in the oceanic domain to allow participating aircraft to fly more advantageous trajectories.

The current system optimizes user efficiency subject to constraints of the current system, including the very large (tens of miles) procedural separation standards. These standards often constrain aircraft to inefficient altitudes and undesirable speeds, as other aircraft are within the separation standard and block the aircraft from its desired operating profile.

A-2.2.2.1 High Level Mid-Term Capabilities

ANSP automation enhancements will take advantage of improved communication, navigation, and surveillance coverage in the oceanic domain. When authorized by the controller, pilots of equipped aircraft use established procedures for climbs and descents.

Improved ANSP automation provides the opportunity to use new procedures and reduce longitudinal spacing. Aircraft are able to fly the most advantageous trajectories with climb and descent maneuvers.

These procedures are intended for aircraft with existing Future Air Navigation System (FANS)-1/A capabilities.

This Mid-Term OI is already at a fairly high level of development maturity and is nearly ready for demonstration. The assumption is that there is no weather integration involved in this OI, nor any new weather information required

A-2.2.2.2 Mid-Term Operational Scenarios

TBD

A-2.2.2.3 Mid-Term Weather Integration and Needs Analysis

Weather integration or weather information needs for Oceanic In-trail Climb and Descent have yet to be identified.

Table A-9 Oceanic In-trail Climb and Descent—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
None	None	None	None

A-2.2.3 OI - Automation Support for Separation Management (102137)

The goal of Automation Support for Separation Management is to allow the controller to better manage aircraft in an environment with mixed navigation equipage and aircraft with varying wake performance characteristics.

Automation enhancements are needed in the en route airspace to manage operations in a mixed separation environment and improve controllers' situational awareness of advanced capabilities. Controllers need to have tools that assist them in coordinating with other facilities or positions when aircraft are performing delegated separation maneuvers, parallel RNAV and RNP routes, identifying equipped vs. non-equipped aircraft, and trajectory flight data management.

A-2.2.3.1 High Level Mid-Term Capabilities

Aircraft with various operating and performance characteristics will be operating within the same volume of airspace. Controllers will use ANSP automation enhancements to provide situational awareness of aircraft with differing performance capabilities (e.g., delegated self-separation maneuvers, equipped vs. non-equipped aircraft, RNAV, RNP, and TFDM). For example in performance-based navigation, RNAV/RNP routes may be spaced closer than the normally required separation for the sector area. The standard system conflict alert and conflict probe for the designated area account for this reduced spacing. These enhancements enable ANSP to manage the anticipated increase in complexity and volume of air traffic.

The separation standards used in mixed use airspace will be enhanced to accommodate new larger aircraft and Unmanned Aircraft Systems (UASs). The separation standards including wake turbulence requirements will be incorporated into ANSP automation providing support for efficiently managing parameter-driven separation, and requires development of standards and procedures.

The supporting documentation for both the NAS and IWP OIs listed above specifically refers to separation assurance and enhanced separation standards, and the IWP OI additionally includes separation standards for wake turbulence. However, the first requirement for the automation should be that it enables the controller to safely and efficiently manage aircraft of differing capabilities, including those controlled solely through voice communication and those with datalink capability, while allowing the more equipped aircraft to take advantage of their advanced capabilities. This implies the automation is aware of, and is tracking, all the aircraft for which the controller has responsibility. The automation must additionally be aware of aircraft performance characteristics, including any degraded capability, so it can calculate the appropriate separation standard to use.

Today's use of vectors to control traffic results in large uncertainties in the aircraft's future path because of the wide range of normal pilot and aircraft response characteristics. To usefully enhance separation standards, such uncertainty must be substantially reduced. As these OIs are intended for mixed aircraft capability environments, a means must be found to control aircraft with voice instructions that, when accepted, are fed back into the automation which then tracks compliance with the instruction. The JPDO Aircraft and ANS Working Groups have suggested that this could be achieved through the automation generating 3-D Path clearances for voiced-controlled aircraft, which the controller then relays to the aircraft, but this is still under discussion. Boeing originally proposed the 3-D Path concept.

Once automation has been developed that can assist the controller in managing traffic of differing capabilities, then it might be possible to enhance separation standards. However, voice controlled aircraft will generate more workload for the controller than datalink aircraft, even if a means of providing closed-loop trajectory changes is implemented as suggested above. Controller workload, together with the reduced flexibility and precision inherent in voice control, will limit the complexity and density of traffic in a mixed equipage environment. Wake avoidance for new very large aircraft such as the Airbus A-380 could be accommodated through a larger separation standard. UAS's might be similarly treated. The automation will also be required to track both delegation of separation responsibility and whether the aircraft remains within the limits delegated.

A-2.2.3.2 Mid-Term Operational Scenarios

TBD

A-2.2.3.3 Mid-Term Weather Needs Analysis

The new capability represented by Automation Support for Separation Management (i.e., to handle and to take advantage of mixed equipage) does not appear to have any weather decisions associated with it directly. The tools to implement this capability will clearly be integrated with tools that do need weather information, but those weather information needs should be captured in other OIs.

Weather integration or weather information needs for Automation Support for Separation Management have yet to be identified.

Table A-10 Automation Support for Separation Management—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
None	None	N/A	N/A

A-2.2.4 OI - Initial Conflict Resolution Advisories (102114)

The goal of Initial Conflict Resolution Advisories is to reduce sector controller workload by integrating existing conflict detection and trial flight planning capabilities with those for conflict resolution advisory and ranking, and introducing data link clearances.

Traffic is expected to increase in volume and complexity. ANSP will require additional automation support to help identify problems and provide efficient resolutions to those problems in order to safely manage the expected traffic levels. Controllers need automation support to help evaluate resolutions of conflicts. Today, the URET notifies the en route controller of predicted problems, but trial planning for developing resolutions is workload intensive.

A-2.2.4.1 High Level Mid-Term Capabilities

The ANSP conflict probe is enhanced not only to recognize conflicts but also to provide rank-ordered resolution advisories to the provider. The provider may select one of the resolutions to issue to the aircraft. Automation enables ANSP to better accommodate pilot requests for trajectory changes by providing conflict detection, trial flight planning, and development of resolutions, as well as an optimal ranking of resolutions.

ANSP resolves tactical trajectory management conflicts using en route automation. The resolution will be tailored to the communication medium (voice or data communication). In the Mid-Term, voice communication between ANSP and flight operators is expected to be the dominant communication medium; in the Far-Term, the role of voice communication will diminish. As a result, this capability will support integration with data communications. Automation provides problem prediction and resolution support to the controller position.

The documented description of Initial Conflict Resolution Advisories cited above makes no mention of weather. Therefore, it appears this OI is limited to expanding current aircraft-to-aircraft conflict capabilities and will not include weather integration. However, since aircraft-to-aircraft conflict resolution is a fairly mature concept, there may be an opportunity to expand the scope of this capability to also include an initial weather problem detection capability and possibly one for weather problem resolution advisories. Some research has been done in developing a concept for a weather problem detection and resolution advisory capability and it is possible that such an initial capability could be ready for implementation in the Mid-Term. The following discussion makes a case for these weather integration capabilities.

There appears to be a need for at least an automated weather problem detection capability, for sectors adjoining convective weather, to evaluate aircraft-to-aircraft conflict resolutions, ensuring they do not inadvertently direct aircraft into the weather. Moreover, one could make the case that a weather problem detection capability is essential, when employed in sectors near convective weather, to provide both the controller and pilot with confidence in the automated aircraft-to-aircraft conflict resolution advisories.

The goal of Initial Conflict Resolution Advisories is to reduce workload. It would significantly reduce the benefit of this capability if it could not be used near convective weather, where workloads are especially high and it is needed the most. Similarly, a weather problem detection capability could be employed to evaluate a pilot requested maneuver around a convective area to ensure the proposed trajectory would not result in the aircraft encountering another convection weather problem just beyond the range of the aircraft's airborne radar.

There also may be a need for an automated weather problem resolution capability to address tactical weather problems resulting from highly dynamic weather that rapidly and unexpectedly closes a TFM-initiated flow through or around a convective weather area. In this case, such a capability could assist the sector controller in responding to pilot requests for assistance in identifying alternate routes around the weather. This case should not be construed to mean the sector controller's decision support would provide resolution advisories that would either "thread" an aircraft through convective weather cells or would extend the sector controller's responsibility to include separating aircraft from weather. Rather this case would provide resolution advisories around the weather, similar to those provided by TFM, and it would be utilized only in response to a pilot's request for assistance, which otherwise the controller would perform cognitively without the assistance of automation. While the sector controller is assisting flights within the impacted sector to negotiate the changing weather constraint, TFM would address upstream flows so that the impacted sector would quickly return to more manageable traffic loads.

Rapidly improving weather is another case for an automated weather problem resolution capability. In this case, airspace previously impacted by weather suddenly and unexpectedly becomes available, allowing aircraft previously rerouted to request maneuvers returning them to their original flight plans. While TFM adjusts upstream flows of aircraft to take advantage of the newly opening airspace, a weather problem resolution capability would allow the sector controller to better respond to a request, from a pilot within the impacted sector, for a more efficient trajectory back to the aircraft's original flight path.

A-2.2.4.2 Mid-Term Operational Scenarios

As Initial Conflict Resolution Advisories is currently described in the NextGen Implementation Plan (NGIP), there are no applicable weather-related scenarios. However, if the scope of the description is extended to include a weather problem detection and possibly resolution advisory capability, then the following scenarios may be applicable. Also, included in this section are scenarios that would not require an automated weather problem capability, to better clarify where an automated capability is and is not needed.

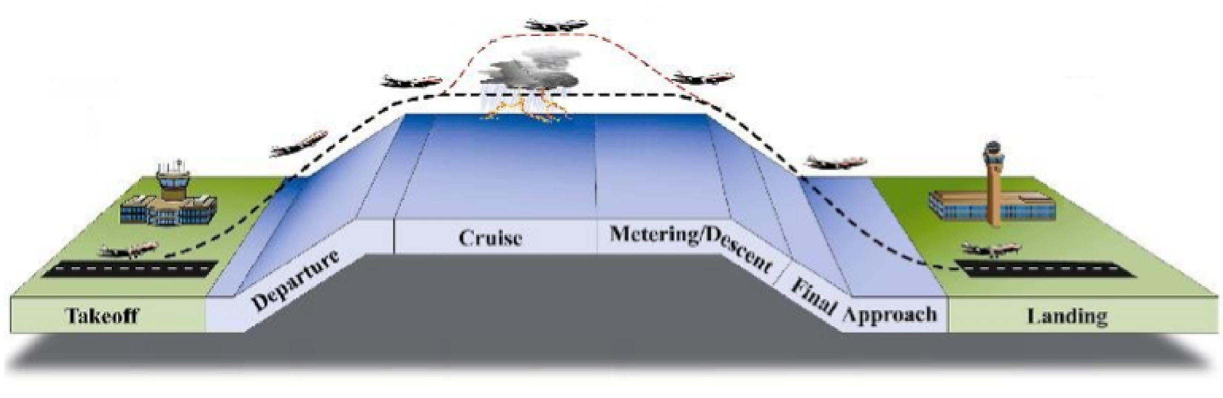


Figure A-15 Convective Weather Encountered En Route

Weather Problem Detection Capability

- Controller uses aircraft-to-aircraft conflict resolution decision support, combined with a weather problem detection capability, to avoid inadvertent aircraft-to-aircraft conflict resolution into hazardous weather.
- Controller uses weather problem detection decision support to evaluate a pilot-requested maneuver around the weather to ensure it would not send the aircraft into another area of convection not yet visible on the aircraft's airborne radar.

Weather Problem Resolution Capability

- Controller uses weather problem resolution decision support to respond to pilot requests for assistance in routing around significant areas of convective weather that are rapidly and unexpectedly worsening.
- Controller uses weather problem resolution decision support to respond to pilot requests for assistance in returning to aircraft's original flight plan when convective weather rapidly and unexpectedly improves.

No Weather Problem Capability

- Controller monitors the traffic on a TFM flow around weather on a day when the convective weather forecast 20-40 minutes out is accurate and the weather is stable, without the need for weather problem detection or resolution decision support.
- Controller vectors an aircraft around an individual convective weather cell with an open-loop clearance, without the need for weather problem detection or resolution decision support.

As Figure A-16 indicates, the NextGen concept for addressing weather problems begins strategically in the TFM domain (from 20 minutes out to several hours prior to an aircraft's encountering of the weather) and ends in the ATC domain (0-20 minutes out). In the Mid-Term, the TMC collaborates with FOCs 2-6 hours out to plan flows through or around the weather. At 1-2 hours out, when there is sufficient confidence in the weather forecasts, planned flows around the weather are implemented. Twenty to forty minutes out, the TMC adjusts the flows, as weather forecast updates require. At 0-20 minutes out, the sector controllers monitor traffic on these flows to maintain aircraft separation.

By 2025, the concept suggests that TFM will resolve the majority of weather problems. However, as indicated above, there are instances in which the dynamic nature of weather would require ATC to tactically address some weather problems. Providing sector controllers with an automated weather problem detection/resolution capability would assist them in working these problems in a safe, timely, and efficient manner, at a time when controller workloads are high.

In the following Mid-Term scenarios, it is assumed that the controller is not responsible for separating aircraft from weather, but will assist the pilot, to the extent possible, when a request is made. In the Far-Term, it is possible that the sector controller's role in separating aircraft from weather may change, but these scenarios do not consider this potential outcome.

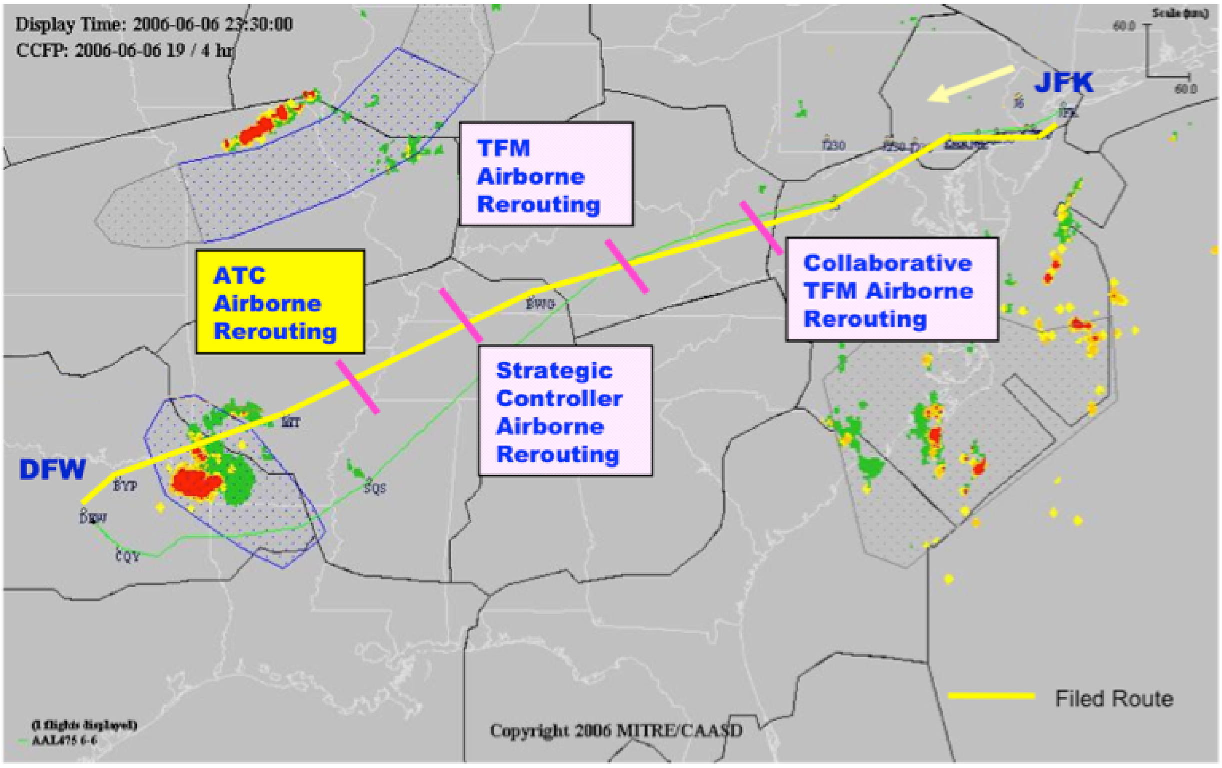


Figure A-16 NextGen Weather Concept Spans Domains

A-2.2.4.2.1 Controller Uses Aircraft-to-Aircraft Conflict Resolution Decision Support, Combined with a Weather Problem Detection Capability, to Avoid Inadvertent Aircraft-to-Aircraft Conflict Resolution into Hazardous Weather

Step 0: The 4-D Wx SAS provides ATC automation and pilots with a common weather picture. The pilot also has on-board weather radar and may have access to commercially obtained weather forecasts. The pilot is responsible for keeping the aircraft a safe distance from the weather. The controller is responsible for separating aircraft from other aircraft and, to the extent possible, assisting pilots in avoiding weather hazards. The aircraft is 15 minutes out from an area of convective weather.

Step 1: ATC aircraft-to-aircraft conflict detection DST determines the flight paths of two aircraft will come into conflict 10 minutes out.

Step 2: ATC aircraft-to-aircraft conflict resolution DST, integrated with a weather problem detection capability and utilizing the weather's impact (rather than the weather forecast alone), generates multiple ranked (weather free) resolutions for the aircraft-to-aircraft conflict.

Step 3: ATC aircraft-to-aircraft conflict DST notifies the controller of the aircraft-to-aircraft conflict and provides ranked resolutions that will keep the aircraft free of weather's impact.

Step 4: The sector controller selects an operationally acceptable resolution from the ranked resolution or uses the ATC aircraft-to-aircraft conflict DST to create and evaluate a trial plan.

Step 5: The sector controller, using voice or data communications, contacts the flight deck to provide the change in trajectory, thereby alerting the pilot of the conflict.

Step 6: The pilot accepts the controller's aircraft-to-aircraft conflict resolution.

Step 7: The pilot enters the new trajectory into the FMS. Or, in the case of low-end GA, executes each leg of the trajectory as it's cleared or flies direct to a designated fix.

A-2.2.4.2.2 Controller Uses Weather Problem Detection Decision Support to Evaluate a Pilot Requested Maneuver Around the Weather to Ensure It Will Not Send the Aircraft Into Another Area of Convection Not Yet Visible on the Aircraft's Airborne Radar

Step 0: The 4-D Wx SAS provides ATC automation and pilots with a common weather picture. The pilot also has on-board weather radar and may have access to commercially obtained weather forecasts; additionally the aircraft has data link. The pilot is responsible for keeping the aircraft a safe distance from the weather. The controller is responsible for separating aircraft from other aircraft and to the extent possible assisting pilots in avoiding weather hazards. The aircraft is 15 minutes out from an area of convective weather.

Step 1: The pilot detects convective weather directly in the aircraft's path.

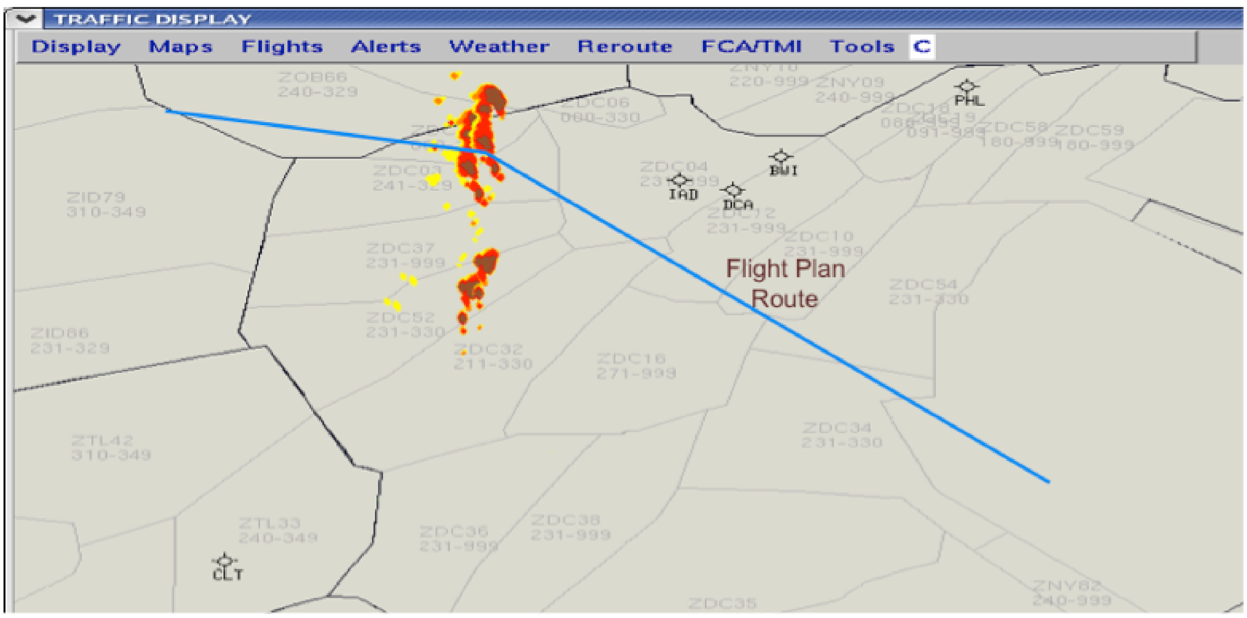


Figure A-17 Pilot Detects Convective Weather Directly in the Aircraft's Path

Step 2: The pilot, using all the weather information at his disposal, cognitively determines a weather problem resolution option and communicates a maneuver request to the sector controller via data communications.

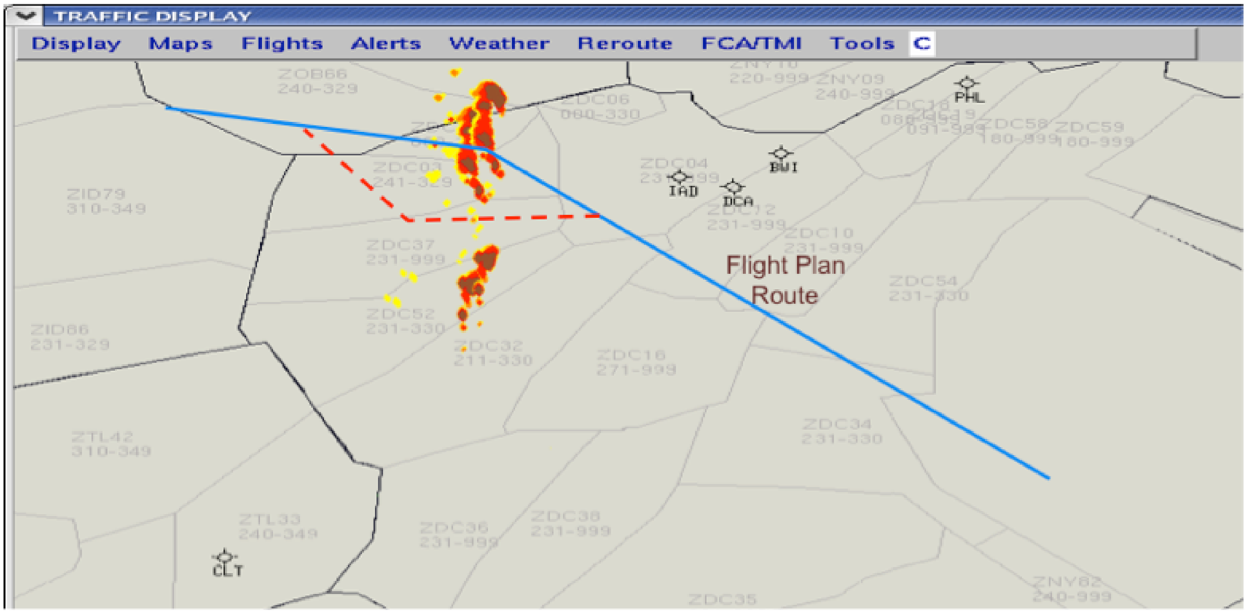


Figure A-18 Pilot Cognitively Determines a Weather Problem Resolution Option

Step 3: ATC DST, integrated with a weather problem detection capability, assesses the pilot's data link requested maneuver to identify potential aircraft-to-aircraft conflicts, as well as any aircraft-to-weather problems; none are found.

Step 4: The sector controller, via data communications, issues a clearance for the pilot's requested maneuver.

Step 5: The pilot accepts the clearance and enters the new trajectory into the aircraft's FMS.

A-2.2.4.2.3 Controller Uses Weather Problem Resolution Decision Support to Respond to Pilot Requests for Assistance in Routing Around Significant Areas of Convective Weather That Are Rapidly and Unexpectedly Worsening

Step 0: The 4-D Wx SAS provides ANSP, ATM automation, and users with a common weather picture. The pilot is responsible for keeping the aircraft a safe distance from the weather. The controller is responsible for separating aircraft from other aircraft and to the extent possible assisting pilots in avoiding weather hazards. One hour prior to an aircraft's encountering of the weather, the TMC, using 4-D Wx SAS integrated with TFM DST, initiates a flow of aircraft through a gap in the forecast convective weather. Thirty minutes prior to an aircraft encountering the weather, the TMC, using the 4-D Wx SAS integrated with TFM DST, adjusts the flow to compensate for changes in the forecast.

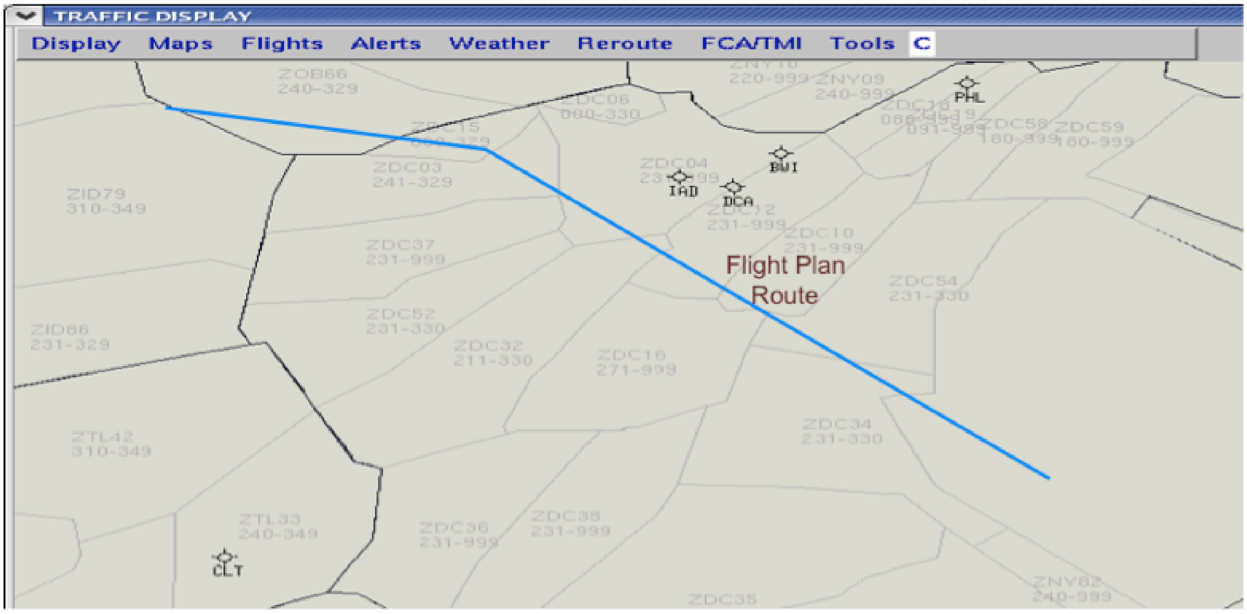


Figure A-19 TFM DST Resolution to Detected Weather Problem

Step 1: 20 minutes out from the weather, the weather rapidly and unexpectedly intensifies deviating from the forecasts used to setup the flow of traffic around the weather. The gap in the weather still exists, but is now further to the South.

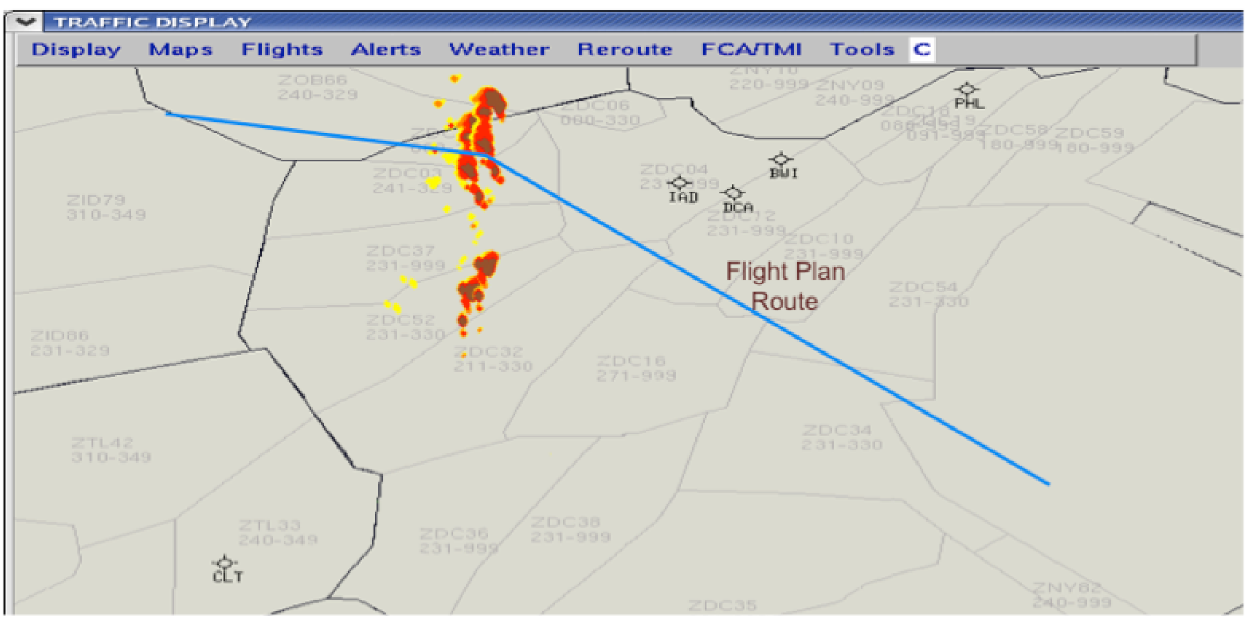


Figure A-20 New Tactical Weather Problem Detected

Step 2: TFM DST identifies the weather problem and alerts the appropriate TMC, providing them with assistance in adjusting the flow for upstream aircraft towards the new gap in the weather.

Step 3: At 15 minutes out from the weather, the pilot of an aircraft detects convective weather directly in the path of the aircraft and requests assistance from the sector controller to find a route around it.

Step 4: ATC DST translates 4-D Wx SAS convective weather forecast information into operational impact, taking weather uncertainty into account. Using this impact information, ATC DST generates and assesses multiple weather problem resolution options and notifies the sector controller of the highest ranked resolutions.

Step 5: The sector controller selects an operationally acceptable weather problem resolution and suggests it to the pilot via voice or data communications.

Step 6: The pilot accepts controller's suggested weather problem resolution.

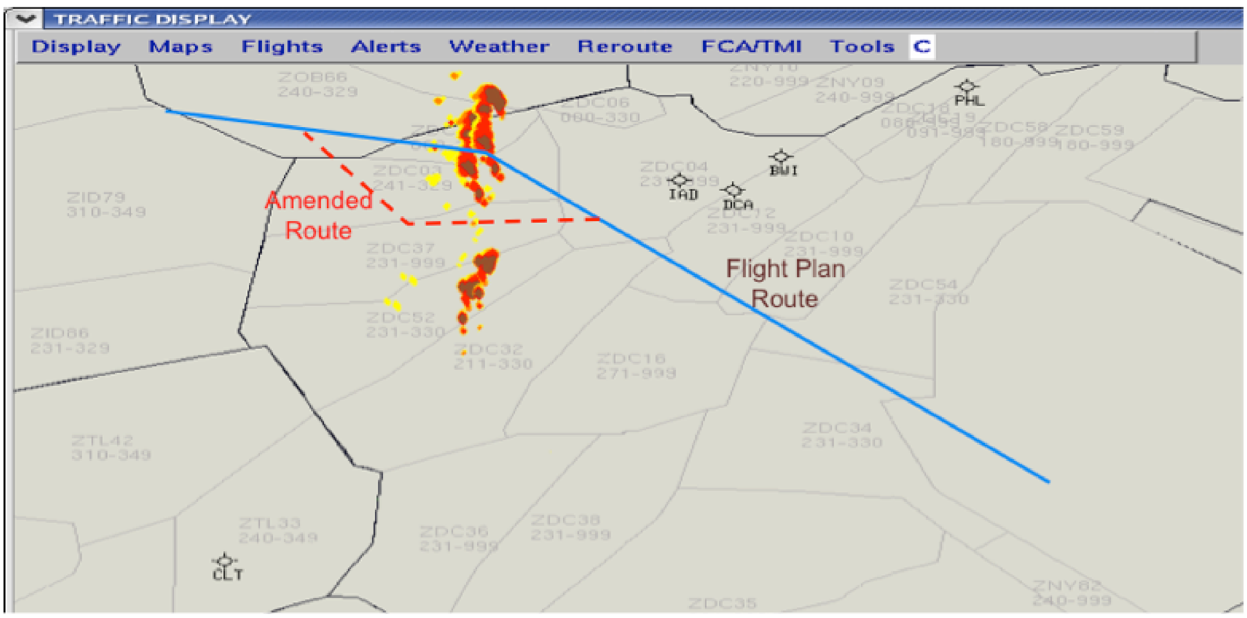


Figure A-21 ATC DST Resolution to Detected Tactical Weather Problem

Step 7: The pilot enters the new trajectory into the aircraft FMS, or, in the case of older, more limited aircraft, executes each leg of the trajectory as it is cleared or flies direct to a designated fix.

A-2.2.4.2.4 Controller Uses Weather Problem Resolution Decision Support to Respond to Pilot Requests for Assistance in Returning Aircraft to Original Flight Plan When Convective Weather Rapidly and Unexpectedly Improves

Step 0: The 4-D Wx SAS provides ANSP, ATM automation, and users with a common weather picture. The pilot also has on-board weather radar and may have access to commercially obtained weather forecasts; additionally the aircraft has data link. The pilot is responsible for keeping the aircraft a safe distance from the weather. The controller is responsible for separating the aircraft from other aircraft and to the extent possible assisting pilots in avoiding weather hazards. One hour prior to an aircraft's encountering of the weather, the TMC, using 4-D Wx

SAS integrated with TFM DST, initiates a flow of aircraft through a gap in the forecast convective weather. Thirty minutes prior to an aircraft's encountering of the weather, the TMC, using 4-D Wx SAS integrated with TFM DST, adjusts the flow to compensate for changes in the forecast.

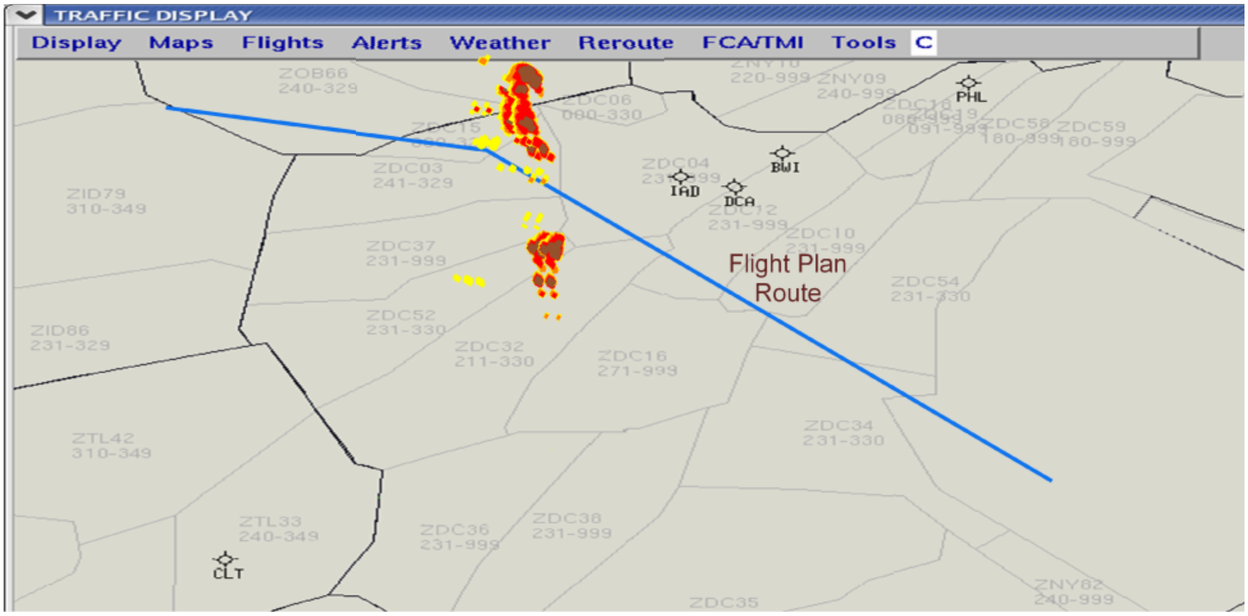


Figure A-22 TFM DST Resolution to Detected Weather Problem

Step 1: 20 minutes out from the weather, the weather unexpectedly and rapidly improves making a return to the originally filed flight plan an option to consider.

Step 2: TFM DST alerts the appropriate TMC of the improving weather and provides them with assistance in returning upstream aircraft to their original flight paths.

Step 3: The pilot, using all the weather information at his/her disposal, cognitively detects the weather improvement, determines a maneuver option to return to his original flight plan, and communicates the maneuver request to the sector controller via data communications.

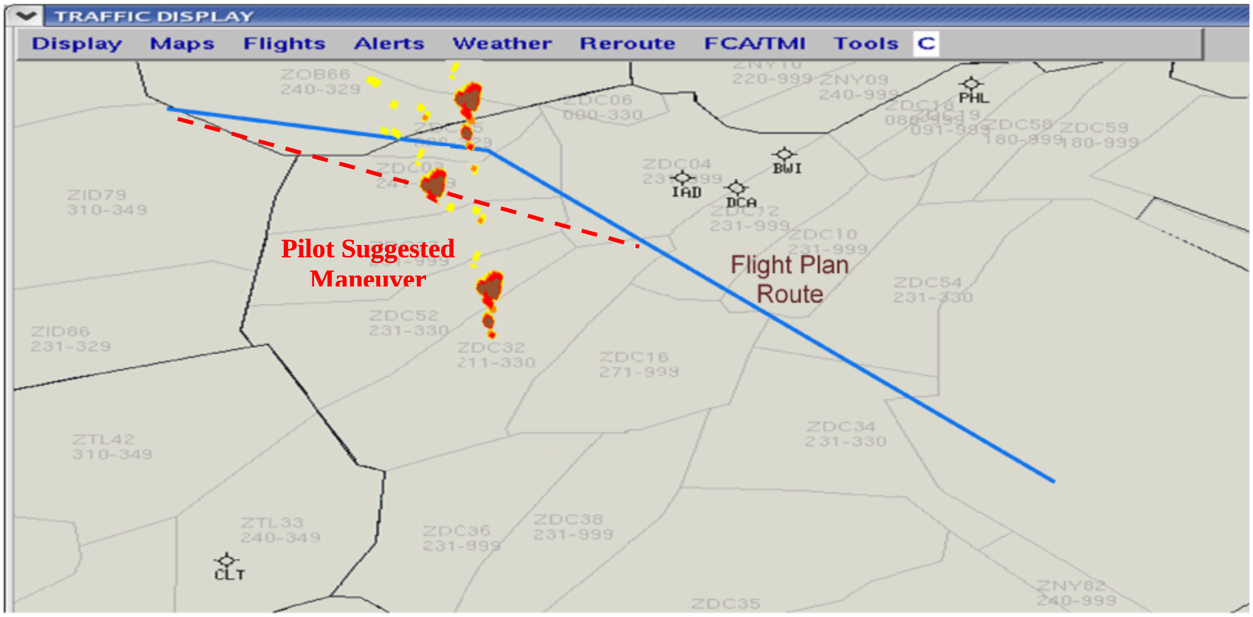


Figure A-23 Pilot Cognitively Determines an Improving Weather Resolution Option

Step 4: ATC DST, integrated with a weather problem detection capability, assesses the pilot data link-requested maneuver to identify potential aircraft-to-aircraft conflicts, as well as any aircraft-to-weather problems; a weather problem is found.

Step 5: ATC DST, using a weather problem resolution capability, generates and assesses multiple resolution options and notifies the sector controller of the highest ranked resolutions.

Step 6: The sector controller selects an operationally acceptable weather problem resolution and suggests it to the pilot via data communications.

Step 7: The pilot accepts the controller's suggested weather problem resolution.

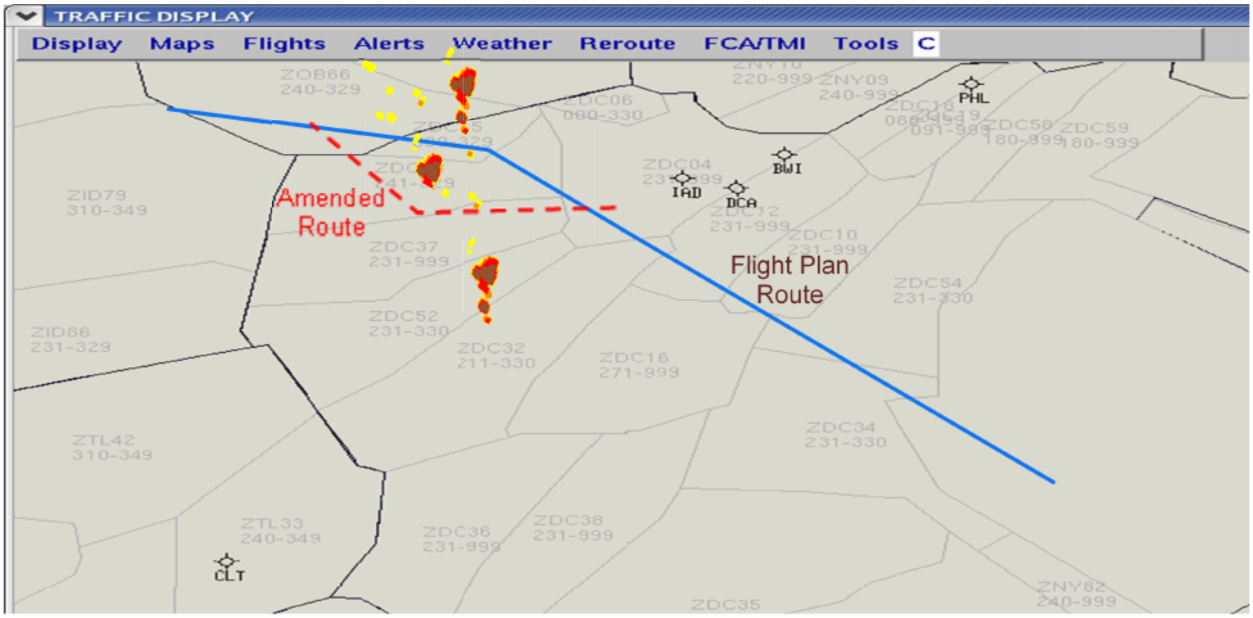


Figure A-24 ATC DST Resolution to Improving Weather

Step 8: The pilot enters the new trajectory into the FMS.

A-2.2.4.2.5 Controller Monitors the Traffic on a TFM Flow Around Weather on a Day When the Convective Weather Forecast 20-40 Minutes Out Is Accurate and the Weather Is Stable, Without the Need for Weather Problem Detection/Resolution Decision Support

Step 0: The 4-D Wx SAS provides the sector controller and the pilot with a common weather picture. The pilot may also use on-board weather radar, as well as commercially obtained weather forecasts. An aircraft is 10 minutes out from convective weather, which is stable and conforming well to the forecast.

Step 1: The pilot, using available weather information, cognitively determines that his trajectory on the TFM initiated flow is clear of weather.

Step 2: The sector controller monitors aircraft separation and maintains weather situational awareness.

Step 3: The pilot clears the weather and proceeds normally on his flight plan.

A-2.2.4.2.6 Controller Vectors an Aircraft around a Convective Weather Cell with an Open-loop Clearance, Without the Need for Automated Decision Support

Step 0: The 4-D Wx SAS provides the sector controller and the pilot with a common weather picture. The pilot may also use on-board weather radar, as well as commercially obtained weather forecasts. An aircraft is 10 minutes out from encountering an isolated convective weather cell on its filed flight plan.

Step 1: The pilot cognitively detects the weather problem, using the airborne weather radar, and determines a maneuver option (vector) around the cell.

Step 2: The pilot contacts the sector controller, using voice communications, and requests this maneuver option (vector).

Step 3: The sector controller issues a clearance for the maneuver.

Step 4: Pilot accepts the clearance and executes the maneuver.

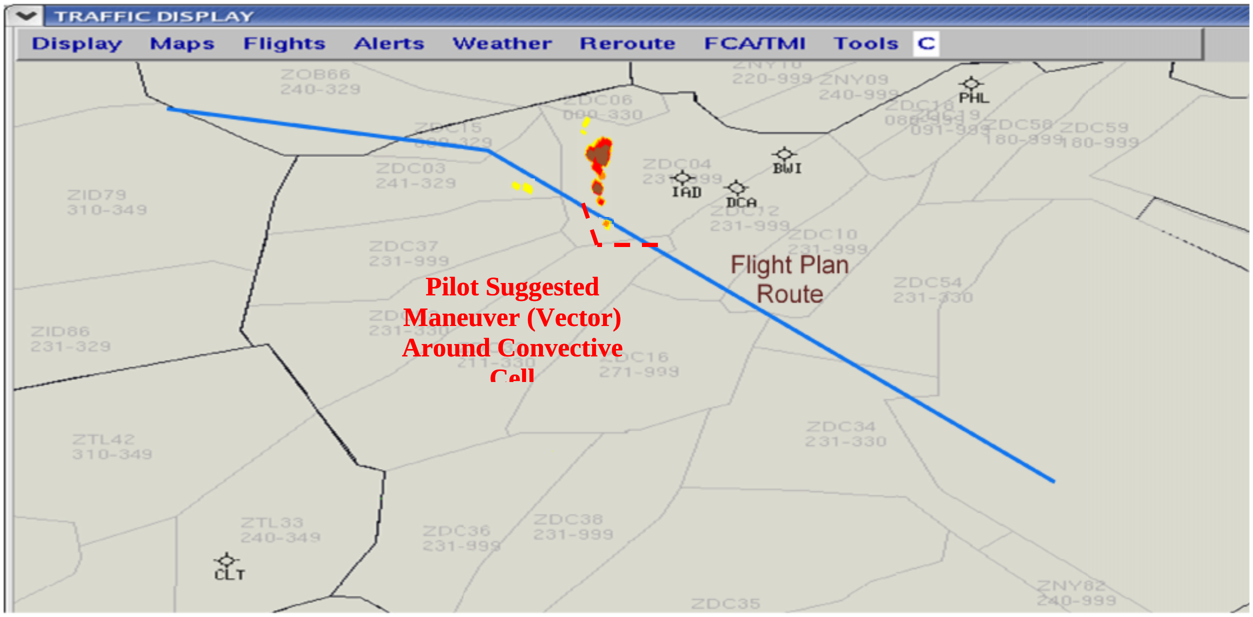


Figure A-25 Pilot Requests a Maneuver Option (Vector) Around a Convective Cell

A-2.2.4.3 Mid-Term Weather Integration and Needs Analysis

A weather integration opportunity for Initial Conflict Resolution Advisories is dependent on expanding the scope of this capability to include weather problem detection and possibly resolution. The following weather-related capabilities have been identified as "potential" candidates for inclusion into Initial Conflict Resolution Advisories:

- Controller weather problem detection decision support to prevent directing aircraft into hazardous weather inadvertently when resolving aircraft-to-aircraft conflicts
- Controller weather problem detection decision support to evaluate a pilot requested maneuver around the weather to ensure it would not send the aircraft into another area of convection not yet visible on the aircraft's airborne radar
- Controller weather problem resolution decision support to respond to pilot requests for assistance to route around significant areas of convective weather that are rapidly and unexpectedly worsening
- Controller weather problem resolution decision support to return to aircraft's original flight plan when convective weather rapidly and unexpectedly improves

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-11.

Table A-11 Initial Conflict Resolution Advisories—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap

None for the aircraft-to-aircraft capability currently described	None	N/A	N/A
Suggested weather integration candidates (assumes weather integration is needed) <u>Weather Problem Detection Capability</u> • Controller uses aircraft-to-aircraft conflict resolution decision support, combined with a weather problem detection capability, to avoid inadvertent aircraft-to-aircraft conflict resolution into hazardous weather • Controller uses weather problem detection decision support to evaluate a pilot requested maneuver around the weather to ensure it would not send the aircraft into another area of convection not yet visible on the aircraft's airborne radar <u>Weather Problem Resolution Capability</u> • Controller uses weather problem resolution decision support to respond to pilot requests for assistance in routing around significant areas of convective weather that are rapidly and unexpectedly worsening • Controller uses weather problem	NextGen shall provide ATC DST with a convective weather analysis (current time weather) and 10-minute interval forecasts, out to 20 minutes, with an update rate of 5 minutes. NextGen shall provide enhanced convective weather observations (e.g., weather radar mosaic), with improved tops altitude information (e.g., tops at each grid point or multiple tops per polygon) and reduced observation data latency. NextGen shall provide convective weather forecast information that can be readily translated into impact for NextGen en route operations including: • Horizontal extent of the weather • Vertical extent of the weather (e.g., improved tops information) • Weather severity (e.g., Video Integrator and Processor [VIP] Level) • Begin/end time • Storm speed and direction • Standardized weather forecast elements (e.g., map projections, underlying forecast rules, grid projections, hazard levels) NextGen shall provide	TBD	TBD

resolution decision support to respond to pilot requests for assistance in returning to aircraft's original flight plan when convective weather rapidly and unexpectedly improves	a net-centric, 4-D Wx SAS of convective weather information (i.e., current and forecast weather) available to all stakeholders. NextGen shall develop methodologies to address ever-increasing volumes of data, as weather forecast information content and resolutions increase. For example, improved weather data compression techniques or tailored weather information that more exactly meets the needs of users (e.g., weather along 4-D trajectory). NextGen shall provide a common framework (e.g., reference grid) of convective weather information and other constraints (e.g., environment, security, traffic levels, equipment outages, and military needs), so ATC DST can easily ingest constraint information, translate it into an integrated NAS impact, and proactively and agilely address the resulting impact. NextGen shall (in the Mid-Term) provide deterministic convective weather area information (also requires adding buffers around weather area or other methodology to allow for forecast uncertainty) and (in the Far-Term) shall provide probabilistic forecasts. Further forecast improvements to reduce		

	forecast uncertainty shall also be needed. *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*		

A-2.2.5 OI - Flexible Entry Times for Oceanic Tracks (104102)

The goal of Flexible Entry Times for Oceanic Tracks is to allow greater use of user-preferred trajectories, by looking ahead to plan near-term climbs when loading oceanic tracks.

The current system optimizes user efficiency subject to constraints of the current system. As fuel costs increase and as traffic increases, constraints must be removed and traffic flows must be improved to achieve further efficiencies (e.g., flight efficiency and system performance).

A-2.2.5.1 High Level Mid-Term Capabilities

Flexible entry times into oceanic tracks or flows allow greater use of user-preferred trajectories. Under the Oceanic Trajectory Management Four Dimensional (OTM4-D) pre-departure concept, flexible entry times into oceanic tracks allow aircraft to fly minimum time/fuel paths. ANSP automation reviews the request and negotiates adjustments to entry time requests. By incorporating entry optimization algorithms within the request review process, flights trade-off some near-term suboptimal profiles to achieve more optimal oceanic profiles.

Oceanic route efficiency is improved through collaborative negotiation of entry times and track loading and oceanic traffic handling is improved through comparison of current routes against desired profiles to identify beneficial control actions. The negotiation for entry times includes looking ahead to plan near-term climbs when loading tracks. Oceanic 4-D profiles of active flights are continually examined to determine control actions that enhance oceanic capacity while providing improved efficiency within traffic flows.

This concept provides initial profile de-confliction and enhanced sequencing optimization (using wind direction and speed), resulting in flexible (or negotiated) entry times, rather than the current RTA at oceanic entry points. Airspace users will supply initial optimal trajectories via their submitted flight plans. Analysis tools will use this information to calculate oceanic entry solutions to optimize airspace usage. To arrive at a preferred trajectory, the pilot request will be used to specify an initial flight level. Trajectory planning tools will then be used to match the new request against other planned trajectories to achieve a preferred achievable trajectory.

A-2.2.5.2 Mid-Term Operational Scenarios

TBD

A-2.2.5.3 Mid-Term Weather Integration and Needs Analysis

This OI needs to integrate oceanic wind forecast information with the calculation of flexible entry times for oceanic tracks. During concept development at MITRE/Center for Advanced Aviation System Development (CAASD), it was determined there may be a need for more frequent oceanic weather forecasts, perhaps every three hours instead of six, to support more efficient pre-departure planning for Flexible Entry Times for Oceanic Tracks. Another possible need is for better real-time weather information to the flight crew, possibly from the leading aircraft.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-12.

Table A-12 Flexible Entry Times for Oceanic Tracks—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Integrate oceanic wind forecast information with the calculation of flexible entry times for oceanic tracks	Forecast oceanic winds, perhaps updated more frequently (e.g., 3 hours). Real-time weather observations, perhaps supplied by lead aircraft. *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	TBD	TBD

A-2.2.6 OI - Point-in-Space Metering (104120)

The goal of Point-in-Space Metering is to provide smooth metering of traffic to a downstream capacity-constrained point by providing an automated sequence of upstream CTAs, at various airspace boundaries along a flight path, to meter traffic rather than imposing MIT constraints.

As air traffic increases, flows into constrained resources must be strategically managed to minimize individual flight and system delays. Currently, a common way to do this is by using MIT restrictions. However, MIT restrictions are controller-workload intensive and are often overly restrictive and not integrated. There is a need to manage flows into constrained resources in order to maximize the use of those resources, as well as minimize additional controller workload.

A-2.2.6.1 High Level Mid-Term Capabilities

ANSP uses scheduling tools and TBO

This capability allows the ANSP to manage the flow of traffic across multiple sectors to help ensure operational efficiency. Rather than using today's MIT restrictions, the ANSP, supported by decision-support automation, establishes a series of upstream metering points and uses CTAs to smooth out the traffic and establish a uniform flow at the appropriate acceptance rate for a downstream resource. This procedure is transparent to the user; the CTAs are not transmitted to the aircraft but rather are used internally by the ANSP to determine the desired 4-D trajectory of the aircraft, which is then translated into clearances (e.g., speed, lateral, or path stretch) and transmitted to the aircraft.

Before this OI capability is applied to the current traffic, CATM TFM processes would have been applied to the traffic to ensure that the overall traffic loads are manageable within the acceptance rate of the downstream resource and to facilitate user prioritization of aircraft within the stream for fleet management.

Although it is transparent to the aircraft, this OI represents a significant step toward the ANSP managing traffic by 4-D trajectories, which is a change that must be accomplished before air/ground trajectory negotiation and full trajectory-based operations can be employed.

Coordination with the Solution Set Coordinator for Increase Arrivals/ Departures at High Density Airports has established that metering in the Mid-Term may be applied to the departure, en route, and arrival phases of flight (also see the Increase Arrivals/Departures at High Density Airports OI: TBM Using RNP and RNAV Route Assignments). This metering capability permits efficient use of NAS assets, such as runways and high density departure, en route, and arrival flows. He also indicated TBO may be applied selectively, so MIT may still have applications at some locations and under certain conditions. It is assumed that Point-in-Space Metering will not replace MIT in the Mid-Term, but rather reduce the need to employ this solution.

A-2.2.6.2 Mid-Term Operational Scenario

A-2.2.6.2.1 Calculate a Sequence of Recommended Upstream CTAs to a Downstream Capacity-Constrained Point, Integrating Weather and Aircraft Performance Information, and Convert These CTAs into Clearances

Step 0: Weather information is made available by the NextGen net-centric 4-D Wx Data Cube and its initial 4-D Wx SAS. CATM TFM processes are used collaboratively (ANSP, AOC, FOC, and pilot) to determine the aircraft's CTA at a downstream capacity-constrained point.

Step 1: Point-in-Space Metering DST recommends a sequence of CTAs for the aircraft, at various airspace boundaries, to ensure that this aircraft can be smoothly incorporated into the traffic converging on the downstream capacity-constrained point. These CTAs also manage the number of aircraft in each section of airspace over time to stay within traffic density/complexity constraints for current weather conditions. While the downstream CTA will have precise timing and position requirements, these upstream CTAs will probably have less precise timing and lateral position requirements. The Point-in-Space Metering calculations of the upstream CTAs incorporate aircraft performance and weather information that may impact the flight trajectory of the aircraft, such as wind information.

Step 2: As the aircraft flies its route towards the downstream capacity-constrained point and encounters various weather changes (e.g., winds), the Point-in-Space Metering DST uses this weather information to calculate the desired trajectory for the aircraft to meet the next CTA in the series and provides recommendations to the ANSP. The ANSP uses this information to manage the aircraft by issuing clearances (e.g., speed, lateral, or path stretch).

A-2.2.6.3 Mid-Term Weather Integration and Needs Analysis

CATM TFM uses strategic weather information to calculate the future acceptance rate at the downstream resource and to route aircraft around major convective weather areas. Once those CATM processes are applied, the weather information needed for Point-in-Space Metering would be more tactical in nature, similar to what is described for the High Density Airports TBM OI: TBM Using RNP and RNAV Route Assignments.

The CTAs generated by Point-in-Space Metering, which are used by the ANSP to provide clearances (e.g., speed, lateral, or path stretch), must reflect what an aircraft can and will actually fly, given the weather conditions along its trajectory. Weather, such as turbulence and winds, impact an aircraft's en route speed.

Discussion with the Solution Set Coordinator for Increase Arrivals/ Departures at High-Density Airports has revealed that convective weather will not be integrated into this Mid-Term OI, but it is an integration that is being considered for follow-on metering capabilities.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-13.

Table A-13 Point in Space Metering—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Calculation of a set of 'attainable' CTAs to a metering point in en route airspace (e.g., merge point), taking weather's impact on aircraft speed and performance into account	Forecasts out ~1 hr: Winds aloft because of their impact on aircraft speed, with detail particularly near merge points and areas of hard to predict winds near the jet stream's edge In-flight turbulence because of its impact on aircraft performance *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	*Winds Aloft* Hi-Res Rapid Refresh (HRRR) 3 km horizontal, hourly update, 15 min resolution, CONUS RUC 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS WRF-RR *Turbulence* Graphical Turbulence Guidance (GTG) Analysis and 1-12hr forecast	TBD

A-2.2.7 OI - Flexible Airspace Management (108206)

The goal of Flexible Airspace Management is to allow ANSP automation to support the assessment of alternate configurations and to reallocate resources, trajectory information, surveillance, and communications information to different positions or different facilities.

Today's airspace configurations and sector boundaries are pre-determined based on historical flows and pre-defined boundaries. This imposes a capacity constraint on the system during periods of peak demand, airspace use restrictions, and convective weather. Currently, airspace management techniques are implemented by degrees; for example: flight data, other automation functions (e.g., automated handoff), and the controller's map displaying changes when the airspace is reconfigured. In another example, only the map would display changes. Each of these implementations requires adaptation in advance of their use. They will be used to varying degrees by different facilities and individuals, according to standard and/or individual practices.

A-2.2.7.1 High Level Mid-Term Capabilities

ANSP automation supports reallocation of trajectory information, surveillance, communications, and display information to different positions or different facilities. The ANSP moves controller capacity to meet demand. Automation enhancements enable increased flexibility to change sector boundaries and airspace volume definitions in accordance with pre-defined configurations. The extent of flexibility has been limited due to limitations of automation, surveillance, and communication capabilities, such as primary and secondary radar coverage, availability of radio frequencies, and ground-communication lines. New automated tools will define and support the assessment of alternate configurations as well as re-mapping of information (e.g., flight and radar) to the appropriate positions.

Automation enhancements enable increased flexibility to change sector boundaries and airspace volume definitions in accordance with pre-defined configurations, as well as allowing assets to be shared across facility boundaries. These flexible configurations would be developed based on historical climate and traffic patterns. Identification of airspace needs and development of a baseline plan for the given flight day would occur 1 to 5 days in advance. The determination of alternative day of flight configurations and the selection of the actual configuration to be employed (along with the timing of the reconfiguration) would be based on predicting weather and traffic demand 1-24 hours out. Configurations should be fairly static. It would not be desirable to change configurations during operations unless something significant is predicted to impact the system (e.g., convective weather moving through an area, large movement of the jet stream, icing). For these occasions, a capability is needed to predict the timing of the triggering event, determine the appropriate change in predefined airspace configuration, and plan accordingly.

As Figure A-26 depicts, there is also a significant interaction between the following OIs that must be discussed in order to more completely understand the capabilities of Flexible Airspace Management:

- Flexible Airspace Management (TBO)
- Continuous Flight Day Evaluation (CATM)
- Flight Plan Constraint Evaluation and Feedback (CATM)

- Initial Integration of Weather Information into NAS Automation and Decision Making (RWI)

By following the steps, one sees the following roles and relationships emerge between these OIs:

- Flexible Airspace Management
  - Determines configurations alternatives and schedules appropriate to the identified NAS constraint resulting from numerous causes (e.g., weather, demand, outages) without needing to know the precise cause of the constraint (i.e., weather is transparent to this operation)
  - Implements the airspace configuration selected by the operator
- Continuous Flight Day Evaluation
  - Provides flight plans (primary/alternates) and assessment criteria so the RWI OI: Initial Integration of Weather Information into NAS Automation and Decision Making can evaluate weather's impact
  - Determines NAS constraints, combining weather and other impacts (e.g., demand, outages)
  - Provides Flexible Airspace Management with the NAS constraint
- Flight Plan Constraint Evaluation and Feedback
  - Provides users with constraint and operational impact feedback
  - Provides users with weather along their flight trajectory
  - Provides Continuous Flight Day Evaluation with users modified flight plan
- Initial Integration of Weather Information into NAS Automation and Decision Making
  - Evaluates a set of individual flight trajectories and determines weather's operational impact on each based on provided criteria
  - Aggregates weather's operational impact on flight trajectories to enable the determination of NAS constraint (Weather and non-Weather) by Continuous Flight Day Evaluation

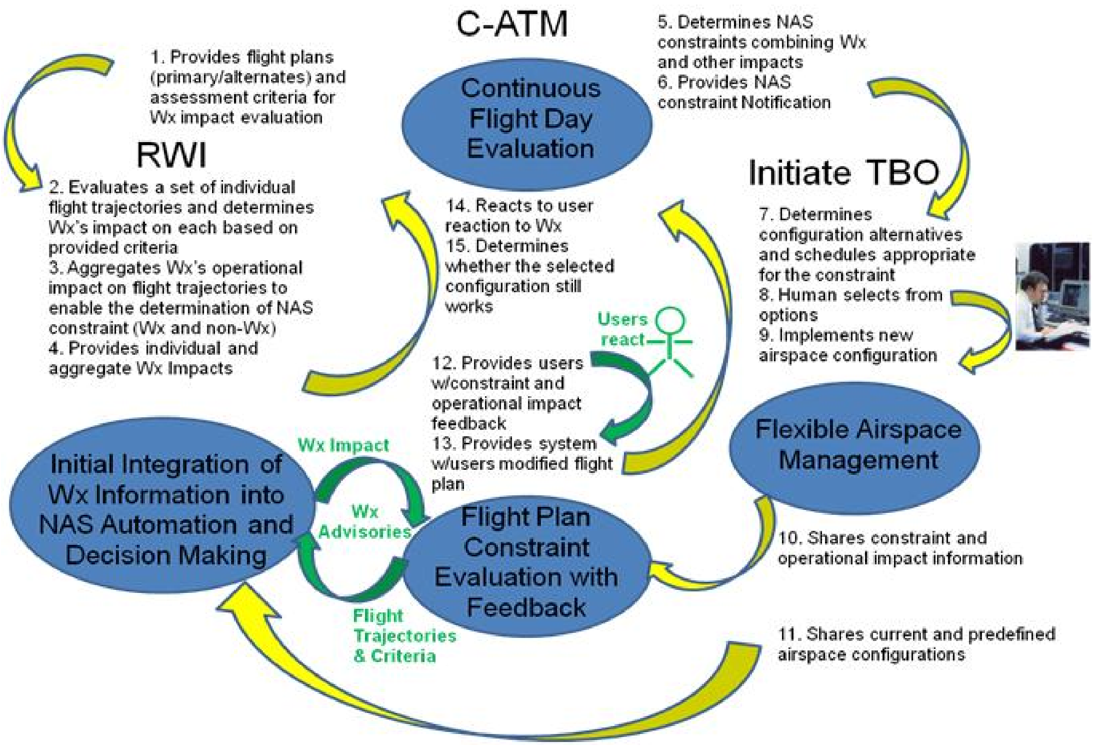


Figure A-26 Flexible Airspace Management – OI Interactions

A-2.2.7.2 Mid-Term Operational Scenarios

A-2.2.7.2.1 Identify Airspace Needs and Develop Baseline Plan for the Given Flight Day, 1 to 5 Days in Advance, Using Weather Constraint Information

Step 0: Months in advance, based on historical traffic patterns and historical weather, pre-defined routes (including RNAV and RNP routes) and pre-defined airspace configurations are defined, along with rules for their usage. At least four weeks in advance of a given flight day, FLM at the facilities establish a first-cut facility staffing schedule.

Step 1: The TMS (1-5 days out) collaborating with TMCs, reviews available flight intent information, historical traffic patterns, controller staffing resources, and long-range forecast weather information to select a baseline configuration.

Step 2: The TMS identifies potential airspace capacity needs where congestion may become a problem (i.e., Hot spots).

Step 3: The TMC proposes a first-cut set of RNAV and RNP routes.

Step 4: The above route selection refines the plan for use of Generic Sectors and pre-canned configurations.

Step 5: The FLM establishes a preliminary schedule for configuration changes.

A-2.2.7.2.2 Establish Baseline Airspace Configuration of the Day, 8-24 Hours in Advance, Using Weather Constraint Information

Step 0: Days in advance, updated airspace needs are identified and a baseline plan is developed.

Step 1: 8 to 24 hours in advance, and before each shift change, primary responsibility shifts from the ATCSCC to local facilities.

Step 2: The TMS prioritizes the hot spots across the NAS and identifies conditions that warrant alternative plays.

Step 3: The Center Team (TMC, strategic controller and FLM), in collaboration with other affected facilities, identifies airspace configurations, and route structures.

Step 4: The Center Team develops a rough schedule for planned transitions in configuration and staffing to move capacity to where it is needed, including designating performance-based access and identifying SAA that may need to be traversed.

Step 5: TMCs negotiate use of SAA with appropriate agency.

A-2.2.7.2.3 Determine Alternative Airspace Configurations, 4-8 Hours in Advance, Using Weather Constraint Information

Step 0: 8-24 hours out, congestion issues are prioritized and the baseline plan is updated

Step 1: TMCs (4-8 hours out) set up prioritized configuration contingencies (i.e., watch list) using the following information: updated flight intent information (including users' prioritized alternatives), weather information, SAA status, and current and planned TMIs. For example: if thunderstorms arrive between 2 and 4 pm, use airspace configuration A, if they arrive after 4 pm, use airspace configuration B, if they move farther North, continue to use current airspace configuration C.

A-2.2.7.2.4 Select and Implement Specific Alternatives, 1- 4 Hours in Advance, Using Weather Constraint Information

Step 0: 4-8 hours out, alternative plays are developed, the baseline is fine-tuned, and a watch list is created.

Step 1: The FLM and/or sector controller (1-4 hours out) monitor the watch list.

Step 2: When watch list parameters indicates a change will be required, the TMC, strategic controller and FLM agree on when to transition to the new airspace configuration. The TMC coordinates the change with adjacent facilities.

A-2.2.7.3 Mid-Term Weather Integration and Needs Analysis

Weather integration for Flexible Airspace Management includes:

- Determination of pre-defined airspace configurations, using existing traffic patterns and historical weather.
- Identification of airspace needs and development of a baseline plan for the given flight day, 1 to 5 days in advance, using constraint information provided by Continuous Flight Day Evaluation (i.e., this includes but is not limited to weather constraints).

- Establishment of a baseline airspace configuration for the day, 8-24 hours in advance, using constraint information provided by Continuous Flight Day Evaluation (i.e., this includes but is not limited to weather constraints).
- Determination of alternative airspace configurations, 4-8 hours in advance, using constraint information provided by Continuous Flight Day Evaluation (i.e., this includes but is not limited to weather constraints).
- Selection and implementation of specific alternatives, 1- 4 hours in advance, using constraint information provided by Continuous Flight Day Evaluation (i.e., this includes but is not limited to weather constraints).

In the case of Flexible Airspace Management, weather is integrated into decision making, but it is made transparent because Continuous Flight Plan Evaluation aggregates constraints (including weather) and Flexible Airspace Management acts directly on the identified constraint.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-14.

Table A-14 Flexible Airspace Management—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Determine pre-defined airspace configuration using existing traffic patterns and climatological weather	NAS-wide climatology	No climatology planned for IOC	NAS-wide climatology
Identify airspace needs and develop baseline plan for the given flight day 1 to 5 days ahead using weather constraint information	Multi-hour forecasts (e.g., 3 hourly) of winds aloft, icing, turbulence and convection 1 to 5 days out *Accuracy TBD* *Resolution TBD*	Currently, no plans for 5 day forecasts of winds aloft, icing, turbulence and convection	Multi-hour forecasts (e.g., 3, 6 hourly) of winds aloft, icing, turbulence and convection 1 to 5 days out
Establish baseline airspace configuration of the day 8-24 hours in advance using weather constraint information	Hourly forecasts of winds aloft, icing, turbulence and convection 8-24 hours out *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD*	*Winds Aloft* RUC 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS *Convection* Corridor Integrated Weather System (CIWS) (0-2 hr) Consolidated Storm Prediction for Aviation (CoSPA) (2-8 hr)	12-24 Turbulence Forecast

		Turbulence GTG Analysis and 1-12hr forecast	
Determine alternative airspace configurations 4-8 hours in advance using weather constraint information	Hourly forecasts of winds aloft, icing, turbulence and convection 4-8 hours out Accuracy TBD Resolution TBD Forecast Update Rate TBD	*Winds Aloft* HRRR 3 km horizontal, hourly update, 15 min resolution, CONUS RUC 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS WRF-RR *Convection* CIWS (0-2 hr) CoSPA (2-8 hr) *Turbulence* GTG Analysis and 1-12hr forecast	TBD
Select and implement specific alternatives 1- 4 hours in advance using weather constraint information	Hourly forecasts of winds aloft, icing, turbulence and convection 1-4 hours out *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	*Winds Aloft* HRRR 3 km horizontal, hourly update, 15 min resolution, CONUS RUC 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS WRF-RR *Convection* CIWS (0-2 hr) CoSPA (2-8 hr) *Turbulence* GTG Analysis and 1-12hr forecast	TBD

A-2.2.8 OI - Increase Capacity and Efficiency Using RNAV and RNP (108209)

The goal of Increase Capacity and Efficiency Using RNAV and RNP is to create more en route structured routes, taking advantage of both RNAV and RNP to enable more efficient aircraft trajectories. RNAV and RNP combined with airspace changes can increase airspace efficiency and capacity.

Traditional airways are based on a system of routes among ground-based navigational aids (NAVAIDS). These routes require significant separation buffers. The constraint of flying from one navigational aid to another generally increases user distance and time. It can also create choke points and limit access to NAS resources, for example, when severe weather forces the closure of some airport arrival routes. Terminal operations today are also constrained by ground-based arrival and departure procedures and airspace design. This limits terminal ingress/egress and access to and from the overhead streams. Additionally, terminal operations are constrained by terrain, environmental requirements/restrictions, Special Use Airspace (SUA), and adjacent airport traffic flows.

A-2.2.8.1 High Level Mid-Term Capabilities

Both RNAV and RNP will enable more efficient aircraft trajectories. RNAV and RNP combined with airspace changes, increase airspace efficiency and capacity. RNAV and RNP will permit the flexibility of point-to-point operations and allow for the development of routes, procedures, and approaches that are more efficient and free from the constraints and inefficiencies of the ground-based NAVAIDS. This capability can also be combined with an ILS, to improve the transition onto an ILS final approach and to provide a guided missed approach. Consequently, RNAV and RNP will enable safe and efficient procedures and airspace that address the complexities of the terminal operation through repeatable and predictable navigation. These will include the ability to implement curved path procedures that can address terrain, and noise-sensitive and/or special-use airspace. Terminal and en route procedures will be designed for more efficient spacing and will address complex operations.

Performance-based RNAV and RNP will help to increase access and options for airport utilization as well as reduce overall environmental impact by addressing noise, emissions and fuel use in the development and use of routes and procedures.

RNAV capability allows an aircraft to fly directly point-to-point rather than following the inefficient zigzag fixed route structure based on ground-based NAVAIDS, resulting in distance, time and cost savings for the aircraft. RNP capability allows aircraft to fly the RNAV route with a defined level of precision. Currently, only lateral (or cross track) precision is defined and implemented, and is referred to as 2D RNP. To support full 4-D TBO, 3D RNP including altitude, and 4-D RNP including both altitude and timing (or along track) conformance bounds will be developed. The combination of RNAV and RNP (also referred to as Performance-Based Navigation) allows more routes to be defined for a given airspace because the separation buffers between routes can safely be reduced, resulting in greater capacity or throughput. The capability defined in this section appears to refer to 2-D RNP for en-route airspace.

RNAV/RNP capability is already implemented in some busy en-route airspace as Q Routes and in terminal airspace as T Routes. Most air transport category aircraft are already RNAV equipped, and many have the RNP 2 or (RNAV 2) capability required to fly these routes. As noted in Section 9.3.1, airspace design changes are needed in addition to aircraft capabilities to implement RNAV/RNP, and this appears to be the focus of this capability.

In the Mid-Term (2018) RNAV/RNP routes would still be fixed, and would not have the capability to be moved to avoid en-route convective weather, so Mid-Term weather integration needs would include determining whether a particular route would be available (i.e., free of hazardous weather).

A-2.2.8.2 Mid-Term Operational Scenario

A-2.2.8.2.1 Use Weather Information to Determine Availability of Predefined RNAV/RNP Routes

Step 0: Weather information is made available by the NextGen net-centric 4-D Wx Data Cube and its initial 4-D Wx SAS. A network of RNAV and RNP routes has been predefined for high density en route airspace. These RNP/RNAV routes are not limited to aligning with ground-based NAVAIDS. The RNP routes can be spaced more closely than today's airways because the aircraft flying on them are constrained to tighter RNP.

Step 1: Increase Capacity and Efficiency Using RNAV and RNP DST identifies whether the predefined RNAV/RNP routes are or soon will be blocked by convective weather and provides a route blockage advisory to the ANSP. En route ANSP managing high-density traffic assigns each aircraft to a structured airway. ANSP accesses information on equipage levels for each aircraft from its flight plan, assigning properly equipped aircraft to RNAV or RNP routes. Aircraft flying on an RNP route are issued an RNP constraint.

Step 2: Aircraft follow assigned structured routes. The use of these additional routes enables higher airspace capacity and the RNP/RNAV routes may involve less distance flown and hence more fuel efficient for users.

A-2.2.8.3 Mid-Term Weather Integration and Needs Analysis

Weather integration will come into play in the identification of whether fixed RNAV/RNP routes are or soon will be blocked by convective weather.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-15.

Table A-15 Increase Capacity and Efficiency Using RNAV and RNP—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3 Increase Flexibility in the Terminal Environment (FlexTerm)

Increase Flexibility in the Terminal Environment Solution Set covers the terminal and airport operations' ability to meet the need of both high-density terminals and other airports. FlexTerm solutions focus on improvements to the management of separation at all airports. Such capabilities will improve safety, efficiency and maintain capacity in reduced visibility high-density terminal operations. FlexTerm solutions will also improve trajectory management and advanced separation procedures employed when demand warrants. At airports where traffic demand is lower, and at high-density airports during times of low demand, operations requiring lesser aircraft capability are conducted, allowing access to a wider range of operators while retaining the throughput and efficiency advantages of high-density operations. Both trajectory and non trajectory-based operations may be conducted within FlexTerm operations. The activities do not rise to a level that requires flow management or flow tools.

Flexible terminal operations are a mix of IFR/VFR traffic with aircraft types ranging from airline transport to low-end GA. Airports in these areas are towered and non-towered, depending on traffic demand. In the future, some satellite airports will experience higher traffic demand due to a migration of air traffic to these smaller airports in the effort to mitigate traffic congestion. In addition, there will be an increase in the use of personal aircraft for pleasure and business and the emergence of on-demand air taxi services using very light jets (VLJs).

Improved access and safe operations in terminals areas and on the surface will be a requirement NAS-wide. Providing safe separation for aircraft, allowing departure and landing in lower visual conditions, will be required. Improved access to runways in a safe, fuel-efficient, and environmentally-sensitive (noise and emissions) operations across the airport environment is necessary to accommodate projected growth.

A primary NextGen objective will be to achieve the most efficient use of airspace and airports, based on actual needs, and where possible, to avoid permanent airspace and route segregation.

The Mid-Term OIs of interest are listed here in the order in which they appear as brick red-colored timelines in the FlexTerm Figures A-27 and A-28:

- WTMD: Wind-Based Wake Procedures
- GBAS Precision Approaches
- Expanded Radar-Like Services to Secondary Airports
- Wake Turbulence Mitigation for Arrivals: CSPRs
- Use Optimized Profile Descent
- Low Visibility Surface Operations
- Low Visibility/Ceiling Approach Operations
- Low Visibility/Ceiling Landing Operations
- Low Visibility/Ceiling Takeoff Operations
- Low Visibility/Ceiling Departure Operations
- Expanded Low Visibility Operations using Lower RVR Minima
- Provide Full Surface Situation Information
- Enhanced Surface Traffic Operations
- Improved Runway Situational Awareness for Controllers
- Improved Runway Situational Awareness for Pilots

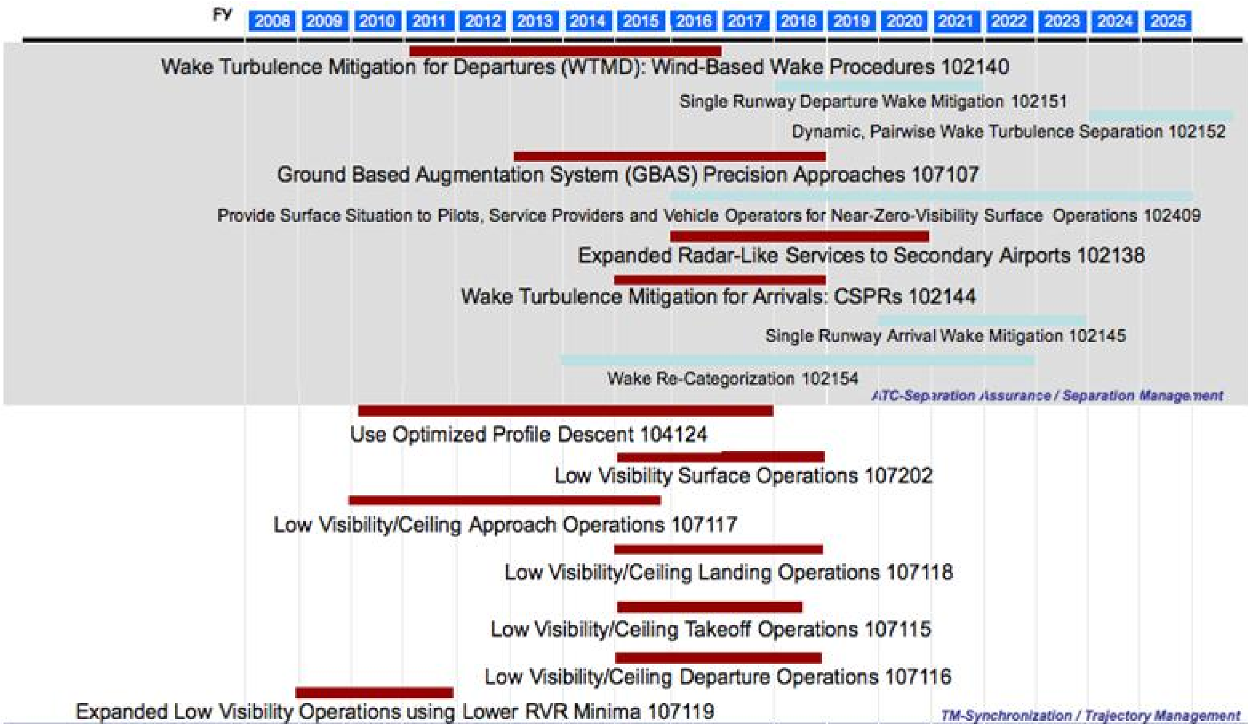


Figure A-27. Increase Flexibility in the Terminal Environment Timeline (1 of 2)

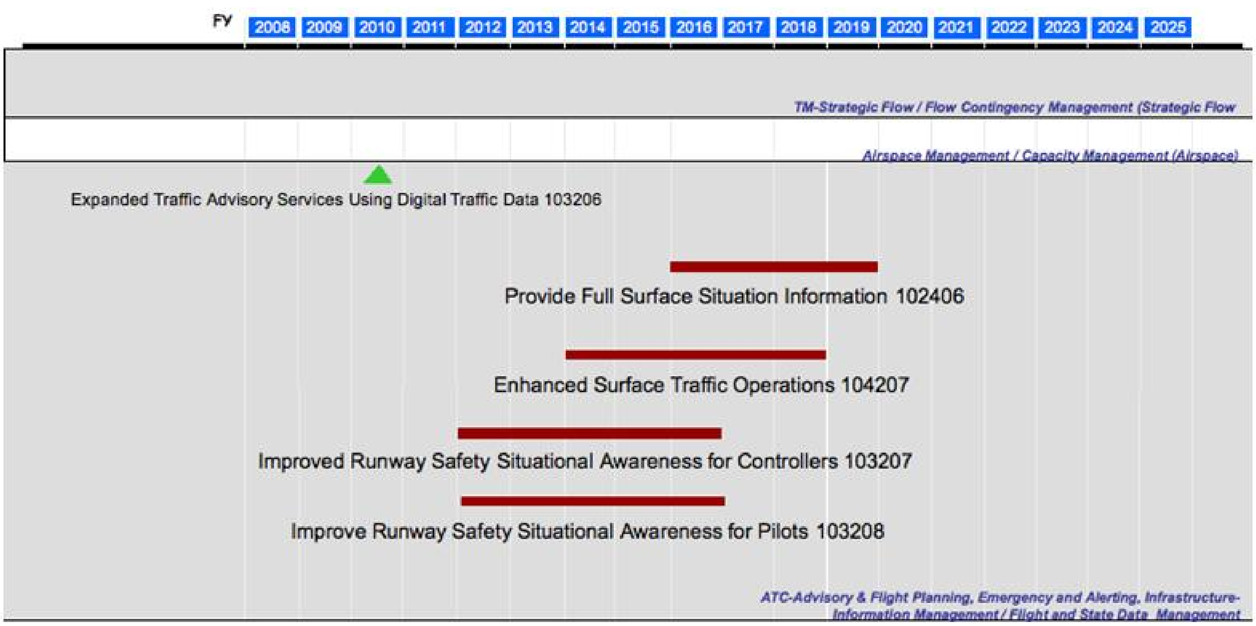


Figure A-28. Increase Flexibility in the Terminal Environment Timeline (2 of 2)

A-2.3.1 OI –WTMD: Wind-Based Wake Procedures (102140)

This OI uses wind observations and forecasts and advanced wake modeling to accurately predict the transport and decay of wake vortices, potentially allowing reduced departure separation minima to be applied on a case-by-case basis.

Departure service is part of an integrated ATC approach and departure procedures provided for airports. These procedures have proved safe for airports with CSPR. They do, however, limit capacity and create significant delays associated with their application during times of heavy airport departure demand, making it difficult for air carriers to maintain scheduling integrity. CSPR departure capacity limitations created by wake vortex separation standards are a liability to the NAS.

A-2.3.1.1 High Level Mid-Term Capabilities

Changes to wake rules are implemented based on wind measurements. Procedures allow more closely spaced departure operations to maintain airport/runway capacity.

Procedures are developed at applicable locations based on the results of analysis of wake measurements and safety analysis using wake modeling and visualization. During peak demand periods, these procedures allow airports to maintain airport departure throughput during favorable wind conditions.

A staged implementation of changes in procedures and standards, as well as the implementation of new technology will safely reduce the impact of wake vortices on operations. This reduction applies to specific types of aircraft and is based on wind transporting an aircraft's wake away from the parallel runway's operating area.

A-2.3.1.2 Mid-Term Operational Scenario

TBD

A-2.3.1.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-16.

Table A-16. Wake Turbulence Mitigation for Departures (WTMD): Wind-Based Wake Procedures –Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.2 OI – GBAS Precision Approaches (107107)

This OI is concerned with the use of GPS information augmented by ground-based signals to create a landing system that will eventually achieve or exceed current CAT II/III capabilities.

There is a need for a system that will allow a facility to accommodate complex approaches (i.e., curved paths, short finals) to Category III minima at multiple runway ends, as well as support surface operations requiring high accuracy and integrity. A Category I capability is viewed as a stepping stone to a future Category II/III GBAS.

A-2.3.2.1 High Level Mid-Term Capabilities

The GBAS system collects data from GPS satellites in view, computes the necessary differential corrections, and transmits them along with integrity data via Very High Frequency (VHF) broadcast to aircraft for multiple runways or landing areas. Standards for Category I GBAS have been adopted by the ICAO.

GPS/GBAS support precision approaches to Category I and eventually Category II/III minimums, for properly equipped runways and aircraft. GBAS can support approach minimums at airports with fewer restrictions to surface movement, and offers the potential for curved precision approaches. GBAS also can support high-integrity surface movement requirements.

GBAS would provide Category I and Category II/III precision approach and landing services and position information for surface operations. GBAS Category I systems may be installed at airports requiring a stand-alone augmented GPS navigation and landing capability, or at airports where Satellite-Based Augmentation System (SBAS) coverage is unable to meet existing navigation and landing requirements due to insufficient satellite coverage or availability (e.g., some locations in Alaska). GBAS Category II/III systems may be installed at higher usage airports that require more capable navigation and landing services.

A single GBAS system provides precision-approach capabilities to multiple runways or landing areas. GBAS provides precision-approach service that is robust to atmospheric phenomena that might cause loss of SBAS vertical guidance.

A-2.3.2.2 Mid-Term Operational Scenario

TBD

A-2.3.2.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-17.

Table A-17. GBAS Precision Approaches–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.3 OI – Expanded Radar-Like Services to Secondary Airports (102138)

This OI is intended to increase capacity and improve safety in IMC at some secondary airports, through the provision of expanded ANSP services and enhanced surveillance coverage and search and rescue coordination.

A-2.3.3.1 High Level Mid-Term Capabilities

Expanded delivery of radar-like coverage with surveillance alternatives such as ADS-B coverage, combined with other radar sources, and with an expansion of communication coverage provides equipped aircraft with radar-like services to secondary airports.

Equipped aircraft automatically receive airborne broadcast traffic information. Surface traffic information is also available at select non-towered satellite airports.

Enhanced surveillance coverage in areas of mountainous terrain where radar coverage is limited, especially to small airports, enables ANSP to provide radar-like services to equipped aircraft. This capability enhances alerting and emergency services beyond normal radar coverage areas.

A-2.3.3.2 Mid-Term Operational Scenario

TBD

A-2.3.3.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-18.

Table A-18. Expanded Radar-Like Services to Secondary Airports–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.4 OI – Wake Turbulence Mitigation for Arrivals: CSPRs (102144)

This OI is the arrival corollary to the previously-discussed WTMD: Wind-Based Wake Procedures (102140). It will use wind observations and forecasts and advanced wake modeling to accurately predict the transport and decay of wake vortices, potentially allowing reduced arrival separation criteria to be applied on a case-by-case basis. Automation will be developed to advise the controller when the separation criteria can be reduced from current levels.

A-2.3.4.1 High Level Mid-Term Capabilities

This OI will be introduced in stages. Initially, dependent separation between aircraft on parallel approach courses to CSPRs will be procedurally reduced in IMC in all crosswind conditions to something less than today's wake separation behind heavy or B757 aircraft based on a safety analysis of the airport geometry, local meteorology, and other factors at each airport. Further separation reduction will be permitted down to radar minima for dependent approaches (1.5 nm stagger) using wind sensing and prediction systems to determine when crosswinds are sufficiently stable and strong enough that wake turbulence drift and decay will ensure safe separation reduction. A decision support aid will indicate to the controller when stable crosswinds (both measured and predicted) will ensure that the upwind approach is safe from wakes generated from heavy or B757 aircraft on the downwind approach.

Changes to wake separation minima are implemented based on measured and predicted airport area winds. Supporting procedures, developed at applicable locations based on analysis of wake measurements and safety, allow more closely spaced arrival operations increasing airport/runway capacity in IMC. During peak demand periods, these procedures allow airports to increase airport arrival throughput during IMC and favorable wind conditions. Implementation of changes in procedures and standards, as well as the implementation of new technology, will safely reduce the impact of wake vortices on airport IMC arrival operations. The achieved separation reduction will depend on the specific lead/trail aircraft pair when crosswinds are taken into account, and could default to the radar minima of 1.5 nm stagger based on wind blowing an aircraft's wake away from the parallel runway's operating area.

Crosswind dependent wake-based arrival procedures at specific airports will be deployed with corresponding operating periods. As technology matures and further study provides more detail and accuracy for wake turbulence drift and decay predictions, the amount of time that reduced wake separation procedures will be available will increase.

A-2.3.4.2 Mid-Term Operational Scenario

TBD

A-2.3.4.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-19.

Table A-19. Wake Turbulence Mitigation for Arrivals: CSPRs–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.5 OI – Use Optimized Profile Descent (102124)

OPDs (also known as CDAs) will permit aircraft to remain at higher altitudes on arrival at the airport and use lower power settings during descent. OPD arrival procedures will provide for lower noise and more fuel-efficient operations. The air navigation service provider procedures and automation accommodate OPDs will be employed, when operationally advantageous.

Predominantly, NAS-published arrival procedures contain combinations of descending and level segments when defining paths from cruise airspace to a runway-approach procedure. Level segments require use of higher engine power settings, resulting in excess fuel consumption and noise. There is a critical need for procedures that optimize aircraft fuel efficiency, resulting in reduced user operating costs and less emissions and noise.

An initial step toward providing such procedures is to design conventional or RNAV arrivals (STAR) designed to allow aircraft equipped with FMS Vertical Navigation (VNAV) to fly a more fuel-efficient and less noisy trajectory.

A-2.3.5.1 High Level Mid-Term Capabilities

An OPD, in its optimal form, is an arrival where aircraft is cleared to descend from cruise altitude to final approach using the most economical power setting at all times. Based on published arrival procedures at final approach, aircraft begin a continuous rate of descent using a window of predetermined height and distance. Thrust may be added to permit a safe, stabilized approach-speed and flap-configuration down a glide slope to the runway.

As an initial step, conventional or RNAV STARs can be defined with vertical constraints incorporated as crossing restrictions. Careful selection of constraints allows most aircraft FMS VNAV systems to calculate a continuously descending flight path, although the flight path may require a slightly non-optimal power setting. In addition, static spacing guidance, based on weight class and winds, as well as speed commands for descending traffic, allows STAR to be used with minimal impact to airport throughput, although with a slight additional environmental penalty compared to the ideal STAR OPD.

At busy airports, achieving full fuel/emissions/noise benefits will be difficult without impacting capacity, unless advanced avionics and/or ground capabilities, and perhaps larger-scale airspace redesign are added.

A-2.3.5.2 Mid-Term Operational Scenario

TBD

A-2.3.5.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-20.

Table A-20. Use Optimized Profile Descent–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.6 OI – Low Visibility Surface Operations (107202)

This OI will allow aircraft and ground vehicle movement on airports in low visibility conditions to be guided by accurate location information and moving map displays, thereby increasing safety, access to the ground movement areas, situation awareness and plan-ahead capability.

A-2.3.6.1 High Level Mid-Term Capabilities

Aircraft and ground vehicles determine their position on an airport from GPS, WAAS, LAAS, via ADS-B and GBT systems with or without surface based surveillance. Location information of aircraft and vehicles on the airport surface is displayed on moving maps using CDTI or aided by EFVS, EVS, SVS or other types of advanced vision or virtual vision technology.

A-2.3.6.2 Mid-Term Operational Scenario

TBD

A-2.3.6.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-21.

Table A-21. Low Visibility Surface Operations–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.7 OI – Low Visibility/Ceiling Approach Operations (107117)

This OI will result in an improved ability to safely and successfully fly approaches in low visibility/ceiling conditions for aircraft equipped with some combination of advanced navigation systems derived from augmented GNSS or ILS and other cockpit-based technologies or combinations of cockpit-based technologies and ground infrastructure.

A-2.3.7.1 High Level Mid-Term Capabilities

The ability to complete approaches in low visibility/ceiling conditions is improved for aircraft equipped with some combination of navigation derived from augmented GNSS or ILS and HUD, EFVS, SVS, advanced vision system and other cockpit-based technologies that combine to improve human performance. Cockpit-based technologies allow instrument approach procedure access with reduced requirements on ground-based navigation and airport infrastructure. Due to onboard avionics airport access is maintained in low visibility/ceiling conditions.

A-2.3.7.2 Mid-Term Operational Scenario

TBD

A-2.3.7.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-22.

Table A-22. Low Visibility/Ceiling Approach Operations–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.8 OI – Low Visibility/Ceiling Landing Operations (107118)

This OI will enhance the ability to land in low visibility/ceiling conditions for aircraft equipped with some combination of navigation derived from augmented GNSS or ILS and other cockpit-based technologies or combinations of cockpit-based technologies and ground infrastructure.

A-2.3.8.1 High Level Mid-Term Capabilities

The ability to land in low visibility/ceiling conditions is improved for aircraft equipped with some combination of navigation derived from augmented GNSS or ILS, and HUD, EFVS, SVS, advanced vision system and other cockpit-based technologies that combine to improve human performance. Cockpit-based technologies allow instrument approach procedure access with reduced requirements on ground-based navigation and airport infrastructure. Due to onboard avionics airport access is maintained in low visibility/ceiling conditions.

A-2.3.8.2 Mid-Term Operational Scenario

TBD

A-2.3.8.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-23.

Table A-23. Low Visibility/Ceiling Landing Operations–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.9 OI – Low Visibility/Ceiling Takeoff Operations (107115)

This OI leverages some combination of HUD, EFVS, SVS, or advanced vision system capabilities to allow appropriately equipped aircraft to takeoff in low visibility conditions. Due to onboard avionics the aircraft will be less dependent on ground based infrastructure at the airport while conducting take-off operations.

A-2.3.9.1 High Level Mid-Term Capabilities

Currently, visibility minimums for takeoff are dependent on aircraft equipment, ground infrastructure, and runway marking and lighting. This ensures that pilots are able to visually maintain the runway centerline during both nominal and aborted takeoffs. By using cockpit-based technologies such as HUD, EFVS, SVS or other advanced vision system technologies, the pilot will be able to maintain an equivalent awareness of runway centerline with reduced dependence on airport infrastructure when visual conditions are below those normally required for takeoff.

A-2.3.9.2 Mid-Term Operational Scenario

TBD

A-2.3.9.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-24.

Table A-24. Low Visibility/Ceiling Takeoff Operations–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.10 OI – Low Visibility/Ceiling Departure Operations (107116)

This OI leverages augmented GNSS capabilities to allow appropriately equipped aircraft to depart in low visibility conditions. Due to onboard avionics the aircraft will be able to depart in low visibility conditions using RNAV/RNP SIDs, EFVS, SVS, or advanced vision systems.

A-2.3.10.1 High Level Mid-Term Capabilities

In order to depart an airfield and enter the enroute structure the aircraft must be able to achieve a minimal prescribed climb performance in order avoid any natural or man-made hazard. If an aircraft cannot meet the required climb performance the aircraft will be able to either use precision navigation or visual see and avoid procedures that enable the aircraft to avoid the hazard while flying at a lower required rate of climb.

Precision navigation will allow for the pilot to safely depart the airfield at a lower climb rate while still maintaining a safe buffer from the hazard.

When the pilot elects to use a see-and-avoid option for the departure, the pilot would normally be required to meet a minimal visibility and/or ceiling requirement to go along with a lower than normal climb performance. By using EFVS, SVS, or an advanced vision system, the pilot would be able to elect the see-and-avoid procedure by achieving an equivalent level of safety to the natural vision requirements.

A-2.3.10.2 Mid-Term Operational Scenario

TBD

A-2.3.10.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-25.

Table A-25. Low Visibility/Ceiling Departure Operations–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.11 OI – Expanded Low Visibility Operations using Lower RVR Minima (107119)

By allowing RVR minima to be lowered from 2400 feet to 1800 feet (or lower depending on the airport and requirement) at selected airports using RVR systems, aircraft capabilities and procedural changes, this OI provides greater access to OEP, satellite and feeder airports during low visibility conditions. Utilization of these improvements will increase NAS capacity and traffic flow during periods of IMC and allowing a greater number of aircraft completing scheduled flights under marginal weather conditions. Without these improvements, flight are either diverted or delayed, both with rippling impact throughout the NAS and a high cost associated with them.

A-2.3.11.1 High Level Mid-Term Capabilities

This improvement allows increased runway capacity during periods of low visibility by providing increased arrivals/departures at high density airports. It also allows the airlines to maintain planned scheduled flights in marginal weather conditions to decrease flight delays, cancellations, and/or very costly diversions. Capacity in NAS is also increased through use of a greater number of airports, extending the base capacity beyond the OEP core. Flight Standards is instituting reduced takeoff and landing minima across the NAS based on RVR and in certain cases, installation of additional RVR are required.

This NextGen program realizes Near-Term benefits that enable other Mid-Term and Far-Term OIs. It also addresses improvements to low visibility operations throughout the NAS. This improvement achieves RNAV benefits as stipulated in the NextGen Implementation Plan and the Roadmap for Performance-Based Navigation.

A-2.3.11.2 Mid-Term Operational Scenario

TBD

A-2.3.11.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-26.

Table A-26. Expanded Low Visibility Operations using Lower RVR Minima–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.12 OI – Provide Full Surface Situation Information (102406)

This OI provides a digital display of the airport environment through the automated broadcast of aircraft and vehicle position to ground and aircraft sensors/receivers. Aircraft and vehicles are identified and tracked to provide a full comprehensive picture of the surface environment to ANSP, equipped aircraft, and FOCs.

Surface Situation Information will complement visual observation of the airport surface. Decision support system algorithms will use enhanced target data to support identification and alerting of those aircraft at risk of runway incursion. In addition, non-ANSP functions, such as airport (movement and non-movement areas) and security operations will benefit from information exchange and situational awareness of aircraft and equipped vehicle surface position and movement.

A-2.3.12.1 High Level Mid-Term Capabilities

Service providers, FOCs, and equipped aircraft need an accurate real-time view of airport surface traffic and movement, as well as obstacle location to increase situational awareness of surface operations. Currently, this is difficult because of several factors, including (but not limited to) poor visibility caused by weather or nighttime conditions; poor sight lines; fast-moving surface traffic; no automated capability to predict movement of surface traffic; limited conflict detection; and the volume of moving vehicles in a limited geographic area

Automated broadcast of aircraft and vehicle position to ground and aircraft sensors/receivers provides a digital display of the airport environment. Aircraft and vehicles are identified and tracked to provide a full comprehensive picture of the surface environment to ANSP, equipped aircraft, and FOCs.

Surface Situation Information will complement visual observation of the airport surface. Decision support system algorithms will use enhanced target data to support identification and alerting of those aircraft at risk of runway incursion.

In addition, non-ANSP functions, such as airport (movement and non-movement areas) and security operations will benefit from information exchange and situational awareness of aircraft and equipped vehicle surface position and movement. *[FlexTerm Solution Set Smart Sheet, 2008]*

A-2.3.12.2 Mid-Term Operational Scenario

TBD

A-2.3.12.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-27.

Table A-27. Provide Full Surface Situation Information–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.13 OI – Enhanced Surface Traffic Operations (104207)

There is a need for enhanced surface operations to reduce delay and environmental impacts while increasing throughput at target airports. This OI provides the needed improvement by using data communications between aircraft and ANSP as the means to exchange clearances, amendments, requests, and surface movement instructions. At specified airports, data communications is the principle means of communication between ANSP and equipped aircraft.

A-2.3.13.1 High Level Mid-Term Capabilities

Terminal automation provides the ability to transmit automated terminal information, departure clearances and amendments, and taxi route instructions via data communications, including hold-short instructions. The taxi route instruction data communication function reduces requests for progressive taxi instructions. Benefits arising from this capability, in conjunction with other NAS investments, include enhanced airport throughput, controller efficiency, enhanced safety, as well as reduced fuel-burn and emissions.

At the outset, the current system will be expanded to include provision of initial and revised departure clearances directly to the aircraft. Initial and revised taxi route instructions will be added, replacing today's use of voice to accomplish these activities. As a second step, Aeronautical Telecommunication Network (ATN)-based capabilities will be added, replacing much of today's system.

A-2.3.13.2 Mid-Term Operational Scenario

TBD

A-2.3.13.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-28.

Table A-28. Enhanced Surface Traffic Operations–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.14 OI – Improved Runway Situational Awareness for Controllers (103207)

This OI is intended to provide a range of capabilities to help improve runway safety for medium- to large-sized airports.

A-2.3.14.1 High Level Mid-Term Capabilities

At large airports, current controller tools provide surface displays and can alert controllers when aircraft taxi into areas where a runway incursion could result. Additional ground-based capabilities will be developed to improve runway safety, including the expansion of runway surveillance technology (i.e., ASDE-X) to additional airports, deployment of low cost surveillance for medium-sized airports, improved runway markings, and initial controller taxi conformance monitoring capabilities.

A-2.3.14.2 Mid-Term Operational Scenario

TBD

A-2.3.14.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-29.

Table A-29. Improved Runway Situational Awareness for Controllers–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.3.15 OI – Improved Runway Situational Awareness for Pilots (103208)

This OI is intended to enhance runway safety operations by providing pilots with improved awareness of their location on the airport surface as well as runway incursion alerting capabilities.

A-2.3.15.1 High Level Mid-Term Capabilities

To help minimize pilot disorientation on the airport surface, a surface moving map display with ownship position will be available. Both ground-based (e.g., Runway Status Lights [RWSL]) and cockpit-based runway incursion alerting capabilities will also be available to alert pilots when it is unsafe to enter the runway. Additional enhancements may include cockpit display of surface traffic (e.g., vehicles and aircraft) and the use of a cockpit display that depicts the runway environment and displays traffic from the surface up to approximately 1,500 feet above ground level on final approach and will be used by the flight crew to help determine runway occupancy.

A-2.3.15.2 Mid-Term Operational Scenario

TBD

A-2.3.15.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-30.

Table A-30. Improved Runway Situational Awareness for Pilots–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.4 Improved Collaborative Air Traffic Management (CATM)

This solution set covers strategic and tactical flow management, including interactions with operators to mitigate situations when the desired use of capacity cannot be accommodated. CATM Solution Set includes flow programs and collaboration on procedures that will shift demand to alternate resources (e.g. routings, altitudes, and times). CATM also includes the foundational information elements for managing NAS flights. These elements include development and management of aeronautical information, management of airspace reservation, and management of flight information from pre-flight to post-flight. Of all the NextGen Solution Sets, the CATM Solution Set almost certainly has the greatest number of ATM-weather integration opportunities and needs, and the Continuous Flight Day Evaluation OI is the key to the success of CATM.

Current tools for managing ATM system demand and capacity imbalances are relatively coarse. Optimal solutions would minimize the extent to which flights are either over or under constrained. Flight restrictions unnecessarily interfere with operator objectives and the cost of travel. Situations where constraints are less than optimal similarly generate excess costs. Restrictions also inhibit operators from specifying a preferred alternative and restrain their involvement in resolving imbalance issues.

The overall philosophy driving the delivery of CATM services in the NextGen is to accommodate flight operator preferences to the maximum extent possible. Restrictions should be imposed only when a real operational need exists, such as meeting capacity, safety, security, or environmental constraints. CATM proposes to adjust airspace and other assets to satisfy forecast demand, rather than constraining demand to match available assets. If restrictions are required, the goal is to maximize the opportunity for an airspace operator to resolve them, based on enlightened historical information.

CATM is intended to allow TMs to deliver an optimal plan to manage NAS air traffic in the face of constraints of all types, including weather. CATM is not a one-time effort done at the beginning of the day, and then forgotten as the events of the day unfold. Instead, CATM is an iterative process that is agile enough to change strategic direction as constraints materialize.

By its very name and nature, CATM requires involvement and input from all three populations that make up the CDM community: pilot, FOC and ATC personnel. This will be especially true in NextGen, as a tight, precise choreography will be required in order to squeeze additional capacity from the NAS.

The OI connectivity depicted in Figure A-29 is provided by SWIM. The information exchange between OIs is enabled by the following NextGen Information Services:

- Initial integration of weather information into NAS automation and decision making, which will rely on the 4-D Weather Data Cube and its SAS, and the downstream translation of weather into constraints.
- On Demand NAS Information (i.e., an information service that disseminates constraint information; capacity, demand, and congestion models; and mitigation strategies).

Collaboration is enabled through common ANSP/user access to the information provided by these information services. Access to this information by DSTs across solution sets and NAS domains enables an integrated NextGen system.

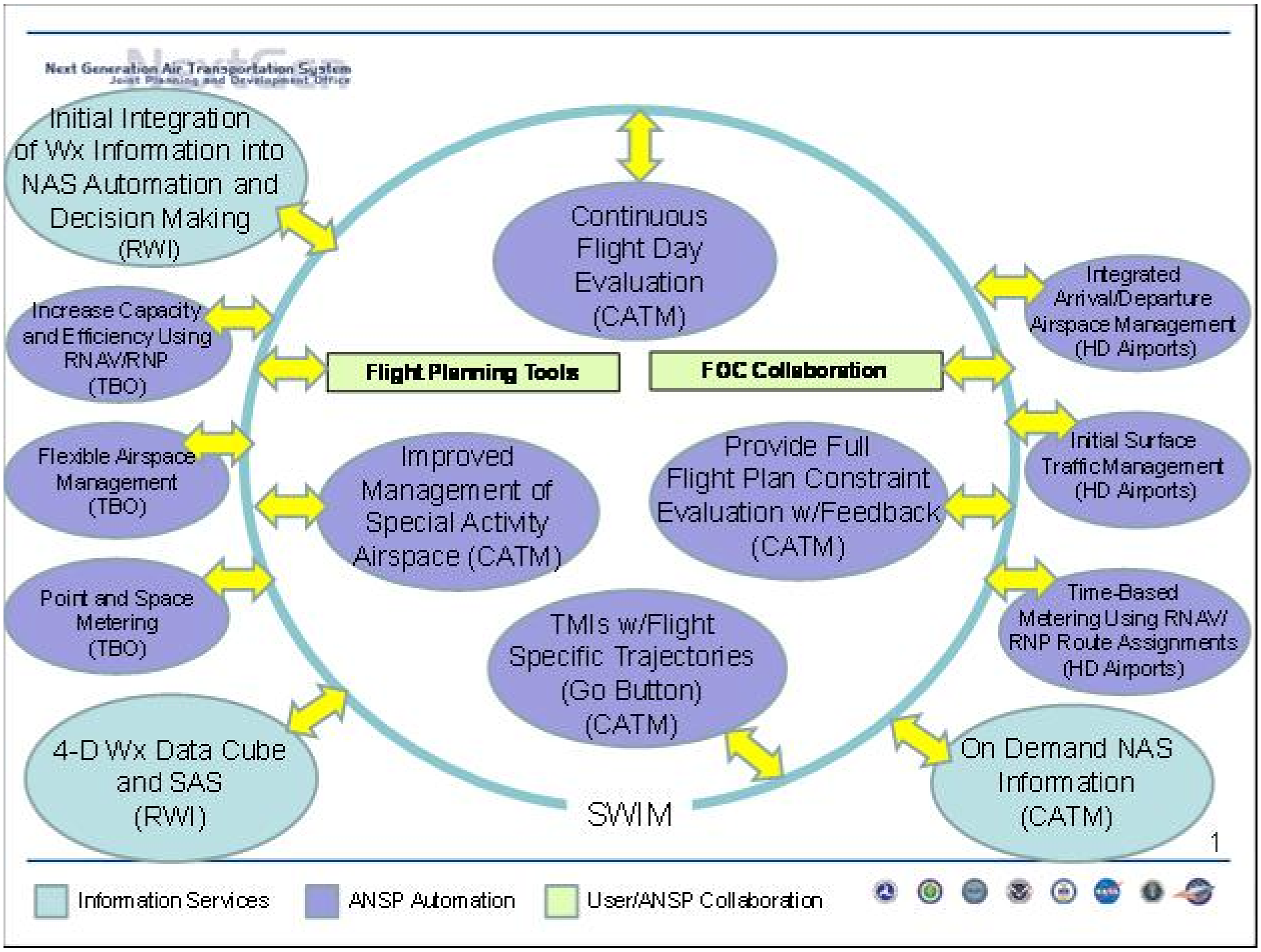


Figure A-29. CATM ATM-Weather Integration Connectivity

The Mid-Term OIs of interest are listed here in the order in which they appear as brick red-colored timelines in the CATM Figure A-30:

- Continuous Flight Day Evaluation
- Traffic Management Initiatives with Flight Specific Trajectories
- Improved Management of Special Activity Airspace
- Provide Full Flight Plan Constraint Evaluation with Feedback
- On-Demand NAS Information

Over time, Far-Term OIs (represented by the light blue shaded timelines in the figures) may be added to this analysis.

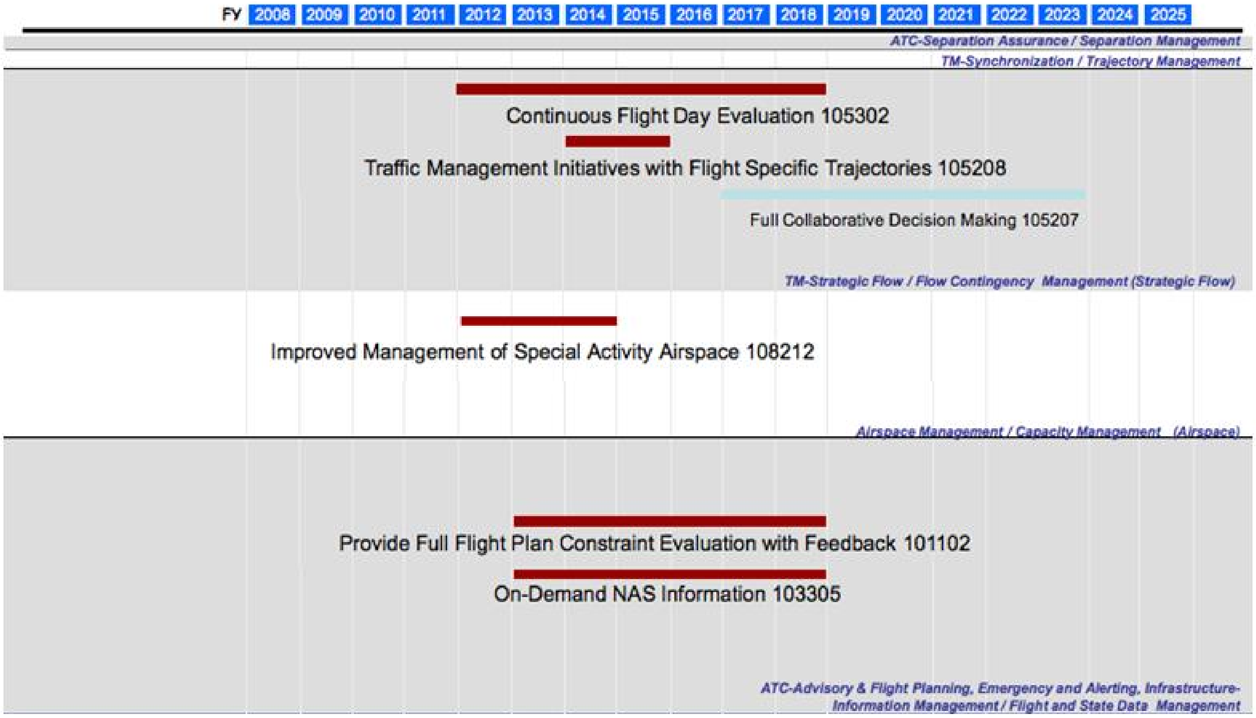


Figure A 30. Improve Collaborative ATM Timeline

A-2.4.1 OI – Continuous Flight Day Evaluation (105302)

Continuous Flight Day Evaluation is intended to improve long-term planning through continual performance assessment, and impose fewer en route capacity constraints by applying tailored incremental responses to predicted congestion.

Traffic-flow managers currently assess their performance after each day and use this information in future operations. This activity is not routine during the day, nor are consistent performance measures used among traffic flow managers. A robust suite of DSTs is required in continuous real-time. These tools will be used to monitor, evaluate, and adjust TMIs. The intended purpose will be based on a commonly agreed upon set of system performance measures. The measures should impose minimum constraints on airport, terminal airspace, and en route airspace capacity.

A-2.4.1.1 High Level Mid-Term Capabilities

Performance analysis, where throughput is constrained, is the basis for strategic operations planning. Continuous (real-time) constraints are provided to ANSP traffic management DSTs and NAS users. Evaluation of NAS performance is both a real-time activity feedback tool and a post-event analysis process. Flight day evaluation metrics are complementary and consistent with collateral sets of metrics for airspace, airport, and flight operations.

ANSPs and users collaboratively and continuously assess (monitor and evaluate) constraints (e.g., airport, airspace, hazardous weather, sector workload, NAVAID outages, security) and associated TMI mitigation strategies. Users and ANSP dynamically adjust both pre-departure and airborne trajectories in response to anticipated and real-time constraints.

ANSP, in collaboration with users, develops mitigation strategies that consider the potential constraints. A pre-defined set of alternatives is developed that maximizes airspace and airport capacity and throughput. ANSP and users use (real-time) constraint information and these mitigation strategies to increase operational predictability and throughput.

ANSP automation traffic management DSTs perform a post-operational assessment of NAS performance. This capability includes ANSP automation to collect and support the analysis of airspace, airport, and flight day operational data as part of a comprehensive post-flight day analysis capability applicable to multiple domains and for multiple purposes. Flight day metrics are compared with performance metrics from each element of the system (e.g., aircraft, pilot, controller, airspace). NAS and operational resources are aligned to meet anticipated demand. This improves the ANSP pre-defined shared plans.

Long-term planning functions will improve due to Continuous Flight Day Evaluation. NAS performance will be improved and decision-makers will be able to predict and plan operations based on a validated tool.

The capability to conduct continuous, real-time, strategic performance analysis to assess constraints and implement associated impact mitigation strategies makes Continuous Flight Day Evaluation a robust ATM integration function, which ties together numerous OIs and solution sets.

Continuous Flight Day Evaluation does the following:

- Ingests predicted weather and non-weather constraint information 0-5 days out and aggregates it to determine estimates of future airport and airspace system resource capacity (i.e., NAS capacity model)
- Ingests demand information and develops a NAS demand model
- Analyzes these models to predict system congestion (i.e., demand/capacity imbalances) and develops a NAS congestion model
- Provides information that allows traffic managers and users to collaboratively develop pre-defined strategies and alternatives to resolve anticipated congestion
- Provides information that allows traffic managers to select from alternative strategies and monitor, evaluate, and adjust as imbalance estimates change

The capabilities of Continuous Flight Day Evaluation and its interactions with NextGen information services are depicted in Figure A-31 and described below.

Continuous Flight Day Evaluation obtains weather constraint information from Initial Integration of Weather Information into NAS Automation and Decision Making and non-weather impact information from On Demand NAS Information. It then combines weather and non-weather constraint information to determine the aggregate NAS constraint. This aggregation of constraints is a complex operation, which will require extensive research and development.

The aggregate constraint information is used by Continuous Flight Day Evaluation to determine the NAS capacity model, which, in turn, is stored by On Demand NAS Information and made available to all stakeholders. Continuous Flight Day Evaluation next obtains NAS demand information from On Demand NAS Information, and determines the NAS demand model. This demand model information is also stored by On Demand NAS Information and made available to all stakeholders.

Continuous Flight Day Evaluation next identifies imbalances in the demand and capacity models and develops a NAS congestion model, which is also stored by On Demand NAS Information and made available to all stakeholders. Lastly, Continuous Flight Day Evaluation enables traffic managers and users to collaboratively develop pre-defined strategies and alternatives to resolve anticipated system imbalances, and allows traffic managers to select/modify alternative strategies as required and as imbalance estimates change. These strategies are also stored by On Demand NAS Information and made available to all stakeholders.

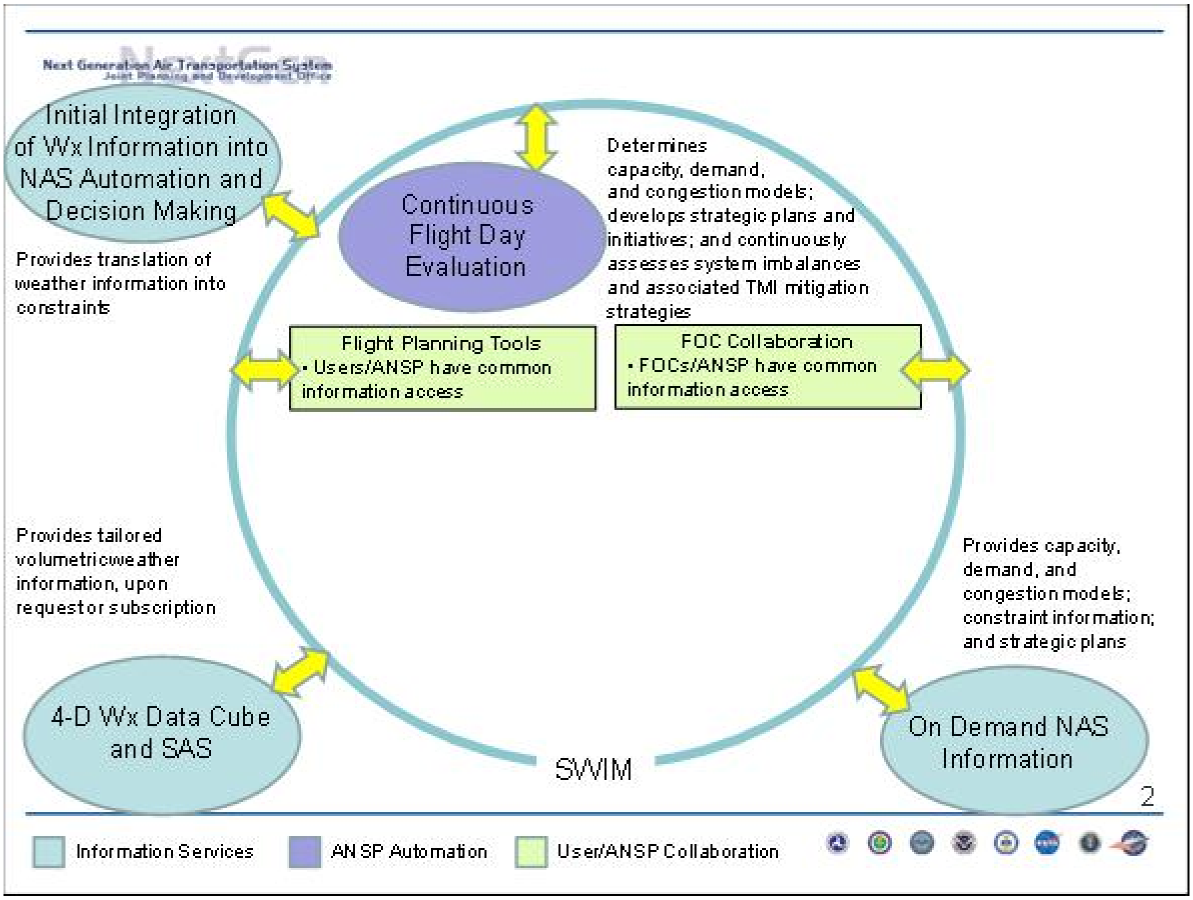


Figure A 31. Continuous Flight Day Evaluation Interactions

A-2.4.1.2 Mid-Term Operational Scenario

TBD

A-2.4.1.3 Mid-Term Weather Integration and Needs Analysis

From a weather integration perspective, Initial Integration of Weather Information into NAS Automation and Decision Making performs the following time-dependent weather-related functions at the request of Continuous Flight Day Evaluation:

- Determine weather constraints on NAS airspace and airport resources 1-5 days in advance, using predicted weather information such as ensemble and/or probabilistic forecasts, to enable identification of staffing needs (e.g., identify forecast model consistency over time, identify forecast consistency between different forecast models, evaluate weather forecast probability to determine potential impacts on controller staffing levels)
- Determine weather constraints on NAS airspace and airport resources 24 hours in advance, using predicted weather probability information such as PDFs, to enable the determination of alternative strategic plans (i.e., what are the most likely predicted weather patterns to plan for and what is the anticipated resource capacity for each)
- Determine weather constraints on NAS airspace and airport resources eight hours in advance, using predicted weather by volume information, to enable refinement of strategic plans
- Determine weather constraints on NAS airspace and airport resources 2 hours in advance, using predicted weather by trajectory information, to enable selection of strategic planning alternatives
- When longer term (~2 hour) weather predictions prove to be inaccurate, determine weather constraints on NAS airspace and airport resources 0-40 minutes in advance, using near term predicted weather by trajectory information, to enable tactical modification of strategic plans implemented two hours in advance

Using the above weather constraint translations along with non-weather constraint information obtained from On Demand NAS Information, Continuous Flight Day Evaluation determines airport and airspace resource capacity, (i.e., develops a capacity model) by aggregating the impacts of weather and non-weather constraints, and develops a corresponding demand model using “flight object” information. These two models are then analyzed and a congestion model is developed, from which traffic managers and users can develop mitigation strategies. As time to constraint decreases, traffic managers can modify strategies as conditions change and select strategies as necessary.

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-31.

Table A-31. Continuous Flight Day Evaluation—Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Determine weather constraints on NAS airspace and airport resources 1-5 days in advance, using predicted Wx information such as ensemble and/or	Probabilistic and/or ensemble forecasts out 5 days: •Convective weather (CONUS) •Winter weather (e.g., snow, freezing mix)	TBD	TBD

probabilistic forecasts, to enable identification of staffing needs (e.g., identify forecast model consistency over time, identify forecast consistency between models, evaluate weather forecast probability to determine potential impacts on controller staffing levels)	*Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*		
Determine weather constraints on NAS airspace and airport resources 24 hours in advance, using predicted Wx probability information such as PDFs, to enable the determination of alternative strategic plans (i.e., what are the most likely predicted weather patterns to plan for and what is the anticipated resource capacity for each)	Probabilistic forecasts out 24 hrs: •Convective weather (CONUS) •High density terminal airspace winds (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) •High density terminal airspace convection •Airport ceiling/ visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	TBD	TBD
Determine weather constraints on NAS airspace and airport resources 8 hours in advance, using predicted Wx by volume information, to enable refinement of strategic plans	Probabilistic forecasts out 8 hrs •Convective weather (CONUS) •High density terminal airspace winds (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) •High density terminal airspace convection •Airport ceiling/ visibility	TBD	TBD

	Accuracy TBD *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*		
Determine weather constraints on NAS airspace and airport resources 2 hours in advance, using predicted Wx by trajectory information, to enable selection of strategic planning alternatives	Probabilistic forecasts out 2 hrs •Convective weather (CONUS) *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	TBD	TBD
Determine weather constraints on NAS airspace and airport resources 0-40 minutes in advance, using predicted Wx by trajectory information, to enable tactical modification of strategic plans implemented 2 hours in advance	Probabilistic and deterministic forecasts out 0-40 min •Convective weather (CONUS) *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	TBD	TBD

A-2.4.2 OI – Traffic Management Initiatives with Flight Specific Trajectories (105208)

TMIs with Flight Specific Trajectories provides a mechanism to implement TMIs generated by Continuous Flight Day Evaluation in a tailored flight-specific manner.

The current automation does not support the assignment of flight-specific trajectories. The ANSP needs to incrementally perform more surgical flight-specific TMIs that will be less disruptive to the system.

Today, the process of identifying and resolving congestion associated with severe convective weather and other constraints (unexpected events, special activity airspace, etc.) is time consuming and imprecise. The current process of identifying and assigning traffic management initiatives such as reroutes and delays to manage congestion are labor intensive for both traffic managers and users. Users have limited options and resources are often underutilized due to conservative approach and non-tailored flight-specific solutions.

A-2.4.2.1 High Level Mid-Term Capabilities

Individual flight-specific trajectory changes resulting from TMIs will be disseminated to the appropriate ANSP automation for tactical approval and execution. This capability will increase the agility of the NAS to adjust and respond to dynamically changing conditions such as bad weather, congestion, and system outages.

TFM automation prepares TMIs appropriate to the situation at the flight-specific level. After ANSP approval, changes/amendments are electronically delivered to the controller for in-flight operations.

TFM automation will continue to incorporate enhancements, including DSTs to enable the collaborative process among service providers and NAS users in the development and implementation of congestion resolutions. DSTs will encompass integration of probabilistic information, management of uncertainty, what-if analysis, and incremental resolution of alternatives supporting development and implementation of flexible, incremental traffic management strategies to maintain the congestion risk to an acceptable level and to minimize the impact to the flights involved in the congestion. The strategies are monitored and modified or canceled to avoid underutilization of resources and over conservative actions. The resolutions may include one or more TMIs such as ground delay, reroutes, altitude profile changes, airspace schedules and if necessary MIT. The automation will propose to the TM flight-specific tailored resolutions or changes (reroutes, altitude, schedules changes) that take into account and accommodate NAS user preference when possible. Impact assessment of the resolution is also presented to the TM to enable the decision to modify, cancel or execute a given initiative. Once the TM decides on the initiative, flight-specific changes are disseminated with automation support to ATC personnel and NAS users to enable the implementation of the strategy and maintain common situational awareness (i.e., knowing why a given flight has been changed).

As Figure A-32 depicts, there is a significant interaction among the following OIs that must be discussed in order to more completely understand the capabilities of TMIs with Flight Specific Trajectories:

- ANSP Automation
  - TMIs with Flight Specific Trajectories (Go Button)
  - Continuous Flight Day Evaluation
- Information Services
  - On Demand NAS Information (i.e., an information service that disseminates constraint information; capacity, demand, and congestion models; and mitigation strategies)
  - 4-D Wx Data Cube and its SAS
  - Initial Integration of Weather Information into NAS Automation and Decision Making (i.e., weather constraint translation information)
- User Collaboration
  - FOC decision making
  - Flight planning

Continuous Flight Day Evaluation provides the information that allows traffic managers to select from alternative strategies and monitor, evaluate, and adjust TMIs as capacity/demand imbalance estimates change. TMIs with Flight Specific Trajectories implements these TMIs in a tailored flight-specific manner. It does so by determining which aircraft are impacted by TMIs, modifying flight specific trajectories in collaboration with users, and communicating the new trajectories to controllers and users via data link.

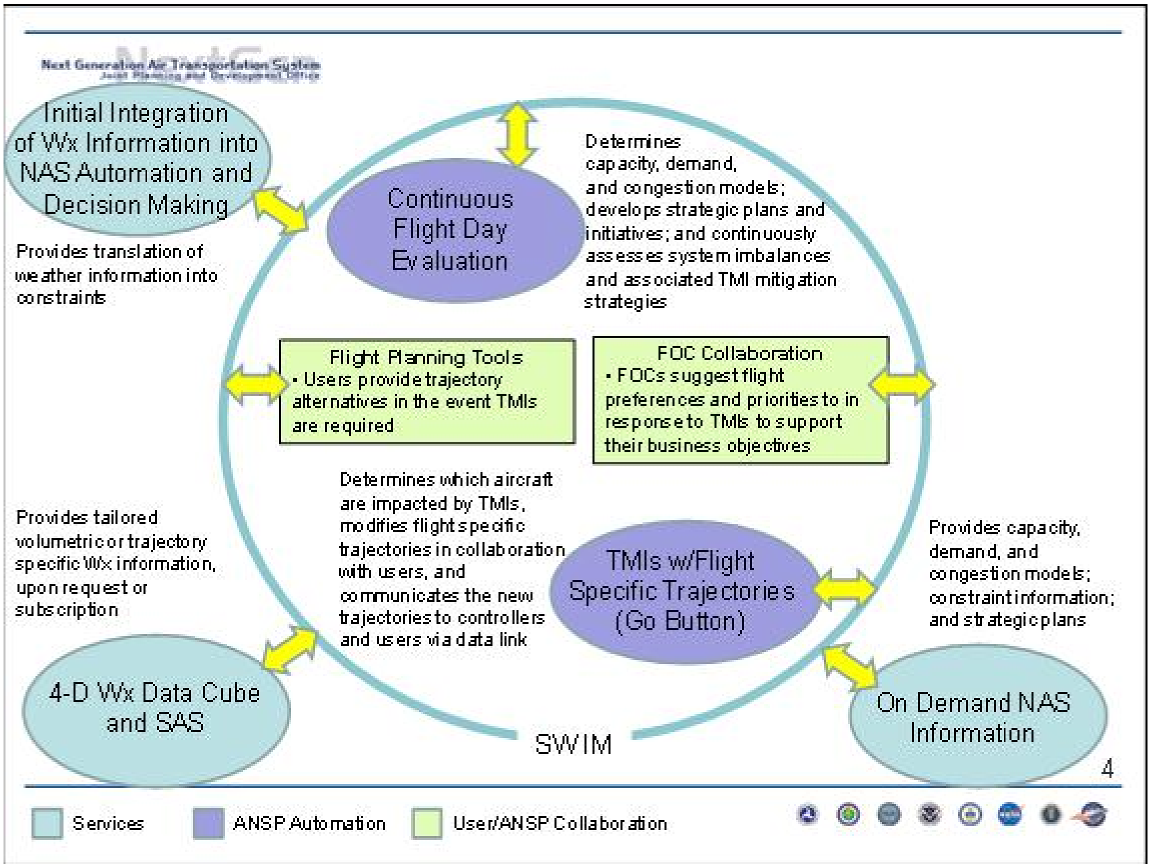


Figure A-32. Traffic Management Initiatives with Flight Specific Trajectories (Go Button) Interactions with Other OIs

A-2.4.2.2 Mid-Term Operational Scenario

TBD

A-2.4.2.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-32.

Table A-32. Traffic Management Initiatives with Flight Specific Trajectories–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.4.3 OI – Improved Management of Special Activity Airspace (108212)

The goal of this OI is to enhance the coordination and communication of SAA information, enabling airspace to be used more consistently and efficiently by ATM personnel and operators.

Both NAS service providers and NAS users need a common, accurate, and timely understanding of the status of airspace for special activities (also referred to as SAA) so that their collaborative planning and decision-making can be done efficiently and effectively. Currently, although most daily SAA status information is readily available in electronic form for immediate use by en route and/or TFM automation via the FAA's SUA Management System (SAMS), there has been no integration of this information across FAA systems. Automated computer–to-computer communications, with acknowledgements, is needed between the DOD scheduling agencies and SAMS.

ANSPs and NAS users need a common, accurate, and timely understanding of the shape and status of airspace designated for special activity usage to support collaborative planning and decision-making and to ensure safe flight. In the current architecture and environment, there is a lack of comprehensive and integrated management of SAA information and processes. The SAMS is the primary system for storing and managing information related to SAAs and to some Air Traffic Control Assigned Airspace (ATCAA). Limitations with the current implementation of SAMS include:

- Long lead-time (56 days) for updates of SAA geometry and other characteristics from the National Airspace System Resource (NASR) database
- Manual data entry process for updating SUA information from NASR and ATCAA information from the National ATCAA database
- SAA information is copied to a compact disk and loaded manually into SAMS
- Text-based ATCAA definitions are parsed from the National ATCAA and re-created into SAMs
- Schedule requests can be made for military use (i.e., SAA) using the Military Airspace Data Entry (MADE) web-based system, but this is not always used, as some military users still use voice and fax to make request to ATC military liaisons
- There is no automated support for non-military SAA reservation requests
- There is no automated feed to "downstream" systems, such as ERAM and ETMS/TFMS, which need SAA definitions, schedules and activation status. This status is entered manually in each system, although ERAM has ERAM-to-ERAM data exchange of status to provide the information to other ERAMs if entered in one ERAM
- Current web-based SAA status display for NAS users is manually updated on an irregular basis

The existing environment does not provide automated management of SAA information to achieve common situational awareness across the NAS, thus limiting collaborative flight planning and ATM. Automation is needed to support the processes of SAA definition (geometry and other characteristics), scheduling, and activation status management and notification. This capability must ensure that all types of SAA usage are dealt with in a consistent and efficient manner, and that network-enabled information sharing is supported where applicable.

A-2.4.3.1 High Level Mid-Term Capabilities

SAA assignments, schedules, coordination, and status changes are conducted automation-to-automation. Changes to the status of SAA are readily available for operators and ANSP. Status changes are transmitted to the flight deck via voice or data communications. Flight trajectory planning is managed dynamically based on real-time use of airspace.

Airspace use is optimized and managed in real time, based on actual flight profiles and real-time operational use parameters. Airspace reservations for military operations, unmanned aircraft system flights, space flight and re-entry, restricted or warning areas, and flight training areas are managed on an as-needed basis. Enhanced automation-to-automation communications and collaboration enables decision-makers to dynamically manage airspace for special use, increasing real-time access and use of unused airspace.

This will enable ANSP DSTs, integrated with automation-to-automation flight planning, to have increased access and improved coordination of airspace use.

Flight deck automation is enhanced to include data communications capabilities and to recognize SAA-encoded data. The SAA status is available via uplink to the cockpit in graphical (e.g., additional airspace information over Flight Information Service-Broadcast [FIS-B]) and automation-readable form, supporting pre-flight and in-flight planning.

SAA management will follow a consistent and comprehensive process, adopting a life-cycle view for SAA information. The SAA lifecycle process includes the following elements:

- SAA Definition - The definition process involves the creation of an SAA by defining a geometric volume and designating it as a specific SAA type (e.g., MOA, Restricted Area, ATCAA); and then recording necessary characteristics for that specific volume of airspace such as Using Agency, Controlling Agency, authorized scheduling personnel, scheduling rules, usage rules, and notification requirements.
- SAA Scheduling - Schedule coordination activities include elements such as validating the scheduling request against rules defined for the specific SAA (such as requesting user authorization, scheduling lead-time, and any potential usage rules or restrictions), routing the request to the appropriate controlling agency personnel, and recording the schedule status.
- SAA Activation/Deactivation - The activation process will ensure that all authorized and interested stakeholders are notified of SAA activations, such as ANSP traffic managers and controllers and NAS users. This process may include a final validation of scheduled usage with the requesting agency prior to activation to reduce congestion caused by activation of unused SAA.

Automation will support the SAA lifecycle process described above. SAA geometric definitions and characteristics will be recorded and the information will be made available through SWIM-based information sharing supporting automation-to-automation flight planning. Web-based schedule request tools will allow authorized users to easily make SAA schedule requests, and the requests will be validated against the SAA definition information. Schedule lead times will be enforced on airspace definition and schedule changes to ensure sufficient ability to notify appropriate ANSPs and NAS users (Policies must be updated to reflect changes in operational capabilities). Authorized SAA scheduling personnel will update and manage schedule requests, and information will flow to appropriate designated personnel for review and approval. Tailoring or customized review and approval processes will be supported for each designated area. Automation will allow real-time coordination of activation notification between ANSP systems and support collaborative flight planning with NAS users. Also, flight deck automation is enhanced to include data communications capabilities and recognize SAA-encoded data. The SAA status is available via uplink in graphical and automation-readable format, supporting pre-flight and in-flight planning.

The Aeronautical Information Management (AIM) Communities of Interest (COI) will support adoption of the Aeronautical Information Exchange Model (AIXM) schema as the most appropriate data schema for exchange of SAA requests and schedules.

In summary, the focus of the Improved Management of Special Activity Airspace capability is to improve the sharing of a common, up-to-date understanding of the status of airspace for special use for improved flight planning and airspace management. This involves automation-to-automation access to this information.

There is a significant interaction between the following OIs that must be discussed in order to more completely understand the capabilities of Improved Management of Airspace for Special Use:

- ANSP Automation
  - Improved Management of Airspace for Special Use
  - Flexible Airspace Management
- Information Services
  - On Demand NAS Information (i.e., an information service that disseminates constraint information; capacity, demand, and congestion models; and mitigation strategies)
  - 4-D Wx Data Cube and its SAS
  - Initial Integration of Weather Information into NAS Automation and Decision Making (i.e., weather constraint translation information)
- User Collaboration
  - FOC decision making
  - Flight planning

A-2.4.3.2 Mid-Term Operational Scenario

TBD

A-2.4.3.3 Mid-Term Weather Integration and Needs Analysis

Although there is weather integration involved with Improved Management of Special Activity Airspace, it is performed by other OIs (see discussion of Continuous Flight Day Evaluation) and is therefore transparent to this OI. The weather integration that precedes Improved Management of Special Activity Airspace involves translation of weather into impact by Initial Integration of Weather Information into NAS Automation and Decision Making and its inclusion, along with other non-weather constraint impacts, into the development of a capacity model by Continuous Flight Day Evaluation, which subsequently performs an analysis of imbalances between the capacity and demand models, resulting in a congestion model which Flexible Airspace Management attempts to resolve, perhaps in part by suggesting use of special airspace.

Weather is assumed to be transparent to Improved Management of Special Activity Airspace, as shown in Table A-33. Nevertheless, special activity airspace assignments, schedules, and status changes may be in direct reaction to the impact of weather.

Table A-33. Improved Management of Special Activities Airspace–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.4.4 OI – Provide Full Flight Plan Constraint Evaluation with Feedback (101102)

The intent of this OI is to increase user route flexibility and reduce large nonlinear cost (e.g., diversions) through negotiated trajectory resolutions which include operator business objectives and preferences for avoiding congested areas.

Aircraft operators must plan flights to best meet business objectives; concurrently, traffic-flow managers need to understand the impact of future aircraft operator demand on system capacity. The current system does not provide feedback on any advisories or constraints that affect the flight plan. Currently, the resolution of TFM issues is often done without specific input concerning user flight preferences, or with limited understanding of operator impact of actual or planned NAS constraints on preferred route of flight.

In today’s environment, the NAS user lacks access to NAS information that would allow planning of flights based on current and integrated information on NAS events, status and resources. There is a need for the NAS user to understand the impact of NAS changes on their own flights, allowing them to perform better planning to meet their business need. In addition, the ANSP can benefit from early user information regarding their intended operations to get a better understanding of the demand on NAS resources and proactively collaborate with the user to meet both the user needs and the overall NAS objectives. Based on discussion with the user community, the following deficiencies have been identified:

- Lack of information sharing on preferred routes, restrictions, SUA, and NAS status information in a timely manner
- Inability to perform trial flight planning for the entire route in advance of filing

- Lack of a single NAS user interface to interact with the ANSP system
- Inconsistency of information between ATC and TFM
- Lack of common standard airspace data
- Inefficient processes for conveying user priorities to ATC and TFM

A-2.4.4.1 High Level Mid-Term Capabilities

Timely and accurate NAS information enables users to plan and fly routings that meet their objectives. Constraint information that impacts the proposed route of flight is incorporated into ANSP automation, and is available to users. Examples of constraint information include SUA status, SIGMETS, infrastructure outages, and significant congestion events.

Constraint information is both temporal and volumetric. Constraint volumes can be hard constraints (no access to this volume for this time period), conditional constraints (flights are subject to access control), and advisory constraints (service reduction or significant weather). Flight trajectories are built from the filed flight plan and the trajectory is evaluated against the constraint volumes. Feedback is provided to the filer (not the flight deck) on the computed trajectory with a listing of constraints, the time period for the constraints, and the nature of access.

A user can adjust the flight plan based on available information, and refile as additional information is received, or can wait for a later time to make adjustments. Up to NAS departure time, as constraints change, expire, or are newly initiated, currently filed flight plans are retested. Update notifications are provided to filers if conditions along the trajectory change. In addition, the user can submit alternative flight plans.

The Flight Plan Constraint Evaluation and Feedback capability will allow the NAS user to be a proactive participant in the collaborative process, by selecting the most efficient routes that conform to both overall NAS objectives and own business needs. Likewise, the ANSP will have access to common flight plan evaluation capabilities to support the planning of TMIs, the coordination with the NAS user, and the allocation of user-requested preferences when possible. Prioritized user preferences will be used by the TM whenever possible to implement a traffic management initiative. In this case, the NAS user will receive feedback indicating that one of its submitted preferences will be used for the TM assigned resolution.

This evaluation capability will provide the user with feedback that is based on consistent information to that of the ANSP, thereby increasing common situational awareness. The feedback will include current and predicted information for a flight along its complete flight path (i.e., full route) throughout the flight's life cycle. The feedback will include weather information, probabilistic information, TMIs (including delay information), airspace information (e.g., High Performance Airspace [HPA]/Mixed Performance Airspace [MPA], RNAV routes), required aircraft performance characteristics (e.g., RNP, RNAV requirements), active routes, restrictions (e.g., Letters of Agreement (LOAs), SOPs, SAA, terminal status information (e.g., airport conditions, runway closures, wind, arrival rates, RVR, airport (current and planned) configurations, surface information, and other NAS status information and changes along the path of the evaluated route or filed route. In addition, the nature (e.g., fully restricted or conditional access), the time, and the impact (e.g., distance, delay) associated with any restriction or constraint will be provided. It is expected that the evaluation feedback will evolve as changes in airspace, and new information systems become integrated and available.

The NAS user will also have the ability to evaluate one or more prioritized alternatives for a single flight or a group of flights. The evaluation capability will be able to provide flight-specific feedback (e.g., estimated departure time, estimated delay, delta distance for a given route) and more generic feedback (e.g., icing conditions at a given airport, restricted airspace) along the path of the flight. The evaluation will also support what if functionality to provide the NAS user with greater flexibility during the evaluation (i.e., time, altitude, routes, and aircraft characteristics).

Based on the evaluation feedback, the NAS user will have the following options:

- Provide intended flights (i.e., as early intents), which represent the best known information about a future flight or intended flight by the NAS user
- File a flight plan or modify an existing filed flight plan
- Provide prioritized alternative routings (i.e., user preferences) for a given flight to address possible events such as the implementation of planned traffic management initiatives, the modification or cancellation of them (i.e., C-TOP and user preference negotiation)

The ANSP will be able to accommodate the user preferences as much as possible based on common, consistent evaluation feedback. The NAS user will receive feedback on the selected option by the TM to address a given TMI. Note that the flight plan negotiation and rules of engagement between the NAS user and the ANSP are to be defined and developed in collaboration with the user community.

It is expected that airline operators, GA, and military users will have access to varying levels of the capability depending on their own level of sophistication of flight planning capabilities. The information, however, is consistent with that of the ANSP.

Although feedback is provided today, it lacks the appropriate level of detail for users to be proactive in better managing uncertainty and gaining predictability. In the Mid-Term, additional capability is required to provide a more integrated and effective feedback picture. Provide Full Flight Plan Constraint Evaluation and Feedback is envisioned to be a pre-departure capability that supports flight planning tools and FOC decision-making by providing information specifically tailored to individual trajectories or flows including a list of applicable constraints (including but not limited to weather), conditions driving the constraints (including weather forecast information), and the nature of planned FAA responses (e.g., TMIs) along with their implementation schedule. Feedback begins days in advance of flight operations as volumetric constraints such as SAA are activated and long-range aviation weather forecasts are translated into airspace configuration schedules. As time to departure approaches, volumetric constraint information becomes increasingly more flight specific. Users may participate in Mid-Term flight planning at different levels of sophistication, from filing basic flight plans similar to today's operations, to filing sophisticated 4-DTs with contingencies. This provides flexibility and allows the user to plan safe and efficient flights with respect to predicted weather, while proactively reacting to NAS constraints and FAA plans. It establishes a user feedback loop, which may help mitigate weather (and non-weather) constraints. After filing a flight plan and up to departure, the user will be updated with changes to weather and non-weather constraints that impact the flight plan, as well as FAA strategies to mitigate these constraints. Also, prior to departure, the user may subscribe to en route weather updates, tailored specifically to the filed flight plan and contingencies.

Post-departure, the safety of the flight is the responsibility of the pilot. Weather updates (for subscribers) and weather advisories (for all aircraft) are automatically provided to the flight deck by Initial Integration of Weather Information into NAS Automation and Decision Making. En route, it may become necessary for the pilot/controller to consider options from among the contingencies formulated pre-departure, in order to react to changing weather conditions and forecasts.

As Figure A-33 depicts, there is a significant interaction among the following OIs that must be discussed in order to more completely understand the capabilities of Provide Full Flight Plan Constraint Evaluation with Feedback:

- ANSP Automation
  - Provide Full Flight Plan Constraint Evaluation and Feedback
  - Continuous Flight Day Evaluation
- Information Services
  - On Demand NAS Information (i.e., an information service that disseminates constraint information; capacity, demand, and congestion models; and mitigation strategies)
  - 4-D Wx Data Cube and its SAS
  - Initial Integration of Weather Information into NAS Automation and Decision Making (i.e., weather constraint translation information)
- User Collaboration
  - FOC decision making
  - Flight planning

User flight planning tools access NextGen Information Services to obtain common situational awareness (i.e., the same information available to ANSP and its automation). With this information, users plan their flights, with alternatives to address predicted NAS constraints. Provide Full Flight Plan Constraint Evaluation and Feedback evaluates the resulting filed flight plans (and alternatives), taking the congestion model and TMIs developed by Continuous Flight Day Evaluation into consideration. Continuous Flight Day Evaluation continuously assesses changing constraints, demand, and capacity to monitor, assess, and modify TMIs. This process establishes a feedback loop allowing the system to move closer to optimum efficiency in the face of predicted constraints and user reaction to those constraints.

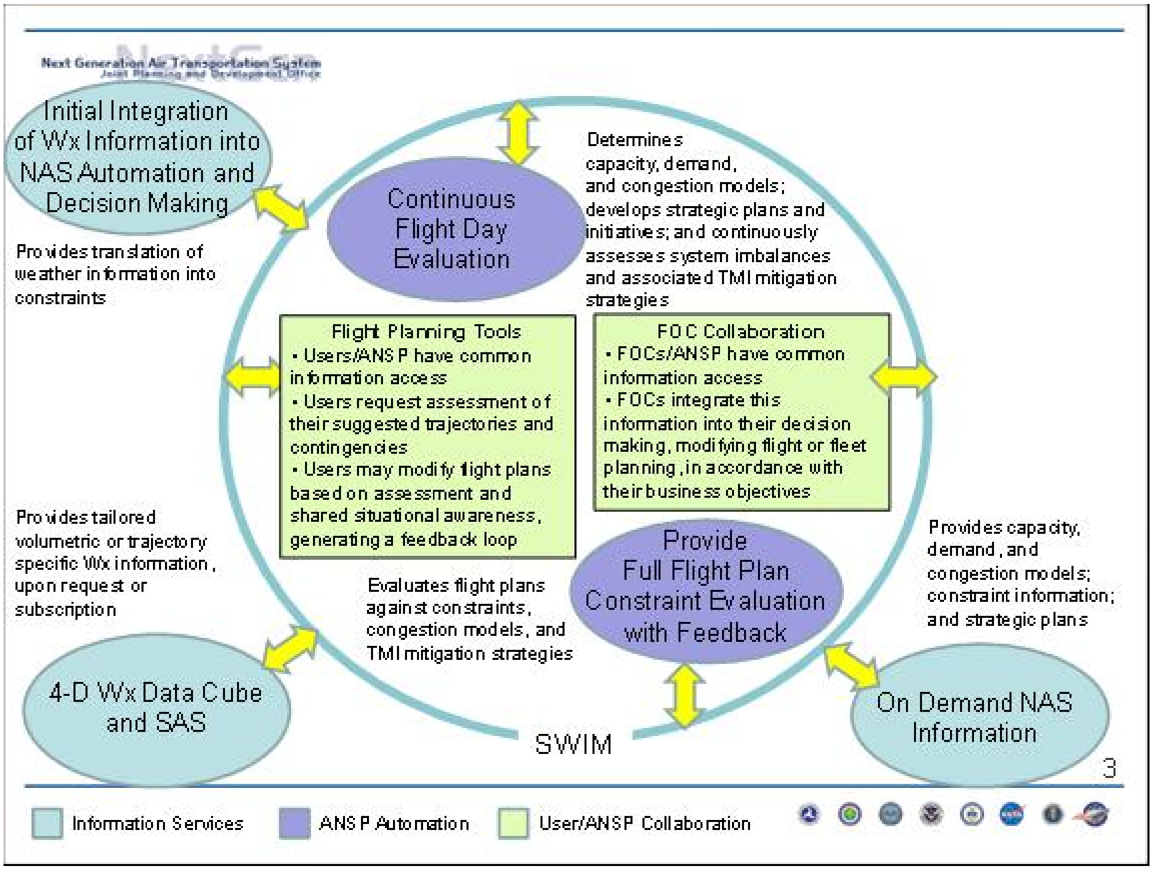


Figure A-33. Provide Full Flight Plan Constraint Evaluation and Feedback Interactions with Other OIs Mid-Term Operational Scenario

A-2.4.4.2 Mid-Term Operational Scenario

A-2.4.4.2.1 Flight Planners Develop Flight Trajectories and Objectives, Utilizing Feedback on Potential Weather Constraints and Operational Impacts

Step 0: Both individual users and flight planning systems have access to the 4-D Wx SAS to obtain weather information that may impact flight planning. The user is free to apply private vendor weather information for flight planning, but the 4-D Wx SAS enables users to understand the weather basis upon which the FAA will make TMI decisions, which may in-turn affect trajectory/flight plan acceptance.

Step 1: The FAA develops FCM plans to address predicted weather and other constraints. These plans may be later impacted by user reaction to theses constraints.

Step 2: The user accesses a flight planning system to plan individual flight trajectories and requests a preferred trajectory and contingencies to be evaluated for constraints, including weather.

Step 3: The flight planning system accesses Provide Flight Plan Constraint Evaluation with Feedback, which interfaces with Initial Integration of Weather Information into NAS Automation and Decision Making to obtain 4-D Wx SAS information tailored to the user's suggested trajectory, or for a GA flight (without a flight plan) volumetric weather information for an area of interest to inform the GA pilot for go/no-go decision making. Provide Flight Plan Constraint Evaluation with Feedback also interfaces with On Demand NAS Information to obtain weather and non-weather constraint information, its aggregate impact on the NAS (i.e., resource capacity), and the system's response to that impact (e.g., TMIs). Then, Provide Full Flight Plan Constraint Evaluation with Feedback assesses the flight trajectory against weather and non-weather constraint information, airspace and airport capacity, and TMIs to determine impact on the flight. The user is then provided with a list of applicable constraints (including weather), conditions driving the constraints (including weather forecast information), and the nature of planned FAA responses (e.g., TMIs) along with their implementation schedule.

Step 4: The user may adjust the requested trajectory, based on the weather situation (e.g., wind field, temperature, convection, turbulence, in-flight icing, airport weather conditions), constraint and operational impact information (e.g., FCAs identified along the preferred route, reduced capacity along the user's trajectory), or other factors (e.g., company weather avoidance policy, pilot experience). The user then submits the flight plan (or develops an alternate that is more acceptable).

Step 5: Prior to departure, Flight Plan Constraint Evaluation with Feedback informs users of any significant weather changes that may impact their submitted flight plans and any potential FAA reactions. User flight plan contingencies/options are maintained by TFDM, in the event weather conditions change and contingency plans must be enacted. Additionally, users may subscribe to Initial Integration of Weather Information into NAS Automation and Decision Making to receive weather updates (both pre- and post-departure) based on their flight plan. If weather is not expected to be an issue, the user may elect not to subscribe. For users who subscribe, weather condition updates, impacting a planned trajectory, will be "pushed" prior to departure, to the user, by Flight Plan Constraint Evaluation with Feedback as follows:

- FOC will be "pushed" flight plan specific impacts
- GA pilots will be "pushed" area or volume of airspace impacts
- Flight Services will be "pushed" these area or volume of airspace impacts, if GA pilot is accessing Flight Services
- The flight-deck will be "pushed" flight plan specific impacts if the crew is on-board and data communications are available

Last minute flight plan changes are negotiated, as necessary, based on the weather changes (e.g., flight plan revisions, or GA no/go decision).

[Note: While the role of Provide Flight Plan Constraint Evaluation with Feedback ends at departure, the scenario continues in order to depict how the Weather Advisories service picks up where Provide Flight Plan Constraint Evaluation with Feedback leaves off.]

Step 6: Post-departure, the pilot monitors weather updates, as provided by Initial Integration of Weather Information into NAS Automation and Decision Making's Weather Advisories service, which include safety-related, flight specific information necessary to avoid weather constraints. Pilots of non-equipped aircraft may still receive advisories in the cockpit via their FOC, Flight

Services, or controllers (as time permits). For airlines, the FOC also receives the automated updates, so common weather awareness can be maintained by the aircrew and flight operations.

Step 7: If lead time is sufficient, pilots can request a specific flight plan change to avoid severe weather, or can state their intention to proceed, regardless of the weather. The pilot submits the request via data communications or voice to the sector controller responsible for the aircraft. The flight plan change is electronically communicated to the Multi Sector Planner (or equivalent function) to assess against active or planned TMIs.

Step 8: If lead time is not sufficient, the pilot acts, as necessary, to avoid severe weather that jeopardizes the flight. At the request of the pilot, the controller assists with weather avoidance, but the overall responsibility remains with the pilot. The controller has access to the same weather advisory information that is provided to pilot, to ensure common situational awareness. Controller assistance in weather avoidance may involve vectoring the pilot through/around the weather or some form of automated DST (see the Initiate TBO OI: Initial Conflict Resolution Advisories).

A-2.4.4.3 Mid-Term Weather Integration and Needs Analysis

Provide Full Flight Plan Constraint Evaluation with Feedback receives a request from a flight planning system to evaluate a flight plan (and possibly its contingencies). User provided assessment criteria (e.g., pilot training and preference, aircraft type and equipage) are also provided with the request. Provide Full Flight Plan Constraint Evaluation with Feedback interfaces with Initial Integration of Weather Information into NAS Automation and Decision Making to request 4-D Wx SAS information from the 4-D Weather Data Cube. This weather information may be trajectory specific or volumetric, by time frame of interest, and is intended to be used, along with the user provided assessment criteria, for flight specific weather impact analysis. Provide Full Flight Plan Constraint Evaluation with Feedback also interfaces with On Demand NAS Information to obtain weather and non-weather constraint information, the impact of aggregate constraints on the NAS (i.e., resource capacity), and the system's response to that impact (e.g., TMIs). Next, Provide Full Flight Plan Constraint Evaluation with Feedback assesses the flight trajectory against weather and non-weather constraint information, airspace and airport capacity, and TMIs to determine impact on the flight. Then, Provide Full Flight Plan Constraint Evaluation with Feedback responds to the flight planning system with a list of applicable constraints (including weather), conditions driving the constraints (including weather forecast information), and the nature of planned FAA responses (e.g., TMIs) along with their implementation schedule.

The user then may file the flight plan that was just assessed or modify it creating a feedback loop responding to the constraints and system responses to those constraints. As flight plans are modified, the system may also consider modifying its original reaction to the constraints confronting the NAS (see Continuous Flight Day Evaluation).

Based on the associated described capabilities, an understanding of the target objectives and, where available, information gleaned from operational scenarios, weather needs are analyzed in Table A-34.

Table A-34. Provide Full Flight Plan Constraint Evaluation with Feedback–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Determine weather constraint (i.e., nominally by trajectory, or by volume for GA) for a specific flight plan using user supplied assessment criteria	Probabilistic forecasts out 8 hrs by trajectory: •Convective weather •In-flight Icing •Turbulence •Winter weather (e.g., snow, freezing mix) •Airport C&V *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	TBD	TBD
Obtain routine weather information needed for flight planning	Probabilistic forecasts out 8 hrs by trajectory: •Winds Aloft •Temperature Aloft *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	TBD	TBD

A-2.4.5 OI – On-Demand NAS Information (103305)

This OI is concerned with the effective delivery of information concerning the status of NAS assets to NAS operators, enabling the effective and safe planning and operation of their flights.

Aircraft operators depend on the timely distribution of information on the status of NAS assets and aeronautical information to plan and conduct safe flights. Currently, the distribution of NAS information is sporadic, at times incomplete, and implemented with a variety of communication methods. Many aviation accidents have been traced to incomplete or untimely reception of NAS information.

A-2.4.5.1 High Level Mid-Term Capabilities

NAS and aeronautical information will be available to users on demand. NAS and aeronautical information is consistent across applications and locations, and available to authorized subscribers and equipped aircraft. Proprietary and security sensitive information is not shared with unauthorized agencies/individuals.

Information is collected from both ground systems and airborne users (via ground support services), aggregated, and provided via a system-wide information environment, data communications, or other means. Information and updates are obtained in near real-time and distributed in a user-friendly digital or graphic format. The data is machine-readable and supports automated data processing. Flight Service Stations will be able to provide improved information for flight planning and in-flight advisories.

This capability is assumed to be a virtual repository of NAS status information, including such information such as weather and non-weather constraints, airspace and airport capacity (i.e., NAS capacity model), NAS demand model, NAS congestion model, and constraint mitigation strategies (i.e., TMIs).

A-2.4.5.2 Mid-Term Operational Scenario

N/A

A-2.4.5.3 Mid-Term Weather Integration and Needs Analysis

On-Demand NAS Information is a virtual repository of information and will not itself require weather integration, although some of the information available through On-Demand NAS Information will include the impact of weather on the NAS. For example, airspace and airport system capacity, which factor in the impact of weather, will be made available via On-Demand NAS Information. However, capacity determination and weather's involvement in its calculation are performed by another OI (i.e., Continuous Flight Day Evaluation).

Table A-35. On-Demand NAS Information–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
TBD	TBD	TBD	TBD

A-2.5 Increase Safety, Security, and Environmental Performance (SSE)

The SSE Solution Set is a collection of efforts that aim to enhance or improve capabilities in the three areas (Safety, Security, and Environmental Performance) described separately below.

Safety

The NextGen system must ensure safety through the implementation of a transformed air transportation system. This system must employ comprehensive, proactive safety practices and new, safer systems that enable the realization of national goals for air transportation. A common vision for safety, safety goals, and safety metrics will drive all aviation system improvement activities and investments. This vision must include operational practices focused on safety risk management, systems designed for safety, as well as regulations and technologies that are implemented consistently worldwide. This vision of Safer Practices requires an implementation of consistent and proactive safety management approaches that incorporate advanced prognostic methods to forecast safety risk potential, and encourages information sharing without fear of retribution. These elements must be coordinated to enable a robust, data-driven safety decision-making process, which is an essential component of the NextGen aviation system. The vision of Safer Systems includes enhanced systems interfaces that reduce risk, and advanced air and ground-based systems that address future air transportation, needs while preventing incidents and accidents. Additionally, the vision of a collaborative worldwide safety environment will increase the level of safety for air transportation across international and intermodal transportation system boundaries.

The Mid-Term Safety OIs of interest are listed here in the order in which they appear as brick red-colored timelines in the SSE Timeline Figure A-34 are as follows:

- Enhanced Emergency Alerting
- ASIAS-Information Sharing and Emergent Trend Detection
- Enhanced Aviation Safety Information Analysis and Sharing
- Improved Safety for NextGen Evolution
- Increased International Cooperation for International Safety
- Improved Safety Across Air Transportation System Boundaries
- Enhanced (Automated) Aviation Safety Information Sharing and Analysis Scope and Effectiveness

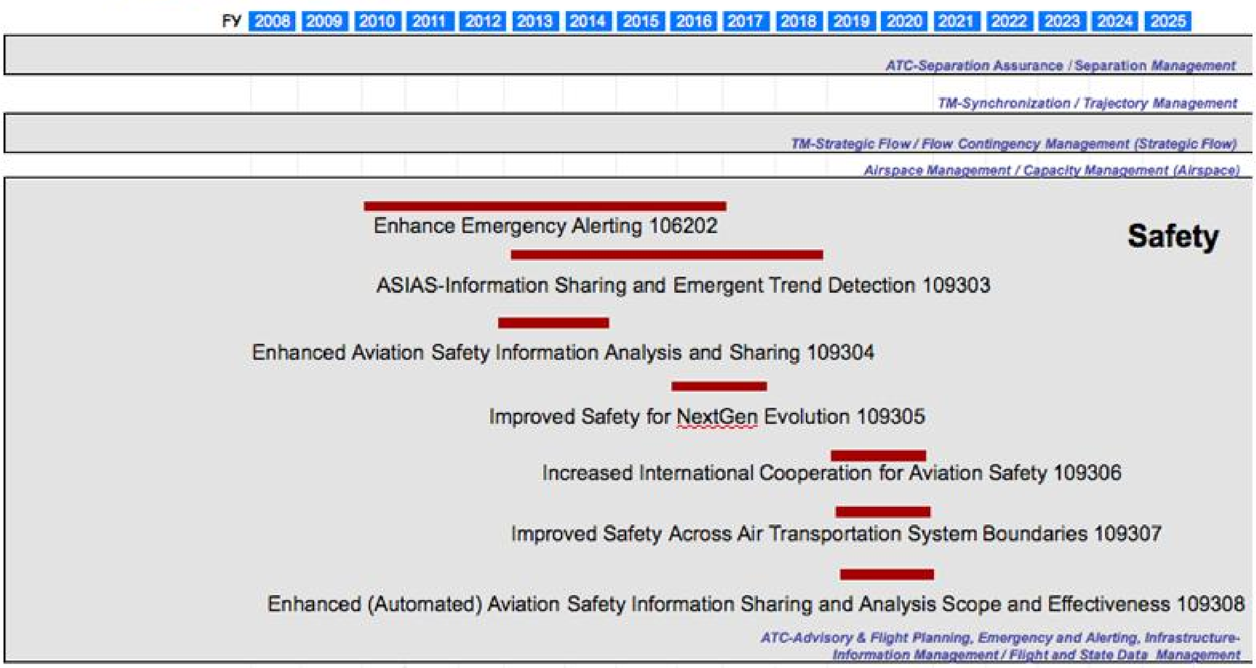


Figure A 34. Safety Timeline

Security

Future airspace security operations are depicted in Figure A-35. The operational security environment consists of various security partners, each with a user-defined operating picture based on common information shared rapidly and securely. This SSA capability will improve security operation by making it more effective. Digital communication, added to voice communication, will ensure accurate information sharing and timely decision-making.

The security environment depicted in Figure A-35 represents a layered, adaptive approach that will permit timely and effective responses. It includes appropriate risk management to security situations through automation and decision-support systems that inform human decision-making.

Figure A35. Future Airspace Security Operations

Security Integrated Tool Set (SITS) will enable the System Operations Security organization to perform data correlation, NAS impact analysis of security or emergency actions, as well as trend analysis. NAS response to security risk assessments by partner agencies is intended to be accomplished in the same manner as for weather, SUA, and TMIs. SITS will also support integrated security restricted airspace development and sharing capabilities. These capabilities will be seamlessly integrated with ATM and support defense, homeland security/disaster recovery and law enforcement operations, and will be scalable to meet required response and projected air traffic demand.

SITS will streamline processes, use automation to enhance human decision-making, improve operational security through shared situational awareness, and enable the FAA to meet increased demand for security services. SITS will also improve coordination and collaboration with various FAA security partners, consisting of other government agencies such as Transportation Security Administration (TSA) in the Department of Homeland Security (DHS), DOD, Department of Justice (DOJ), Federal Bureau of Investigation (FBI), U.S. Secret Service, and the international partners.

SITS will enable future NAS airspace security to be achieved with layered, adaptive security services as outlined in the NextGen Concept of Operations. In addition, SITS will provide a platform to host partner agency requirements, if desired and funded by them.

The Mid-Term Security OIs of interest are listed in the order in which they appear as brick red-colored timelines in the SSE Timeline Figure A-36 are as follows:

- Operational Security Capability for Threat Detection and Tracking
- NAS Impact Analysis
- Risk-Based Assessment

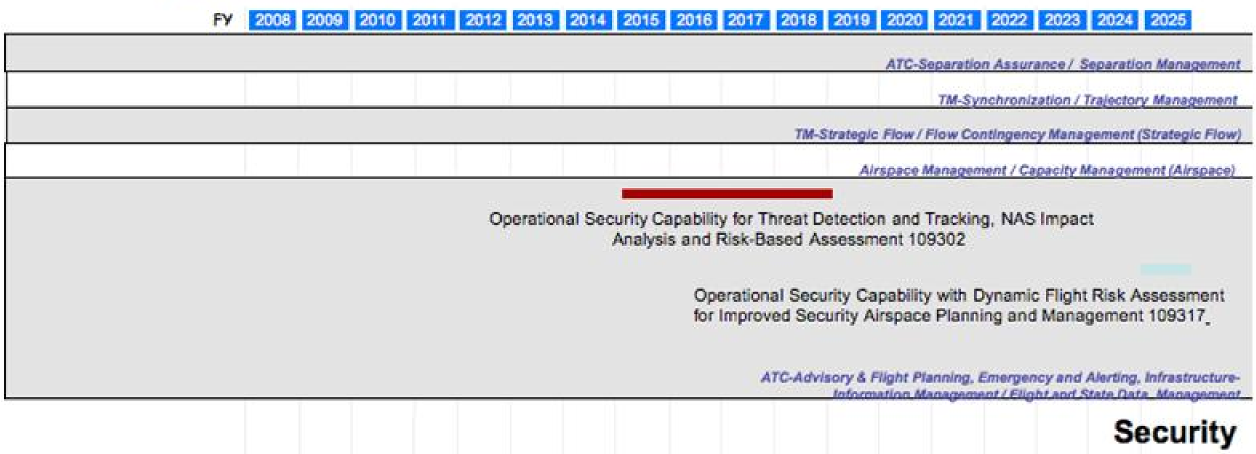


Figure A 36. Security Timeline

Environmental Performance

Improvements in this area are targeted in three directions as follows:

Operational Procedures to Mitigate Environmental Impacts: The development and integration of clean and quiet operational procedures will foster NAS operational capabilities that function more efficiently and that contribute to mitigating environmental impacts. Improvements to increased efficiency will span across numerous operational procedures, policies and practices and automation systems in the NAS. These improvements will have to provide proof of lower noise and engine emissions as well as reduced fuel usage. By continuing to leverage the investments of the Partnership for Air Transportation Noise and Emissions Reduction Center of Excellence and its stakeholders, environmentally-friendly CDA operational procedures are being transitioned into the OEP and integrated into the NAS. CDA demonstrations have proven that optimal trajectory-based aircraft procedures offer significant reductions of environmental impacts. Trials and demonstrations reinforce maturation of operational approaches, where appropriate, and support the environmental goals of NextGen ConOps. Environmental efficiencies beyond terminal operations are also being pursued to include surface traffic movements and en route operations management. For example, under the Atlantic

Interoperability Initiative for Reduced Emissions (AIRE) and the Asia and South Pacific Initiative to Reduce Emissions (ASPIRE) Programs, ATC system demonstrations are being launched to investigate potential environmental benefits. Additional investments will further explore and demonstrate new capabilities. By 2025, coordinated decision-making through comprehensive automated systems communication/data networking of surface movement/en route/ terminal domains will be vital for total gate-to-gate environmental efficiency.

Continuous Low Energy, Emissions and Noise (CLEEN) Consortium: CLEEN will demonstrate alternative fuels as well as aircraft and engine technologies that reduce noise, improve air quality and lower greenhouse gas emissions. The goal is to have a fleet of quieter, cleaner aircraft that operates more efficiently with less energy. To accomplish this goal, a fleet that operates more efficiently with less energy usage and permits expansion of airports in a manner consistent with the environmental goals of the NextGen plan is mandated. A TRL must demonstrate industry's application of new environmental technologies. Solutions should involve technology improvements in engines and airframes in a timeframe capable of demonstrating successful maturation and certification of new technologies within the next five to eight years. Starting in FY09, this initiative established a consortium to demonstrate aircraft and engine technologies that reduce noise and air quality and greenhouse gas emissions at the source. This structure focuses on developing and accelerating industry implementation of these new environmental technologies. As a result, it will progressively define a fleet that will operate more efficiently with less energy usage and permit expansion of airports in a manner consistent with the environmental goals of the NextGen plan. It will also show how alternative fuels for aviation will reduce emissions affecting air quality and greenhouse gas emissions and increase energy supply security for NextGen.

Environmental Management System (EMS): Support the design, development and implementation of an EMS that will optimize, administrate, and track environmental protection procedures, policies, and practices in a dynamic NAS environment as it moves towards NextGen.

Specific activities include the following:

- Advance noise, air quality, and climate metrics to quantify and manage the impacts of technologies and operations associated with NextGen
- Develop DSTs to dynamically manage environmental impacts
- Conduct validation modeling and field demonstrations of mitigation approaches.
- Conduct activities that foster FAA ability to support the NextGen goal of environmental protection that allows sustained aviation growth, including:
  - Reducing, in absolute terms, significant aviation environmental impacts associated with noise, emissions, global climate change, energy production and use and water quality.
  - Balancing aviation's environmental impact with other societal objectives, both domestically and internationally.

The Mid-Term Environmental Performance OIs of interest are listed here in the order in which they appear as brick red-colored timelines in the SSE Timeline Figure A-37 are as follows:

- Implement EMS Framework - Enhanced
- Environmentally and Energy Favorable En Route Operations
- Environmentally and Energy Favorable En Route Operations – Enhanced
- Environmentally and Energy Favorable Terminal Operations
- Environmentally and Energy Favorable Terminal Operations – Enhanced
- Implement NextGen Environmental Engine and Aircraft Technologies
- Increased Use of Alternative Aviation Fuels

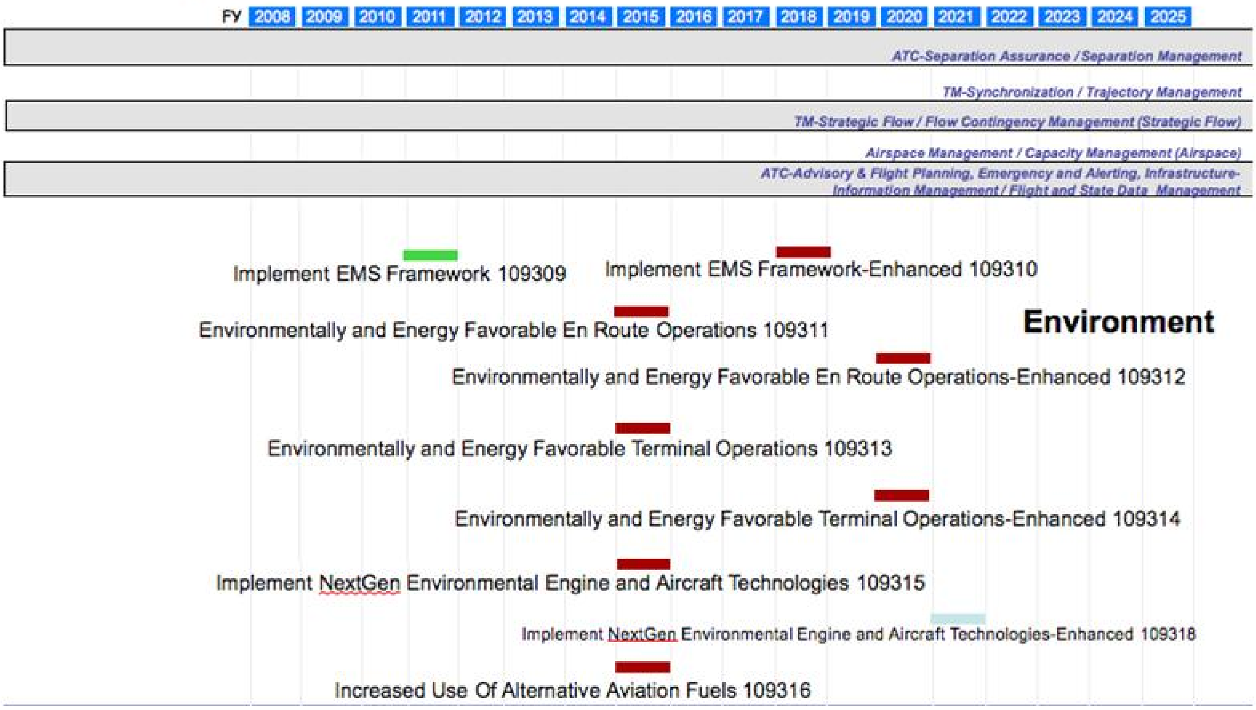


Figure A 37. Environment Timeline

Discussion of each of these efforts continues below in the order they are introduced in this section, starting with the Enhanced Emergency Alerting OI (106202) in the Safety group, and ending with Increased Use of Alternative Aviation Fuels (109316) in the Environmental Performance group.

A-2.5.1 OI – Enhance Emergency Alerting (106202)

This OI is intended to enable controllers and search and rescue personnel to quickly locate distressed or downed aircraft by using ADS-B to provide position information and discrete aircraft identification, without having to resort to 1200 beacon tracks. It reduces the need for Civil Air Patrol search flights by enabling controllers to improve their ability to assist in locating a downed aircraft and to identify and track aircraft operating under visual flight rules.

When an ATC facility receives information indicating an aircraft may be missing (usually via an Alert Notice (ALNOT)), it checks the position records to determine whether the aircraft has contacted the facility. The status of this check is determined within one hour of the time the alert was received. It retains the alert in an active status, and immediately notifies the originator of subsequent contact, until a cancellation is received. The ARTCC plots the flight path of the aircraft on a chart, including position reports, predicted positions, possible range of flight, and any other pertinent information, derived from DSR and the en route Host Computer System (HCS). ATC personnel solicit the assistance of other aircraft known to be operating near the aircraft in distress or its last known position, and forward this information to the Rescue Coordination Center (RCC) as appropriate.

It is anticipated that, with GPS position information from aircraft (made available via ADS-B), controllers and the ATC system will be able to provide better assistance in locating a downed aircraft. It should be noted that the overall effectiveness of this operational improvement is dependent on the level of user community equipage with ADS-B avionics. While the end goal is universal equipage with ADS-B, the mid-term timeframe contemplated here will likely see only a gradual ramp up in user equipage levels. Nonetheless, the ground system automation and techniques described here can employ any available surveillance or flight following information, and this evaluation of weather capabilities and needs is still applicable.

A-2.5.1.1 High Level Mid-Term Capabilities

This OI assumes the capability to retrieve recent weather data and apply it against other information about the flight (filed flight plans, ATC communications, surveillance radar or ADS-B position information, etc.) in order to better focus initial search and location efforts.

A-2.5.1.2 Mid-Term Operational Scenario

Actual Search-And-Rescue (SAR) scenarios can vary widely depending on what initial information is available. This mid-term operational scenario assumes no other information (such as distress (“mayday”) calls from the missing aircraft, or eyewitness information of an aircraft in distress) is available to determine if the aircraft is, in fact, missing, and where to focus initial search activities.

Step 0: An aircraft is deemed missing or overdue, and an ALNOT is issued to area ATC facilities.

Step 1: A query is made of recent ATC surveillance records (ADS-B reports, if the aircraft was equipped) to determine if the missing aircraft was being tracked by ATC surveillance resources. If so, a track file is extracted to establish last-known location and probable direction of flight. If not, a broader evaluation is made of proximate unidentified tracks to determine if any of them might display characteristics associated with an unintended flight termination.

Step 2: An analysis is made of prevailing weather and other operational factors (e.g., terrain, facilities, etc.) during the time of the missing flight to assess any potential difficulties the flight could have encountered. The purpose of this analysis is to provide focus to the search areas that should be considered initially.

Step 3: If necessary, SAR resources are dispatched to the initial targeted search areas. If airborne SAR resources are employed (such as the Civil Air Patrol), flight planning and flight conduct for SAR flights are performed using the weather resources described in earlier sections of this appendix.

A-2.5.1.3 Mid-Term Weather Integration and Needs Analysis

Based on the capabilities and the operational scenario described above and an understanding of the target objectives, the weather needs are analyzed in Table A-36.

Table A-36. Enhance Emergency Alerting–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Ability to retrieve recent weather conditions and "replay" against a background of candidate surveillance tracks of missing aircraft	Recently-archived reports of actual conditions, including •Weather Radar •Winds Aloft •Surface Observations •PIREPS	TBD	TBD

A-2.5.2 OI – ASIAS - Information Sharing and Emergent Trend Detection (109303) [Safety]

Aviation Safety Information Analysis and Sharing (ASIAS) is part of the FAA comprehensive strategy for a proactive approach to safety. The information analysis and sharing mission directly supports safety promotion and safety assurance initiatives with analytical results such as baseline information and trends; and indirectly supports safety risk management through issue identification, information and tools for analysis of hazards. System wide analysis and modeling support risk assessment and management for both existing and future systems by identifying potential systemic risks associated with new systems (in NextGen) as well as existing systems. To fully realize the benefits of the SMS approach to safety and to reach the safety levels demanded by the public, it will be necessary to address shortcomings in the current aviation system by taking the following actions:

- Replacing inadequate, informal communication with prompt and comprehensive exchanges of aviation safety information
- Coordinating and sharing the resources required to maximize the effectiveness of tool development and issue analysis
- Establishing a collaborative approach to identifying and mitigating system safety issues posing the highest risks

There are five types of data analyses that can be conducted under Phase 1 ASIAS: Benchmark Analysis, Known Risks Monitoring, Vulnerability Discovery, Tool Development, and Rapid Response (Thread) Study. Applications of ASIAS data to NextGen programs will be conducted by integrating ASIAS data into existing or newly constructed models. Two types of models will be developed: a system-wide baseline and individual component performance forecasts, each aimed at providing both a high-level estimate of system performance and an integrated analysis of how all of the actors in the system (passengers, operators, controllers, etc.) and domains (airport surface, terminal airspace and enroute airspace) will be affected by system changes.

ASIAS will improve system-wide risk identification, integrated risk analysis and modeling, and the implementation of emergent risk management. Source software, meta-ware and analytical processes will be developed to link together existing databases, expert knowledge, the results of experimentation and modeling capability to continually assess the performance of the NAS for safety risk management. All participants in ASIAS, including FAA organizations such as Aviation Safety (AVS) and Air Traffic Organization (ATO), industry and other government agencies, ASIAS participants will collaborate to study and evaluate aggregate level system issues within the NAS at the organization level. They will be able to access ASIAS information and analysis tools to support the safety management of their own operations or those they regulate. Collaborative ASIAS activities allow stakeholders to draw on more information as context, to raise issues to be worked by the larger community, and to share their assessments with others. The aggregation of information and the sharing of benchmarks, analysis tools, and issues create a context and framework for individual stakeholders'SMS activities. The modeling and analysis conducted under SSMT extend the capability of the ASIAS data and stakeholder community to identify and manage systemic risks, as preparation to implementation of NextGen systems, and to monitor the impact of system deployments (including but not exclusively NextGen).

The functions of ASIAS will include the following:

- Sharing relevant safety information via protected, net-centric approaches that can be used within stakeholder organizations and by ASIAS to permit the setting of system-wide benchmarks
- Sharing the development and use of advanced tools for safety analysis
- Supporting safety communities by providing information and tools that can be used to identify and prioritize risk and design corrective actions.
- Providing data sources for integrated system-wide modeling and forecasts.

ASIAS will benefit safety management at the aggregate level while also enhancing the ability of the stakeholders to manage safety within their organizations.

A-2.5.2.1 High Level Mid-Term Capabilities

ASIAS will be more effective by having access to historical, archived weather data to correlate weather conditions associated with those events that prompt the safety reports to be submitted. A capability to retrieve observed weather data for any previous time is necessary. Additionally, as a means of ensuring the quality and timeliness of forecast weather products, it will be desirable to be able to compare observed weather conditions against the forecasts that were issued for that time period.

A-2.5.2.2 Mid-Term Operational Scenario

Step 0: An ASIAS report is received regarding a potential safety event in which weather is cited as a factor.

Step 1: The authorized ASIAS event review committee accesses the archived weather data for the time period of the event to better understand the safety implications of the weather factor, to search for any possible prescriptive measures and to identify emerging trends.

A-2.5.2.3 Mid-Term Weather Integration and Needs Analysis

This application is slightly different in that the major weather needs are historical in nature. They are analyzed in Table A-37.

Table A-37. ASIAS - Information Sharing and Emergent Trend Detection–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
The ability to easily access and retrieve archived weather information	All associated weather reports and forecasts pertaining to the time period of the event	TBD	TBD
The ability to compare weather forecasts against observed conditions (for quality assurance)	All associated weather reports and forecasts pertaining to the time period of the event	TBD	TBD

A-2.5.3 OI – Enhanced Aviation Safety Information Analysis and Sharing (109304) [Safety]

ASIAS will improve system-wide risk identification, integrated risk analysis and modeling, and implementation of emergent risk management. Source software, meta-ware and analytical processes will be developed to link together existing databases, expert knowledge, the results of experimentation and modeling capability to continually assess the performance of the Air Transportation System (ATS) for safety risk management. All participants in ASIAS, including FAA organizations such as AVS and ATO, industry, and other government agencies, will collaborate to study and evaluate aggregate level system issues within the ATS at the organization level. Participants will be able to access ASIAS information and analysis tools to support the safety management of their own operations or those they regulate. Collaborative ASIAS activities allow stakeholders to draw on more information as context, to raise issues to be worked by the larger community, and to share their assessments with others. The aggregation of information and the sharing of benchmarks, analysis tools, and issues create a context and framework for individual stakeholders' SMS activities. The modeling and analysis conducted under the AVS System Safety Management Transformation (SSMT) extend the capability of the ASIAS data and stakeholder community to identify and manage systemic risks, as preparation to implementation of NextGen systems, and to monitor the impact of system deployments (including but not exclusively NextGen).

A-2.5.3.1 High Level Mid-Term Capabilities

This effort assumes the capability to interface safety analysis tools and research centers with archived weather data to enable more comprehensive safety studies and trend spotting.

A-2.5.3.2 Mid-Term Operational Scenario

TBD

A-2.5.3.3 Mid-Term Weather Integration and Needs Analysis

The nature of the weather integration and needs are quite similar to those described in the previous section, and are summarized in Table A-38.

Table A-38. Enhanced Aviation Safety Information Analysis and Sharing–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
The ability to easily access and retrieve archived weather information	All associated weather reports and forecasts pertaining to the time period of the event	TBD	TBD
The ability to compare weather forecasts against observed conditions (for quality assurance)	All associated weather reports and forecasts pertaining to the time period of the event	TBD	TBD

A-2.5.4 OI – Improved Safety for NextGen Evolution (109305) [Safety]

This OI mitigates safety risk associated with NextGen evolution by providing enhanced safety methods that support making changes to the ATS, including: advanced capabilities for integrated, predictive safety assessment; improved Validation and Verification (V&V) processes supporting certification; an enhanced focus on safe operational procedures; and enhanced training concepts for safe system operation. Developers discover and mitigate hazards more quickly allowing the flying public and ATS stakeholders to experience a safety benefit through more rapid and reliable implementation of NextGen systems. An advanced integrated, predictive safety assessment capability will ensure the management of safety risk associated with complex systems and interactions between these systems. It will involve the monitoring of system safety performance to accelerate the detection of unrecognized safety risks and thus contribute to overall safer operational practices. Improved V&V processes will ensure that systems are certified to be reliable enough to perform automated operations, to include recovery from critical failures, without compromising safe operations. Automated operations are necessary to achieve ATS efficiency and capacity benefits. As particular operations become more automated, newly developed operational procedures that involve human interaction must be optimized with assurance that an acceptable level of safety is maintained. Additionally, advanced training concepts will maintain levels of proficiency for humans to conduct safe operations in place of degraded or failed automation.

A-2.5.4.1 High Level Mid-Term Capabilities

No specific additional weather capabilities are anticipated with this OI, other than those associated with making weather information (both archived and real-time) available for associated research and V&V.

A-2.5.4.2 Mid-Term Operational Scenario

N/A

A-2.5.4.3 Mid-Term Weather Integration and Needs Analysis

No unique weather needs are derived from this OI as summarized in Table A-39.

Table A-39. Improved Safety for NextGen Evolution–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.5 OI – Increased International Cooperation for Aviation Safety (109306)

This OI promotes worldwide aviation safety enhancements for the traveling public through international participation in the development and implementation of safer practices and safer systems. Specifically, increased U.S. participation in international aviation safety efforts will result in the establishment of international aviation partnerships which enhance safety, such as the ICAO Global Aviation Safety Roadmap and the associated implementation plan. This OI also contributes to the continued viability of the U.S. aviation industry by supporting the required harmonization of international standards for an interoperable SMS.

A-2.5.5.1 High Level Mid-Term Capabilities

No additional unique weather capabilities are derived from this OI.

A-2.5.5.2 Mid-Term Operational Scenario

N/A

A-2.5.5.3 Mid-Term Weather Integration and Needs Analysis

No unique weather needs are derived from this OI as summarized in Table A-40.

Table A-40. Increased International Cooperation for Aviation Safety–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.6 OI - Improved Safety Across Air Transportation System Boundaries (109307) [Safety]

This OI seeks to reduce the safety risk associated with intermodal and international operations by harmonizing standards, regulations and procedures, and improving their implementation. In particular, dangerous goods handling for air transportation is made safer through harmonization of intermodal and international standards that ensures sufficient information to support risk management for and among all modes of transportation resulting in reduced net transportation risk.

A-2.5.6.1 High Level Mid-Term Capabilities

No additional unique weather capabilities are derived from this OI.

A-2.5.6.2 Mid-Term Operational Scenario

N/A

A-2.5.6.3 Mid-Term Weather Integration and Needs Analysis

No unique weather needs are derived from this OI as summarized in Table A-41.

Table A-41. Improved Safety Across Air Transportation System Boundaries–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.7 OI - Enhanced (Automated) Aviation Safety Information Sharing and Analysis Scope and Effectiveness (109308) [Safety]

This OI will enhance aviation operational safety and contribute to reduced risk by automating risk identification and notification processes in the ASIAS. Following the creation of the ASIAS environment and the integration of existing analytical tools within it, improvements will be made to the environment and the analytical capabilities to extend their coverage, improve the speed of risk identification and notification, and enhance safety mitigation evaluation. Expansion of the ASIAS environment to include additional data sources, combined with actions that improve data security, quality, and scope will provide continuous improvement of the ASIAS environment. Improvements in the analytical techniques and tools used to extract information from the various data sources will continuously improve the understanding of the data and its implications.

A-2.5.7.1 High Level Mid-Term Capabilities

No additional unique weather capabilities are derived from this OI.

A-2.5.7.2 Mid-Term Operational Scenario

N/A

A-2.5.7.3 Mid-Term Weather Integration and Needs Analysis

No unique weather needs are derived from this OI as summarized in Table A-42.

Table A-42. Enhanced (Automated) Aviation Safety Information Sharing and Analysis Scope and Effectiveness–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.8 OI – Operational Security Capability for Threat Detection and Tracking, NAS Impact Analysis and Risk-Based Assessment (109302) [Security]

The operational security personnel of the ANSP address NAS security threats by more effective and efficient prevention, protection, response and recovery based on net-enabled shared situational awareness and a risk-informed decision-making capability. NAS airspace security measures balance both security and other NAS criteria/goals. Security operations are continuously improved through operational performance analysis.

The ANSP security personnel have network access to security-relevant data (including surveillance of cooperative and non-cooperative flights) provided by the Security Service Provider (SSP) and Defense Service Provider (DSP). A secure collaboration environment is available for intra-ANSP and inter-ANSP/SSP/DSP coordination and joint decision-making.

Flight risk profiles are derived from trajectory-based risk assessment provided by the ANSP and risk levels provided by the SSP. These flight-specific risk profiles will be the basis for developing security risk mitigation strategies in all four security missions: prevent, detect, respond and recover.

Like other constraints, NAS security airspaces are expressed in volumetric expressions, and are developed, coordinated, and implemented either off-line or in real-time with considerations given both to national airspace security needs and resultant NAS impact.

NAS security services operations data are logged and analyzed with automation tools. Feedback and lessons-learned from performance metrics analysis and post-event analysis enable the ANSP security operations to continuously improve.

A-2.5.8.1 High Level Mid-Term Capabilities

This OI assumes connectivity of ANSP Security functions (including SSP and DSP) to the 4-D Weather Data Cube (4D Wx Cube) to enable security personnel to (1) evaluate the weather impacts on the security posture of the NAS and (2) allow quick notification of the need to restrict specified volumes of airspace for national security purposes. It also assumes there are automation tools to support security personnel in these activities.

A-2.5.8.2 Mid-Term Operational Scenario

N/A

A-2.5.8.3 Mid-Term Weather Integration and Needs Analysis

This OI does not require additional weather integration or needs that have not been identified for other OIs.

Table A-43. Operational Security Capability for Threat Detection and Tracking, NAS Impact Analysis and Risk-Based Assessment–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.9 OI - Implement EMS Framework – Enhanced (109310) [Security]

The goal of this OI is to further enable the use of the EMS framework for subsequent applications, including refined environmental goals and DSTs, to address, plan and mitigate environmental issues through implementation of ongoing EMS improvements and availability of enhanced environmental information.

A-2.5.9.1 High Level Mid-Term Capabilities

No weather-related capabilities are anticipated.

A-2.5.9.2 Mid-Term Operational Scenario

N/A

A-2.5.9.3 Mid-Term Weather Integration and Needs Analysis

No anticipated weather integration and needs for this OK as summarized in Table A-44.

Table A-44. Implement EMS Framework – Enhanced–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.10 OI - Environmentally and Energy Favorable En Route Operations (109311) [Environment]

This OI intends to optimize enroute operations to reduce emissions, fuel burn and noise, apply new operational capabilities such as advanced aircraft technologies including capabilities for FMS and avionics to achieve more efficient en route operations, and to improve efficiency in operations system-wide including, as appropriate, in sensitive areas (e.g., national parks).

A-2.5.10.1 High Level Mid-Term Capabilities

No unique weather-related capabilities are anticipated.

A-2.5.10.2 Mid-Term Operational Scenario

N/A

A-2.5.10.3 Mid-Term Weather Integration and Needs Analysis

No anticipated weather integration and needs for this OI as summarized in Table A-45.

Table A-45. Environmentally and Energy Favorable En Route Operations–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.11 OI - Environmentally and Energy Favorable En Route Operations – Enhanced (109312) [Environment]

This OI is focused on further optimization of en route operations to reduce emissions, fuel burn and noise. It intends to utilize an environmental management system embedded into real time route planning to reduce environmental impact and improve efficiency in operations system-wide including, as appropriate, in sensitive areas (e.g., national parks).

A-2.5.11.1 High Level Mid-Term Capabilities

This OI does not require any unique weather capabilities or data, but is likely to be part of other automation tools (e.g., route planning – described in other OIs) that make use of such data.

A-2.5.11.2 Mid-Term Operational Scenario

N/A

A-2.5.11.3 Mid-Term Weather Integration and Needs Analysis

No unique anticipated weather integration and needs for this OI as summarized in Table A-46.

Table A-46. OI - Environmentally and Energy Favorable En Route Operations – Enhanced–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.12 OI - Environmentally and Energy Favorable Terminal Operations (109313) [Environment]

The main goals of this OI are to optimize aircraft arrival, departure, and surface operations to reduce emissions, fuel burn, and noise through the use of environmentally friendly procedures, to develop STAR procedures that permit use of the OPD technique (also known as CDA), to develop RNAV SID procedures that minimize level segments on climb out, and to develop enhanced surface operation mechanisms and procedures to maximize airport throughput while further reducing aircraft fuel burn and emissions.

A-2.5.12.1 High Level Mid-Term Capabilities

This OI does not require any unique weather capabilities or data, but is likely to be part of other automation tools (e.g., route planning – described in other OIs) that make use of such data.

A-2.5.12.2 Mid-Term Operational Scenario

N/A

A-2.5.12.3 Mid-Term Weather Integration and Needs Analysis

No unique anticipated weathe integration and needs for this OI as summarized in Table A-47.

Table A-47. Environmentally and Energy Favorable Terminal Operations–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.13 OI - Environmentally and Energy Favorable Terminal Operations – Enhanced (109314) [Environment]

This OI intends to achieve further optimization of aircraft arrival, departure, and surface operations to reduce emissions, fuel burn, and noise. It will promote the use of environmentally friendly procedures managed through an EMS, such as OPD/RNAV procedures and the use of automation and enhanced surveillance to schedule and control arriving and departing aircraft in an optimum manner to reduce environment and energy use impacts. OPD is also known as CDA.

A-2.5.13.1 High Level Mid-Term Capabilities

This OI does not require any unique weather capabilities or data, but is likely to be part of other automation tools (e.g., route planning – described in other OIs) that make use of such data.

A-2.5.13.2 Mid-Term Operational Scenario

N/A

A-2.5.13.3 Mid-Term Weather Integration and Needs Analysis

No unique anticipated weather integration and needs for this OI as summarized in Table A-48.

Table A-48. Environmentally and Energy Favorable Terminal Operations – Enhanced–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.14 OI - Implement NextGen Environmental Engine and Aircraft Technologies (109315) [Environment]

This OI aims for reductions in aircraft noise, emissions, and fuel burn through improvements in aircraft engine and airframe technologies and alternative fuels. Technologies will be at sufficient readiness level to achieve the goals of the FAA CLEEN program.

A-2.5.14.1 High Level Mid-Term Capabilities

No weather-related capabilities anticipated.

A-2.5.14.2 Mid-Term Operational Scenario

N/A

A-2.5.14.3 Mid-Term Weather Integration and Needs Analysis

No unique anticipated weather integration and needs for this OI as summarized in Table A-49.

Table A-49. Implement NextGen Environmental Engine and Aircraft Technologies–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.5.15 OI - Increased Use of Alternative Aviation Fuels (109316) [Environment]

The goal of this OI is to determine the feasibility and market viability of alternative aviation fuels for civilian aviation use. It will obtain American Society for Testing and Materials (ASTM) certification of Hydrotreated Renewable Jet (HRJ) fuels from fossil and renewable resources that are compatible with existing infrastructure and fleet thus meeting requirements to be a drop in alternative fuel.

A-2.5.15.1 High Level Mid-Term Capabilities

No weather-related capabilities anticipated.

A-2.5.15.2 Mid-Term Operational Scenario

N/A

A-2.5.15.3 Mid-Term Weather Integration and Needs Analysis

No unique anticipated weather integration and needs for this OI as summarized in Table A-50.

Table A-50. Increased Use of Alternative Aviation Fuels–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
N/A	N/A	N/A	N/A

A-2.6 Transform Facilities (Facilities) Solution Set

NextGen transforms the national air transportation system by establishing enhanced and expanded services through new technologies, policies, procedures, and methods of operation to meet future demand and avoid gridlock in the sky and at the airports.

NextGen activity focuses on delivering a facility infrastructure that support the transformation of air navigation service delivery unencumbered by legacy constraints. NextGen facilities will provide for expanded services; service continuity; optimal deployment and training of the workforce –all supported by cost-effective and flexible systems for information sharing and back-up. Traffic is assigned to facilities on both a long-term and daily basis with service continuity a foremost requirement. Business continuity is built into the system and provides for a more resilient infrastructure, better contingency operations, and a higher degree of service.

Within the NextGen facility solution set, there are three planned activities. The first is the establishment of an integration, development and operations analysis capability. NextGen introduces evolutionary and revolutionary ConOps and new technologies into the ATS. The integration, development and operations analysis capability provides for the conduct of early evaluations, concept development, alternatives analyses, and/or demonstrations in a flexible, real-time NextGen integrated environment introduced by NextGen.

The second activity, future facilities planning, includes a full range of studies that will address NextGen facility alternatives to meet the need to transform operations in an environment that provides flexibility by reducing the need to be geo-dependent and proximate to the air traffic being managed.

Lastly, the NextGen tower activity will identify the necessary requirements and specifications for future towers as well as determine a common tower display and look at the possibility of certification of ASDE-X and/or alternatives to support ground separation. Work accomplished will support a planned 2011 initial investment decision.

The mid-term Facilities OIs of interest are listed here in the order in which they appear as brick red-colored timelines in the Facilities Timeline Figure A-38 as follows:

- NAS-Wide Sector Demand Prediction and Resource Planning
- Remotely Staffed Tower Services

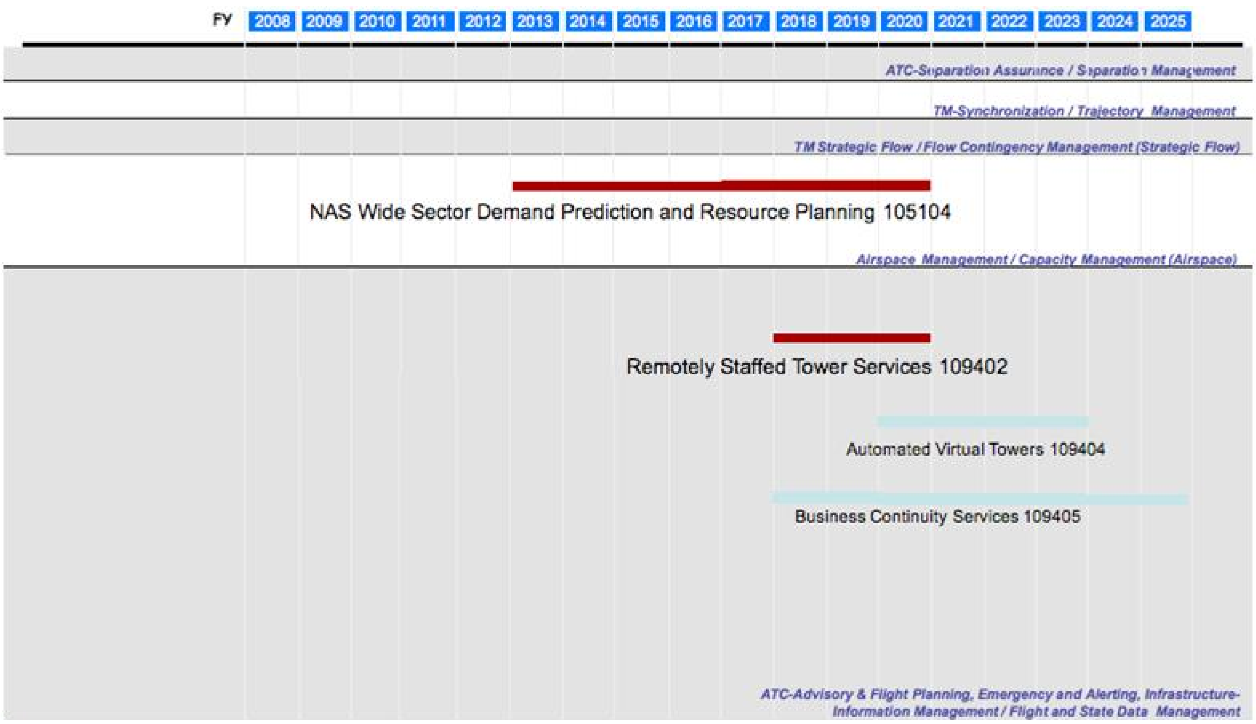


Figure A 38. Transform Facilities Timeline

A-2.6.1 OI – NAS-Wide Sector Demand Prediction and Resource Planning (105104)

This OI develops an integrated model of NAS-wide resource capacity drivers and robust, consistent user-supplied demand information to provide one integrated DST.

The model includes the capacity impact of key resource constraints: (1) gate, airspace or runway blockages (for safety, security or weather); (2) fleet mix and performance characteristics; (3) flow structure that modifies the complexity of the operation; and (4) workload. Strategic resources (e.g., airspace, sectors, personnel, facilities, NAS systems) are modeled in parallel with systemic changes in demand due to increases in air traffic, seasonality, or city pair business case decisions. As part of the continuous evaluation process, future traffic loads are modeled against various solutions to mitigate adverse impacts to users.

The ANSP and stakeholders use decision management systems to achieve consensus once NAS-wide modeling efforts are accomplished and analyzed. This includes proactively adjusting airspace configurations based on projections of shift in demand due to seasonal changes, as well as city pair business adjustments by NAS users. Strategic long-term planning with dynamic and flexible airspace and airports minimizes adverse impacts to users. ANSP is responsible for managing the NAS, while the CDM process leads to consensus among the stakeholders about proposed resolutions.

A-2.6.1.1 High Level Mid-Term Capabilities

This OI considers a longer-term planning timeframe (e.g. months or years) and has a need for more generalized climate information, rather than just near-term weather information. Therefore, this OI assumes the availability of and access to archived weather data to be used to model broad characterizations of weather patterns across longer planning horizons for future planning decisions.

A-2.6.1.2 Mid-Term Operational Scenario

N/A

A-2.6.1.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities and an understanding of the assumed objectives, weather needs for this OI are analyzed in Table A-51.

Table A-51. NAS-Wide Sector Demand Prediction and Resource Planning–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Ability to access archived weather data for characterization of climatology trends for future planning	No additional unique weather information need	N/A	N/A

A-2.6.2 OI - Remotely Staffed Tower Services (109402)

Remotely Staffed Towers provide ATM services for operations into and out of designated airports without physically constructing, equipping, and/or sustaining tower facilities at these airports. Instead of out-the-window visual surveillance, controllers maintain situational awareness provided by surface surveillance displayed on an ANSP display system and a suite of DSTs using aircraft-derived data.

Weather, traffic, and other relevant information are displayed on the ANSP display system to avoid discontinuities associated with the mix of heads-up versus heads-down operations.

With the deployment of Remotely Staffed Towers, ANSP personnel may be able to service multiple airfields from a single physical location, allowing for reductions in the total number of service delivery points. This accommodates managing increases in life cycle costs to sustain, expand, and improve services in response to steadily increasing demand.

In the end state, Remotely Staffed Towers will provide advanced surface management. The ANSP personnel will have access to the necessary ground and terminal surveillance information and DSTs to provide separation, sequencing, and spacing services. DSTs will assist ANSPs with planning taxi routes, and arrival and departure sequencing. Clearance delivery and pushback into movement or non-movement areas is accomplished by voice and/or data communications to the aircraft, aided by situational awareness derived from surveillance sensors and conformance monitoring tools presented directly on the ANSP display. Some separation responsibility and some traffic synchronization responsibility are delegated to properly equipped aircraft.

To improve common situational awareness, weather, traffic management initiatives, and flight plan data are available to ANSPs and flight operators via net-centric information capabilities. Weather data is distributed to and from aircraft using digital communications and will conform to the NNEW concept. Special airport sensors detect runway hazards at the airport and automatically alert controllers and pilots of the hazard via voice and/or data communications.

A-2.6.2.1 High Level Mid-Term Capabilities

Airports with Remotely Staffed Towers will require weather sensing and communications equipment to ensure ATC personnel and local air traffic are apprised of current and forecast conditions at the airport.

A-2.6.2.2 Mid-Term Operational Scenario

Remotely staffed tower personnel provide weather advisories to local traffic based on weather conditions reported by automated systems and supplemented by any available PIREPs.

A-2.6.2.3 Mid-Term Weather Integration and Needs Analysis

Based on the associated described capabilities and an understanding of the assumed objectives, weather needs for this OI are analyzed in Table A-52.

Table A-52. Remotely Staffed Tower Services–Mid-Term Weather Needs Analysis

Mid-Term Weather Integration Need	Mid-Term Weather Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Weather Information Gap
Ability of remotely staffed tower personnel to obtain weather observations and forecasts	No additional weather information needed	TBD	TBD

B. TECHNOLOGY AND METHODOLOGY

B-1. Survey of ATM-Weather Impact Models and Related Research

B-1.1 En route Convective Weather Avoidance Modeling

In order to determine the impacts of convective weather on en route air traffic operations, it is necessary first to partition airspace into passable and impassable regions. As shown in Figure B-1, en route Convective Weather Avoidance Models (CWAM) calculate Weather Avoidance Fields (WAFs) as a function of observed and/or forecast weather. WAFs are 2D or 3D grids whose grid points are assigned either a probability of deviation or a binary deviation decision value (0 or 1).

Since the pilot is responsible for weather avoidance, CWAM requires both the inference of pilot intent from an analysis of trajectory and weather data and an operational definition of deviation. Two approaches have been taken to model and validate weather-avoiding deviations using trajectory and weather data: trajectory classification [RKP02, DE06, DRP08, CRD07] and spatial cross-correlation [PBB02, K08].

In the trajectory classification approach, planned and actual trajectories of individual flights are compared and each flight is classified as a deviation or non-deviation, based on criteria derived from fair weather operations (e.g., operational route boundaries) or the judgment of a human analyst. Characteristics of the weather encountered along the planned trajectories and the trajectory classification are input to statistical pattern classification algorithms to identify the weather characteristics that best predict deviations.

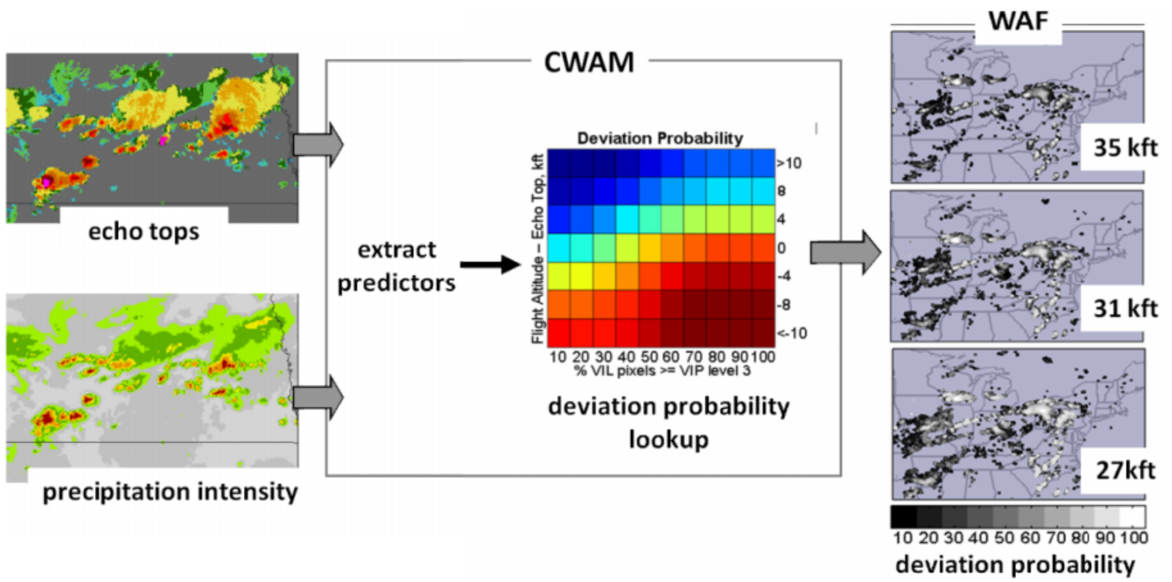


Figure B-1 CWAM implementation to create WAFs.

In the spatial cross-correlation approach, spatial grids of aircraft occupancy are cross-correlated with grids of weather data. Occupancy counts on weather-impacted days are compared to fair-weather counts. Regions where weather-impacted counts are low relative to fair-weather counts are assumed to be areas that pilots are avoiding due to the weather present in the area. The correlation of observed weather with areas of avoidance is used to identify the weather characteristics that best predict the observed weather avoidance.

Both approaches have strengths and weaknesses. Trajectory classification is highly labor intensive, restricting the size of the statistical dataset used in the model, but gives very detailed insights into pilot behavior. Spatial cross-correlation greatly reduces the labor involved in the analysis, vastly increasing the modeling dataset, but does not provide information about individual decisions. Spatial cross-correlation is also subject to errors arising from the displaced weather impacts (e.g., local air traffic counts are abnormally low because airways leading to the region are blocked by weather upstream) or traffic management initiatives that distort demand (e.g., pro-active reroutes to avoid predicted weather that does not materialize as expected).

To date, CWAM studies have only considered weather characteristics derived from ground-based weather radar products (precipitation intensity, echo top height). Studies using both methodologies have identified the difference between aircraft altitude and echo top height as the primary predictor of weather-avoiding deviation in en route airspace, with precipitation intensity playing a secondary role. Current CWAM are most prone to error for en route traffic flying at altitudes near the echo top, particularly in regions of moderate precipitation intensity. Since current CWAM are based only on ground-based weather radar, they do not readily discriminate between relatively benign decaying convection and stratiform rain and turbulent downwind from thunderstorms, both of which are often characterized by echo tops in the 30-40 kft. range and moderate precipitation intensities [DCF09]. Further research is needed to examine additional weather information (e.g., satellite, winds, convectively-induced turbulence estimates [CML04]) that may help differentiate between benign and hazardous regions with similar radar signatures. Research is also needed to identify the human factors (see C-5) associated with pilot decision-making, particularly in circumstances where CWAM performs poorly.

B-1.2 Terminal Convective Weather Avoidance Modeling

In order to determine the impacts of convective weather on terminal air traffic operations, it is necessary to partition terminal area airspace into passable and impassable regions. CWAM that take into account the constraints of terminal area flight need to calculate WAFs that apply specifically to terminal area operations. Each WAF grid point is assigned a probability and/or a binary value (0 or 1) that represents that likelihood that pilots will choose to avoid convective weather at a point location in the terminal area.

CWAM for terminal areas are likely to differ from en route CWAM in significant ways. Departures and arrivals are constrained to follow ascending or descending trajectories between the surface and cruise altitude, leaving little flexibility to avoid weather by flying over it. Pilots of aircraft ascending or descending through weather are likely to have few or no visual cues to inform their decision, unlike those in en route airspace who may have clear views of distant thunderstorms as they fly above the clouds. Aircraft flying at low altitudes in the terminal area appear to penetrate weather that en route traffic generally avoids [K08]. The willingness of pilots to penetrate severe weather on arrival increases as they approach landing [RP98].

CWAM for departures and arrivals are also likely to differ from each other, for example, as illustrated in Figure B-2. The observed difference in behavior is not completely surprising, since arriving and departing flights are characterized by very different constraints and circumstances: arrivals must get down from the sky, while departures can wait on the ground until the weather is more favorable; departures must climb out at full power and hence have little opportunity to deviate to avoid weather in the first few minutes of flight, while arrivals have flexibility to maneuver until final approach; arrivals descending from above the cloud base have less information about the severity of the weather below than departures climbing from the ground.

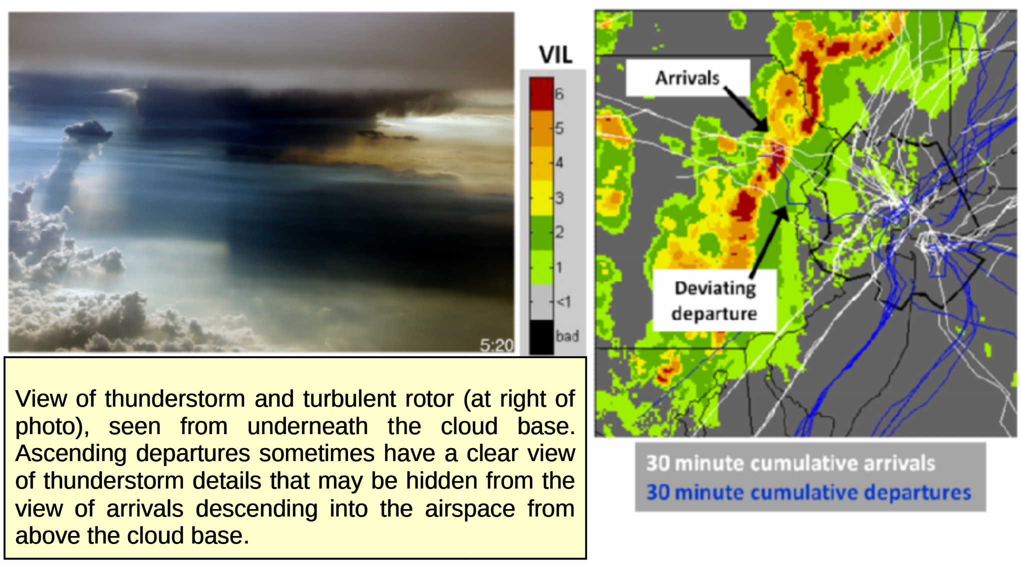


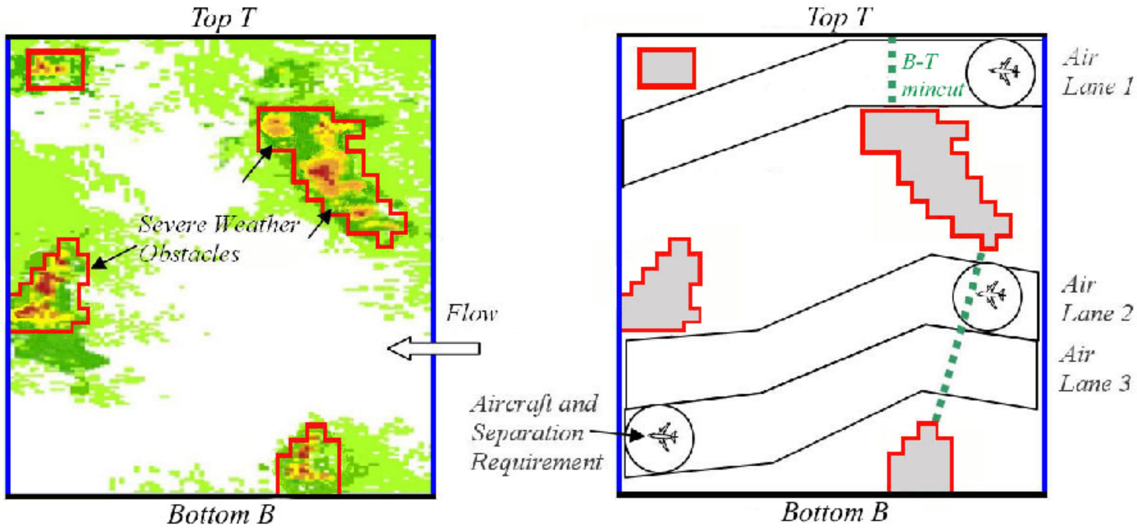
Figure B-2 Arriving pilots penetrate weather that departures seek to avoid.

For NextGen, terminal area CWAM research is needed both to understand the factors that affect pilot decision making in the terminal area during departures and arrivals, to identify the set of weather characteristics that correlate best with observed weather avoidance in the terminal area, and to understand how unstructured routing and Required Navigation Performance (RNP) in NextGen may change the characteristics of terminal area throughputs [KPM08].

B-1.3 Mincut Algorithms to determine Maximum Capacity for an Airspace

For NextGen when jet routes can be dynamically redefined to adjust flows of traffic around weather constraints and when controller workload is not a significant constraint, the maximum capacity of an airspace region may be determined using extensions of MaxFlow/Mincut Theory [AMO93,M90,KMP07]. The network MaxFlow/Mincut Theorem has been extended to a continuous version of the maximum flow problem [M90, I79, St83], which is suitable for estimating the maximum throughput across an en route airspace given a traffic flow pattern [SWG08], a uniform distribution of flow monotonically traversing in a standard direction (e.g., East-to-West), or random, Free Flight conditions [KMP07]. The maximum capacity of transition airspace may also be determined by transforming the problem into an analysis over the ascent or descent cone modeling terminal airspace [KPM08].

The translation is shown in Figure B-3. Given convective weather constraints and a method of defining the weather hazard (e.g., thresholding convective weather at NWS Level 3 or using the CWAM model [CRD07]), a geometric hazard map (or WAF) may be determined. Next, one defines the width of an air lane (equivalently, the required gap size between adjacent hazardous weather cells) that is required for a flow of traffic passing through the airspace, any geometric polygonal shape (such as a sector, FCA, grid cell, or hex cell) in a given period of time. The required gap size between weather constraints may be expressed in terms of RNP requirements for aircraft using the air lane passing through those gaps. In one version of the problem, mixed air lane widths are used to represent a non-uniform RNP equipage and/or set of preferences by aircraft arriving into the airspace [KPM08]. An algorithmic solution identifies the mincut bottleneck line – this mincut line determines the maximum capacity in terms of the maximum number of air lanes that can pass through the gaps in the weather hazards. The maximum number of air lanes can be determined by analyzing weather constraints as a function of time given a weather forecast product.



(a) Weather hazard is defined

(b) Mincut bottleneck determines the maximum number of lanes of traffic that may pass

Figure B-3 The translation of convective weather into maximum ATM throughput.

The described approach is a geometric analysis of the weather constraints transformed into maximum throughput for a given flight level. For NextGen, complexity and human workload (controller and/or pilot) limitations must be taken into account for determining the capacity of an airspace.

B-1.4 Weather-Impacted Sector Capacity considering CWAM and Flow Structure

Sector capacity as an indicator of controllers' workload threshold is not a single value even on clear weather days, since controller workload is not only a function of the number of aircraft, but also a function of traffic complexity. One way to describe traffic complexity is with traffic flow patterns [SWG06]. Traffic flow patterns are described with clustered flow features, which are more predictable and perturbation-resistant than metrics which rely on single-aircraft events or aircraft-to-aircraft interactions. NAS sectors typically exhibit a small set of common traffic flow patterns, and different patterns represent different levels of traffic complexity. In higher-complexity conditions, it takes fewer flights to generate high workload for the controller team, and thus the sector capacity is lower.

As illustrated in Figure B-4, quantifying sector capacity as a function of traffic flow pattern [SWG06] provides a basis for capturing weather impact on sector capacity. In addition to the size of the weather, the shape and the location of the weather in a sector are also captured in a flow-based weather-impacted sector capacity prediction [SWG07]. A Weather Avoidance Altitude Field (WAAF) that most aircraft would deviate is generated based on a CWAM model [DE06, CRD07]. (Note: The WAAF is a 3D version of the WAF of the CWAM.) The future traffic flow pattern in the sector is predicted and described with flows (sector transit triplets) and flow features. The available flow capacity ratio of each flow in the predicted traffic flow pattern is then determined by the MaxFlow/Mincut Theory [AMO93, M90, KMP07]. The available sector capacity ratio is the weighted average of the available flow capacity ratio of all the flows in the predicted traffic flow pattern. The weather-impacted sector capacity is the available sector capacity ratio times the normal sector capacity given the predicted traffic flow pattern. The flow-based available sector capacity ratio has a strong linear correlation with the estimated actual sector capacity for the sectors with dominant flows [SWG08].

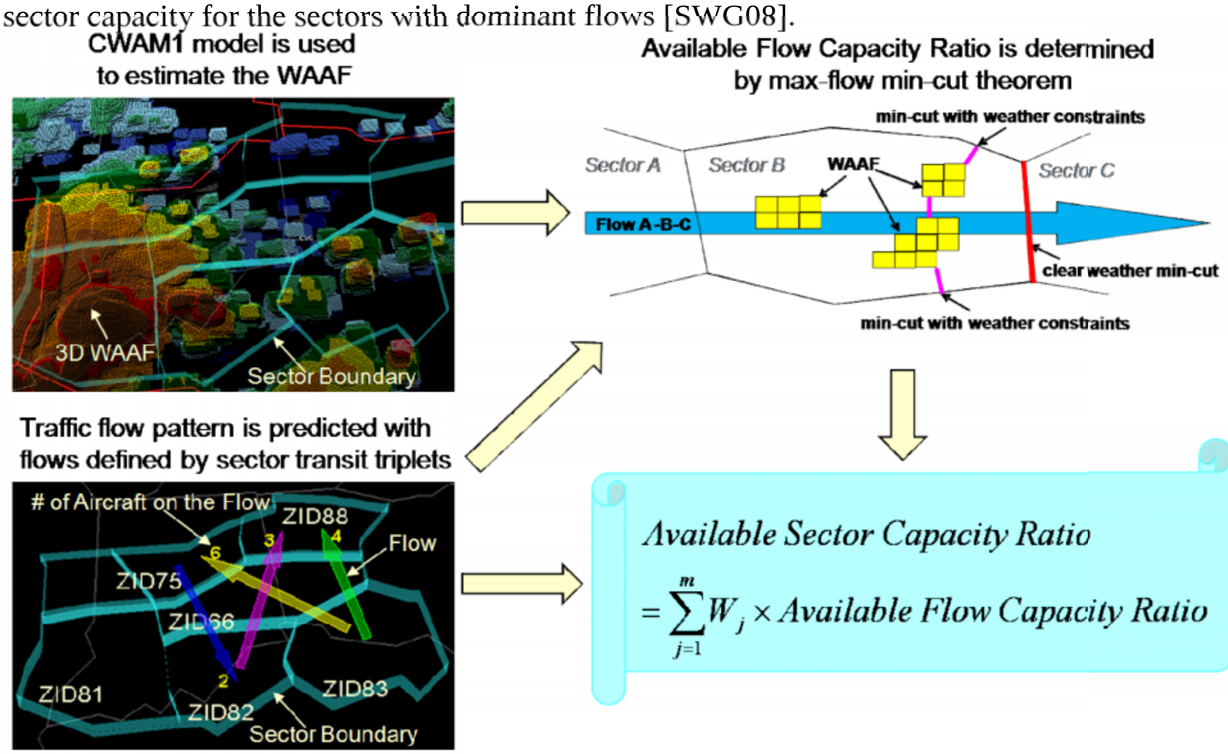


Figure B-4 Weather impacted sector capacity estimation

An alternative approach to quantifying sector capacity given the fair weather traffic flow patterns is to determine to what extent the fair weather routes are blocked and the fraction of the overall sector traffic carried by those routes [M07]. This model estimates the usage of the sector predicted by a route blockage algorithm (which is discussed next).

B-1.5 Route Availability in Convective Weather

Several ATM tasks, including departure and arrival flow management and the planning of weather-avoiding reroutes, require the assessment of the availability and/or capacity of individual traffic routes or flows. Thus, it is natural to extend Maxflow/Mincut, CWAM, and WAF concepts into route availability prediction tools.

A route defines a spatially bounded trajectory. A route is available if there is a way for traffic to generally follow the trajectory and stay within the bounds while avoiding hazardous weather. The route capacity is the rate of traffic flow that an available route can support. Estimating route availability may be achieved by Maxflow/Mincut (MM) [M90, KMP07, SWG07, SWG08] and Route Blockage (RB) techniques [RBH06, M07]. Both methods identify weather-avoiding paths that traverse a portion of airspace along a route. Capacity estimates based on MM and RB must account for the workload and uncertainty involved in flying the weather-avoiding trajectories that they identify.

MM begins with a deterministic partition of the airspace into passable and impassible regions. MM identifies all paths that traverse the airspace without crossing weather obstacles, and characterizes each path by its minimum width. Route availability and capacity are related to the number, required width (gap between hazardous weather cells), and complexity of paths identified.

RB uses a probabilistic partition of airspace, in which each pixel is assigned a probability of deviation around the pixel. RB finds the best path that traverses the space, defined as the widest path that encounters the minimum probability of deviation in the traversal. The route blockage is a weighted average of all pixels in the space with deviation probabilities ≥ the minimum probability encountered by the best path. RB differs from MM in that it identifies a single path that traverses the airspace, and it takes into account the nature of the weather that trajectories are likely to encounter on their traversal of the airspace (Figure B-5, left).

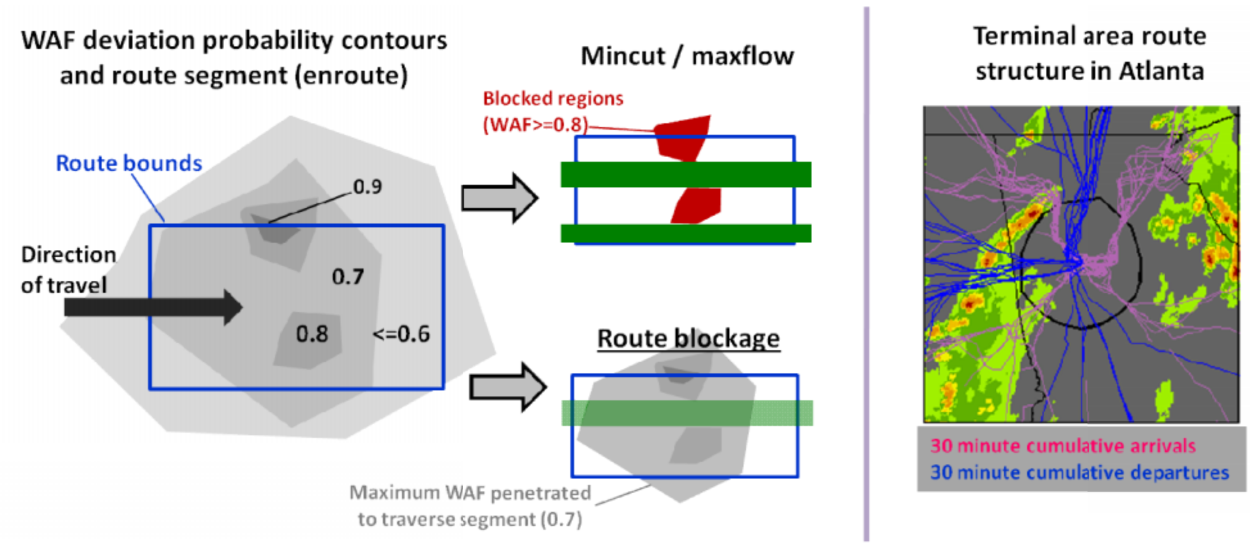


Figure B-5 Maxflow/Mincut and Route Blockage estimate route availability in structured, en route airspace (left) and flexible routing to avoid terminal area convective weather (right).

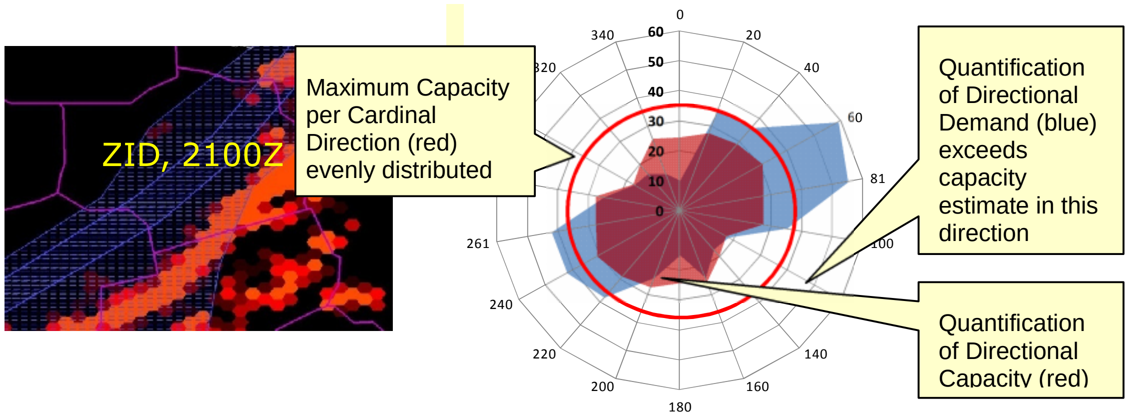
Estimating route availability in terminal areas has additional difficulties. Air traffic controllers have considerable flexibility to route aircraft around weather in terminal areas, and the bounds on traffic flows may be fluid and difficult to define (Figure B-5, right). Route availability in the terminal area may not be accurately determined simply by characterizing the weather impacts on nominal (i.e., fair weather) departure and arrival routes and sector geometry. The constraints on traffic flows at any given time depend on specific details of the flow structure and the nature of the demand (balance between arrivals and departures). Uncertainty in predicting flight time from runway to departure fix (or from metering fix to runway) when aircraft are maneuvering to avoid weather also has an impact on capacity that is difficult to estimate. Significant research is needed to develop terminal area airspace usage models that can be combined with WAFs to provide reliable estimates of route availability and time of flight between the runway and en route airspace.

B-1.6 Directional Capacity and Directional Demand

In addition to capacity being a function of flow pattern for a given airspace unit, airborne separation and RNP requirements, and convective weather impacting the airspace, capacity is also a function of traffic demand, both spatial and temporal. Since traffic flow patterns are directional, capacity is also directional. If the majority of traffic in a given period of time wants to traverse a center in the east-west direction and the center airspace capacity cannot accommodate this demand (e.g. due to weather blocking large portions of the east-west flows), the fact that the center might have, in principle, plenty of capacity to accommodate north-south traffic does not help. Consider for instance, the case of a squall line weather system, and traffic flow trying to pass through gaps in the squall line vs. parallel to it. Queuing delays will ensue when the capacity is limited in a particular direction, and upstream traffic will be forced to deviate around the constraint, be held upstream, and/or back at origin airports.

The capacity of an airspace can be estimated for a series of ‘cardinal’ directions, e.g., the standard directions of North (N), East (E), South (S), West (W) and the diagonals NE, NW, SE, and SW [ZKK09]. Also, directions can be quantified every Θ degrees (e.g., Θ=20 deg.), spaced around a given NAS resource, for instance, around an airport, metroplex, or fix location, or within a section of airspace [KPM08, KCW08]. For each angular wedge of airspace, the maximum capacity for traffic arriving from or traveling in that direction may be established. MaxFlow/Mincut techniques [ZKK09, KPM08] as well as scan line techniques [KCW08] have been demonstrated for this purpose. The maximum capacity for a particular angular wedge of airspace will quantify the permeability of the weather with respect to traffic arriving from [KPM08] or traveling in [KCW08] this particular direction. The permeability can be calculated using pre-defined permeability thresholds [SSM07] that indicate at what probability or actual intensity of convective weather will most aircraft be likely to deviate (or plan the flight around the weather in the first place).

Directional capacity percent reductions may be used to determine the acceptable number of aircraft that can be accepted from or can travel in a particular direction. This may be expressed in units relative to the maximum capacity for the airspace when no weather is present. Demand can also be calculated in each direction using the primary direction a flight will take within a given unit of airspace (grid cell, hex cell, sector, center, FCA, etc.). By comparing directional capacity vs. demand on a rose chart, for instance as illustrated in Figure B-6, directional demand-capacity imbalances can be identified as well as regions where there may be excess directional capacity to accommodate additional demand. In NextGen, en route traffic flow patterns may be adjusted [ZKK09] or terminal traffic flow patterns may be adjusted (e.g., route structures and metering fix locations around a metroplex [KPM08]) in order to maximize the capacity by restructuring the traffic flow pattern (demand) to best meet the directional capacity.



b) Forecasted Weather Constraint (b) Directional Impact

Figure B-6 Directional capacity and demand rose chart.

NextGen researchers must still address how directional capacity should consider the complexity of the traffic demand and controller workload issues. Hence, if flow is largely directional, but there are very important traffic merge points within the region of interest [HH02], or if there are occasional crossing traffic constraints, then the directional capacity estimates must address these issues.

B-1.7 ATM Impact based on the Weather Impacted Traffic Index

The Weather Impacted Traffic Index (WITI) measures the number of flights impacted by weather (Figure B-7). Each weather constraint is weighted by the number of flights encountering that weather constraint in order to measure the impact of weather on NAS traffic at a given location. Historically, WITI has focused on en route convective weather, but the approach is now applied to other weather hazard types as well. In WITI's basic form, every grid cell of a weather grid W is assigned a value of 1 if above a severe weather threshold and a value of 0 otherwise. The CWAM model [CRD07] can be used to identify whether a pilot will fly through a weather hazard or will deviate around it at a given altitude. The number of aircraft T in each grid cell of the weather grid W is counted. The WITI can then be computed for any time period (such as 1 minute intervals) as the sum over all grid cells of the product of W and T for each grid cell [CDC01]. A WITI-B variation evaluates the extent to which a flight would have to reroute in order to avoid severe weather [KCWS08]. If a planned trajectory encounters severe weather, the algorithm finds the closest point in a perpendicular direction to the flow where no severe weather is present. The WITI score for that route is then weighted by the number of cells between the original impeded cell and the unimpeded cell found for the re route.

Various methods for determining the traffic count have been explored. WITI can use actual flight tracks from "good weather days" as the traffic data source [CS04], current day flight plan trajectories [PBB02], or great circle tracks between the origin and destination airports as the ideal, shortest-path unimpeded flight trajectories [KJL07]. Actual scheduled flight frequencies on these flows for the day in question are used. The En route WITI (E-WITI) for a flow is the product of its hourly flight frequency and the amount of convective reports in rectangular or hexagonal grid cells. This is then aggregated to the NAS level and to a 24-hour day, as well as by center, sector, or general airspace geometry. Another approach apportions all en route WITI measures to origin and destination airports. Even though en route delays may not be due to any local airport weather, the resulting delays will originate and/or eventuate at the departure or arrival airports. A grid cell's WITI score for a flow is apportioned to each airport proportional to the square root of the distance from the cell to those airports. The closer a weather cell is to an airport, the larger the portion of the WITI will be assigned to that airport. This provides a national WITI score broken out by airport – consistent with how NAS delays are recorded in ASPM today [KJL07].

Given that the WITI is an estimation of NAS performance, WITI has also been used as a measure of NAS delays [S06]. Multiple years of weather, traffic, and delay data have been analyzed, and a strong correlation exists between the WITI metric and NAS delays. Recent research considers other factors in addition to delay, such as the number of cancellations, diversions, and excess miles flown in reroutes [Kl05].

The correlation between the WITI and delays has improved as additional types of weather besides en route convection have been considered. Terminal WITI (T-WITI) considers terminal area weather, ranked by severity of impact, and weights it by the departures and arrivals at an airport. Types of weather include local convection, terminal area winds (direction, severity, and altitude), freezing precipitation, and low ceilings/visibility. The impact of turbulence on en route flows is also being studied as an inclusion to WITI [CKW08].

The National Weather Index (NWX) implements the WITI for the FAA. In addition to calculating E-WITI and T-WITI, it considers the additional delays due to queuing during periods where demand exceeds capacity, both en route and at airports. This 4-component NWX is referred to as the NWX4 [CKW08]. Current research is now exploring the use of the WITI for airline route evaluation, departure and arrival fix evaluation at TRACONs, and principal fix evaluation in ATM centers [KMK09].

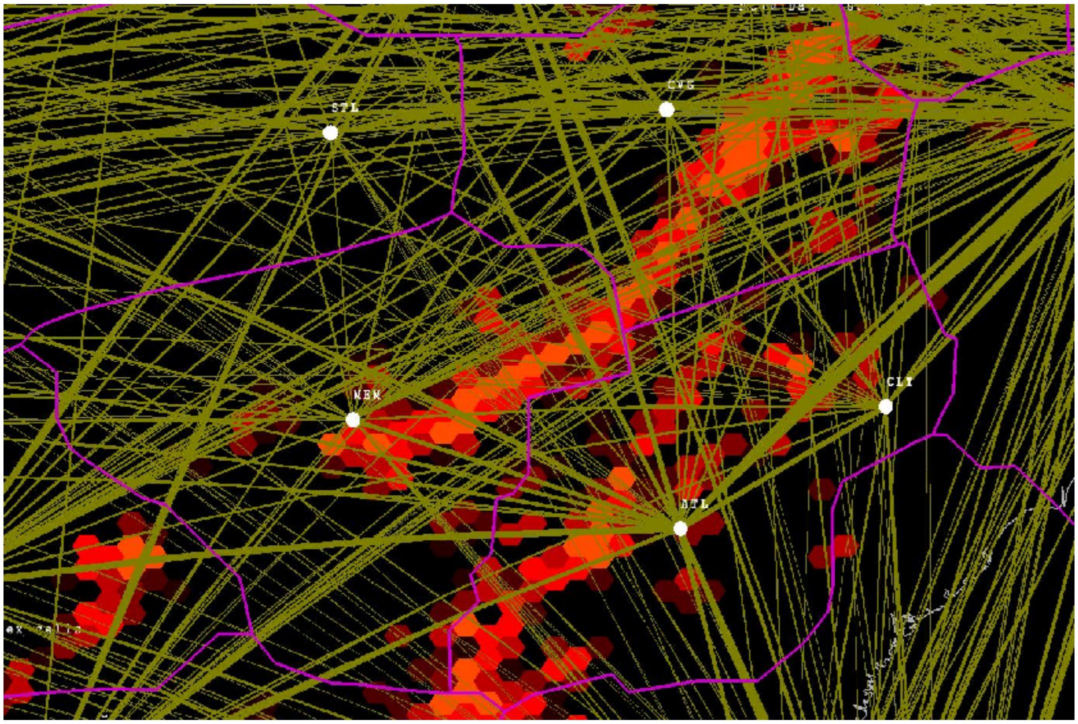


Figure B-7 Factors included in a WITI calculation.

B-1.8 Weather-Weighted Periodic Auto Regressive Models for Sector Demand Prediction

Traditional air traffic flow prediction models track the aircraft count in a region of the airspace based on the trajectories of the proposed flights. Deterministic forecasting of sector demand is routinely done within ETMS, which relies on the computation of each aircraft's entry and exit times at each sector along the path of flight. Since the accuracy of these predictions is impacted by departure time and weather uncertainties [MC02, E01], and since weather forecast uncertainty causes errors in the sector count predictions [KRG02, WCG03], traditional methods can only predict the behavior of NAS for short durations of time – up to 20 minutes. It is difficult to make sound strategic ATM decisions with such a short prediction accuracy. If a severe storm blocks a sector or regions near it, both sector capacity and demand may drop dramatically [SWG07 SWG08]; trajectory predictions must account for this.

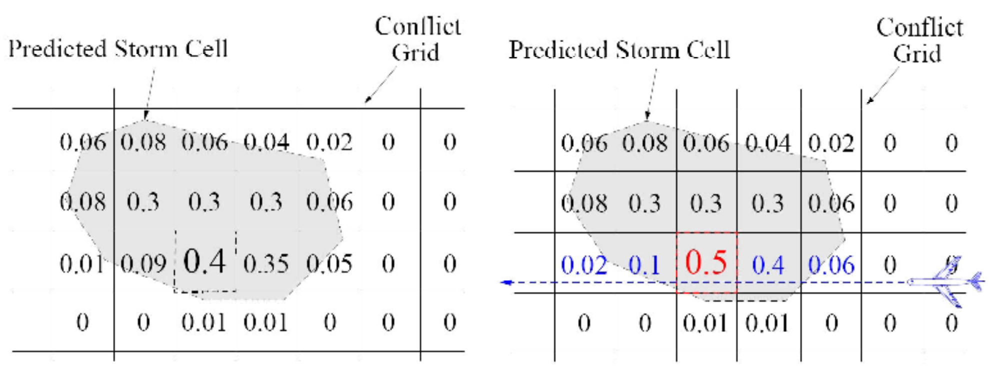
An empirical sector prediction model accounts for weather impact on both short-term (15 minutes) and mid-term (30 minutes to 2 hours) predictions. Different from traditional trajectory-based methods, a Periodic Auto-Regressive (PAR) model and its variants [Lj99, FP03] evaluate the performance of various demand prediction models considering both the historical traffic flows to capture the mid-term trend, and flows in the near past to capture the transient response. A component is embedded in the model to reflect weather impacts on sector demand. In addition, to capture the impact on all low, high, and super high sectors, storm echo tops information is needed. Only the storms with the echo tops above the lower boundary of the sector are considered. Results indicate improvements over the traditional sector demand models [CS09].

B-1.9 ATM Impact in terms of a Stochastic Congestion Grid

The effects of weather (convection, turbulence, or icing) on airspace capacity may be formulated in terms of a Stochastic Congestion Grid (SCG) [J05]. The SCG quantifies congestion (density of aircraft) in a way that accounts for the uncertainty of the aircraft demand and uncertainty of the weather forecast for long look-ahead times, as required by strategic TFM planning processes.

As illustrated in Figure B-8, each grid cell (a horizontal 2D grid is shown) records an estimate of the probability that the expected traffic exceeds a threshold level established by the ANSP. In NextGen, 4-D trajectories are submitted for each aircraft flying in the NAS, they are stored in the 4-D congestion grid by projecting the 4-D trajectory onto the grid with an error model for along track error and cross track error. An increase in probability of congestion occurs where the traffic flow increase coincides with the predicted weather constraint. A probability that a weather constraint will exist is described on a grid cell instead of a binary value for a constraint versus no constraint. If the probability that traffic in any 4-D grid cell exceeds tolerable thresholds set by ANSP (dependent on a weather-to-ATM impact model [CRD07, SWG08]), then an airspace resource conflict is monitored and appropriate action is taken by the ANSP.

For strategic look-ahead times, all information is probabilistic for when and where TFM strategies must take action. As an aircraft nears a location of a weather constraint, the probability for when and where the aircraft traverses the grid cell becomes more tightly bounded (that is, more deterministic as the variance goes down). Furthermore, the geometry and severity of the forecasted weather constraints are also more tightly bounded. This congestion management method limits the number of aircraft within a given region of airspace, but at this point it does not need to specifically determine which aircraft are in conflict with one another, nor the specific conflict geometry between two aircraft; the SCG is simply a congestion monitor.



(a) before addition of aircraft demand at time t

(b) congestion prediction after addition of the probability of an aircraft passing at time t

Figure B-8 Stochastic congestion grid with combined traffic and weather constraint probabilities.

The SCG is a prediction of large-scale regions of high aircraft density, including bottleneck regions between weather constraints or airspace regions with high demand. The SCG may be implemented with square or hex cells, and may be applied to sectors, centers, or the entire NAS. The ANSP can use the SCG to help make strategic decisions to identify FCAs and manage the predicted congestion.

B-1.10 ATM Impact in terms of Network Flow Adjustments

Network flow models [MK08] address the strategic adaptation of traffic flows in the NAS due to en route weather constraints. These models estimate the level of congestion that may result as weather constraints reduce the capacity in certain parts of the NAS which causes increased demand elsewhere (e.g., Figure B-9). Network flow models consider aggregate traffic flow adjustments instead of individual reroutes. Weather impacts on network flows may be modeled to capture the movement of traffic across a grid of triangles, squares, or hexcells. The optimal cell to cell movement of aggregate traffic through and around weather hazards is captured in discrete time steps (e.g., 15 minutes). During each time step, aggregate flows of traffic can move from one cell to any of the adjacent cell as long as the flow does not exceed the capacity limit (e.g., as determined by capacity models based on convection, turbulence, icing, etc.). The resulting traffic counts typically go down to zero inside hazardous weather constraint regions but increase around the corners of those constraints as flows of traffic pass around constraints. These traffic counts represent optimal (least delay) adjustment of traffic flows to projected weather constraints, however, they do not account for any changes to the demand distribution due to TFM actions.

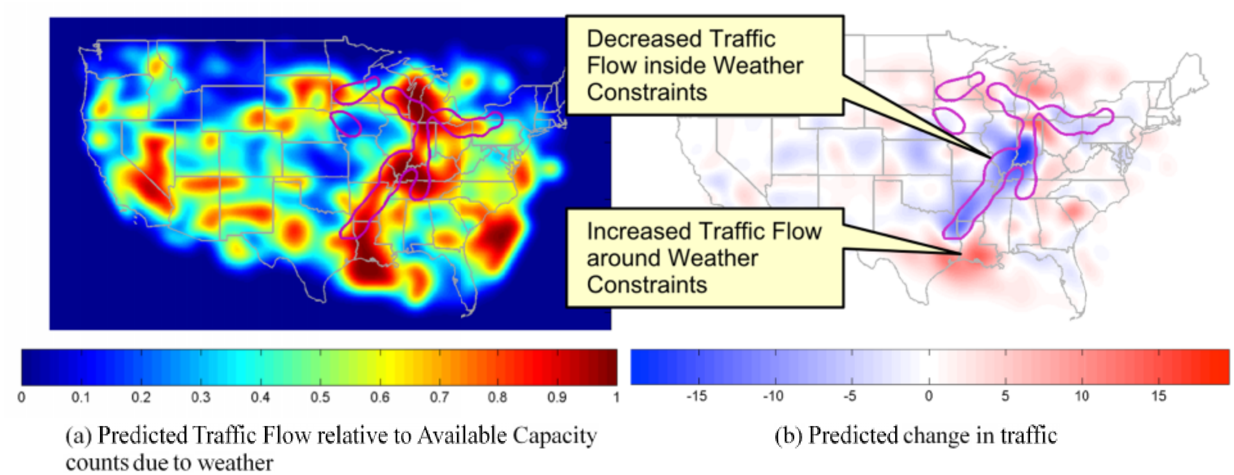


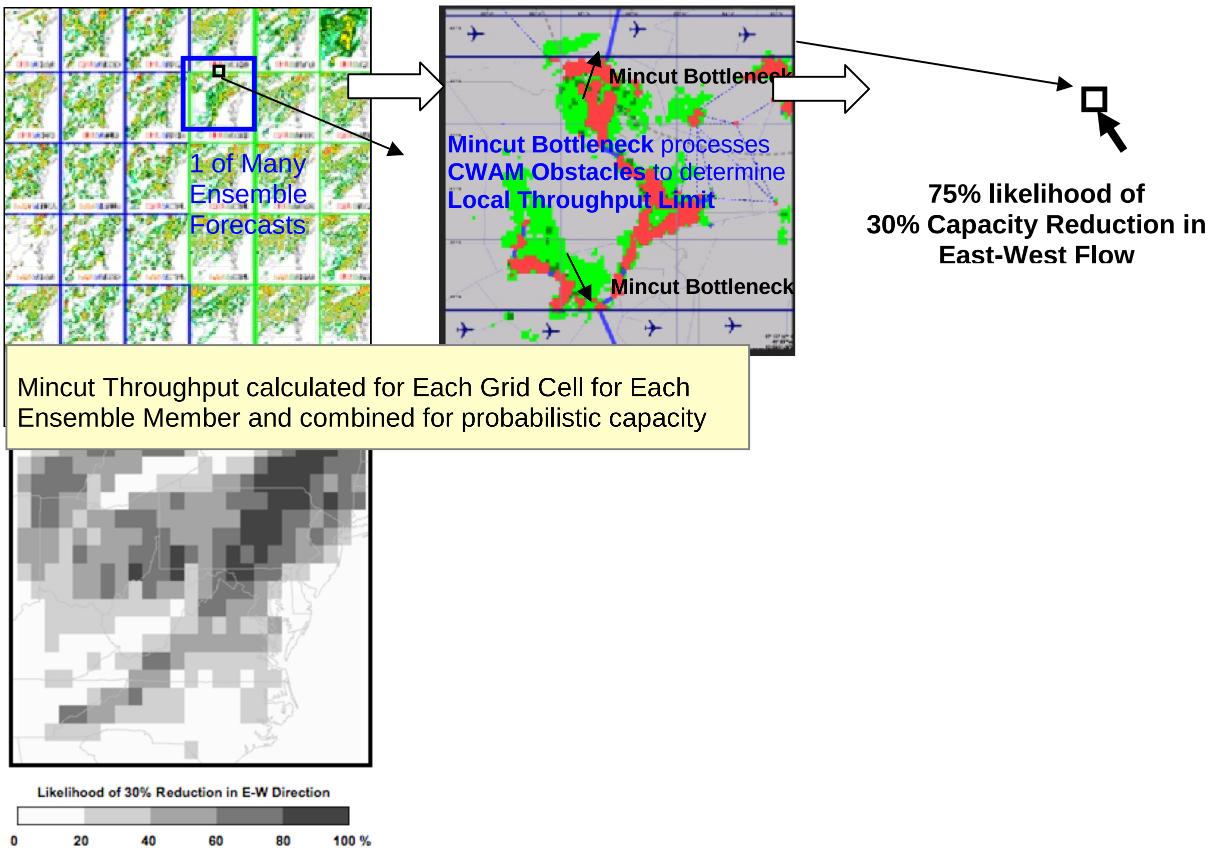
Figure B-9. Network flow approach for describing the redistribution of traffic demand due to convective weather constraints in the NAS.

B-1.11 Translation of Ensemble Weather Forecasts into Probabilistic ATM Impacts

In NextGen, in order to capture the uncertainties posed by long-term weather forecasting, ATM will rely on utilizing automated Decision Support Tools (DSTs) that will integrate probabilistic ensemble weather forecast information into ATM impacts [SM08, SB09], thus forming the basis for strategic TFM planning. The use of probabilistic forecasts will provide better tools to assist with a risk-based decision making. In the coming years, however, an understanding of the operational use of probabilistic forecasts will need to be developed, where probability may be either a measure of how likely it is that an event will occur (in space and time) or a number expressing the ratio of favorable cases to the whole number of cases possible. The move to probabilistic forecasting has been helped with the continued development of high-resolution

Numerical Weather Prediction (NWP) models and ensemble prediction systems, both spurred by increases in computing power and a decrease of equipment cost, which enables NWP models to process more data in a shorter time period. Future research must explore the benefits from the breadth of short-range to long-range forecasts, as well as fine-scale to course-scale forecast grids to better understand the trade space.

Figure B-10 illustrates the ensemble-based translation concept. Ensemble forecast systems generate a series of deterministic forecasts of potential weather outcomes (i.e., members of the ensemble). Each ensemble forecast represents a possible weather scenario that may emerge later in the day. These ensemble weather forecasts, in turn, are translated into ATM impacts with relative likelihoods and probability density functions (pdfs) for either use by humans-over-the-loop or computer-to-computer ATM applications [SK09].



(a) Ensemble of Forecasts (b) Local ATM impact per Grid Cell (c) ATM Impact Map

Figure B-10 Procedure for translating an ensemble of weather forecasts into a probabilistic capacity map in terms of likelihood of a given capacity reduction.

This process will be adapted to the needs of particular ATM applications. It can be performed using tactical 1-hour as well as strategic 2, 4, or 6-hour forecasts, processing anything from 2-member to 30-member (or more) ensemble weather forecasts. The definition of a weather hazard could be for convection, turbulence, icing, or other aviation-relevant hazards and events (e.g., major wind shifts at an airport), and any appropriate weather hazard model can be placed into the ensemble-translation process; for instance, the CWAM WAF [DE06, CRD07] for a given altitude range. The airspace capacity reduction could be directional [KCW08, ZKK09], for instance, in the East-West direction, or in any particular direction where TFM plans to organize and direct traffic.

The resulting probabilistic ATM impact maps, once they become routinely available during the NextGen era (perhaps a decade from now), will be used by many decision makers to assess risks when formulating tactical and strategic plans. Air traffic controllers, traffic flow managers, airline dispatchers, airport operators, and NextGen automated DSTs, for example, will use these results to help reason about the weather forecast uncertainties when making decisions about traffic flows and operational impacts from one to several hours into the future.

B-1.12 Translation of a Deterministic Weather Forecast into Probabilistic ATM Impacts

While the previously mentioned ensemble approach for characterizing uncertainty of forecasts is promising for long term weather forecasts, other methods may be useful in short look ahead times. In NextGen, systems can benefit from understanding how a single deterministic forecast in a grid-based format, and some error bounds associated with the forecast, can be used to create probabilistic ATM impacts for a given region of airspace [KZM09].

Providing error bounds to a deterministic forecast attempts to characterize the forecast uncertainty. The estimate of error bounds could be based on general approximations about potential errors in forecast intensity, location, and shape, or the error bounds could be a lot more sophisticated, possibly based on some probabilistic approach (e.g., the statistical post-processing of a forecast). In contrast, a probabilistic forecast can be created based on spatial filtering or on ensemble forecasting. If probabilistic forecasts are properly calibrated to be reliable and have sharpness to them, they may be more accurate and useful than a deterministic forecast (even if error bounds are provided). However, the creation of a proper calibration of probabilistic forecasts is a non-trivial problem that is still under research, so in the short term, use of deterministic forecasts with estimated error bounds may hold merit for ATM impact analysis.

Figure B-11 illustrates the concept for convective weather. A single deterministic forecast is input, and variations on this forecast are created by considering error models that account for possible errors in timing, errors in coverage, translational errors, or echo top errors. Given a standard deviation that describes the potential error in each of these dimensions, a synthetic ensemble of forecasts is created that are similar (perturbations) to the input deterministic forecast. The intermediate ensemble of erroneous forecasts is then input into an ATM-impact model, for instance, a Maxflow/Mincut method, route blockage method, or CWAM model, and a set of ATM-impacts is output. The ATM impacts may be quantified in terms of a cumulative distribution function (cdf), probability density function (pdf), a set of scenarios or maps and associated metrics, or some other format. The set of erroneous forecasts represents “what if” cases; “what if the weather system arrives early”, “what if it arrives late”, “what if it is larger than expected”, “what if it is smaller than expected”, etc. The underlying assumption is that the weather organization has been correctly forecasted, but the growth or decay of weather cells may be in question. The ATM impact model can determine, say, through a cdf, what is the probability that two lanes of traffic will be available for routing traffic through transition airspace to the North-East quadrant around a metroplex.

This process will be adapted to the needs of the particular ATM application. This process can be performed using tactical 15-minute to 1-hour look ahead. At some point, true ensemble methods (ensembles of NWP forecasts) will perform better than this method of creating synthetic ensembles, so future research is needed to identify at what look ahead time this method should be replaced with the processing of true ensemble forecasts. The benefit of the synthetic ensemble method is that it provides a well-defined sensitivity estimate of the ATM impact given errors in a single deterministic forecast. This method helps the user (or DST) reason about potential weather forecast uncertainties when making decisions about traffic flows and operational impacts.

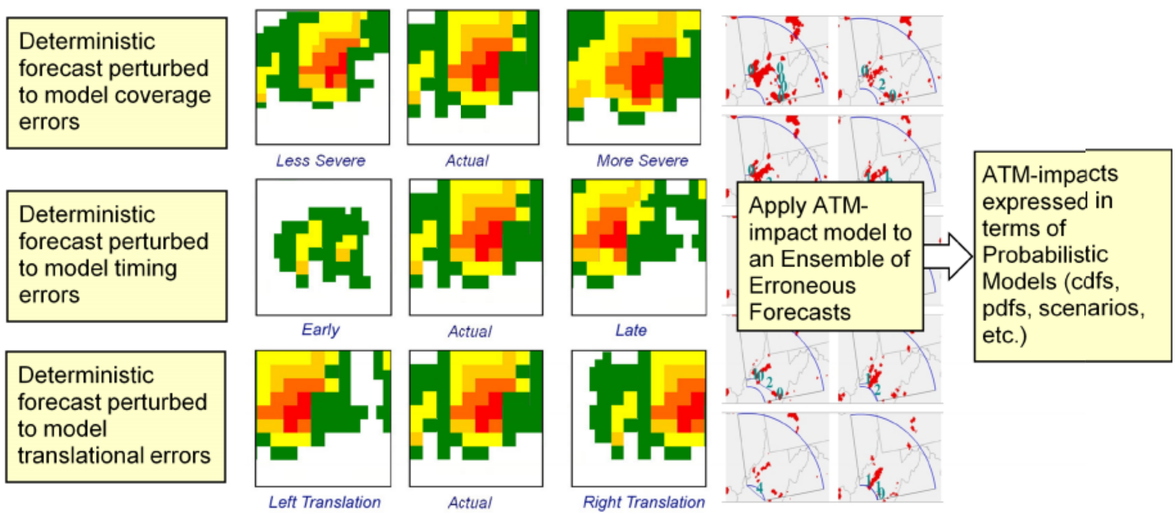


Figure B-11 Weather forecast errors characterized in terms of coverage, timing, and translational errors create an ensemble of weather constraints for a probabilistic ATM-impact assessment.

B-1.13 Sensitivity of NAS-wide ATM Performance to Weather Forecasting Uncertainty

Planners need to understand sensitivity of ATM performance to the weather forecasting uncertainty in order to make research and development decisions. The ATM performance improvement (benefit) is determined by comparing the performance sensitivity and the contemplated forecasting uncertainty reduction.

The ATM performance sensitivity to the weather forecasting uncertainty is difficult to understand for several reasons. First, there are challenges to modeling the ATM response to weather constraints. For instance, ATM performance can be characterized in a variety of ways, and likewise weather includes a variety of phenomena and no two scenarios are exactly alike. Second, not only must the ATM response to weather be modeled, but the ATM response to weather forecasts must also be modeled. Also, weather forecasting improvements may reduce uncertainty in a variety of ways. For instance, the forecasting may be improved for the short-term, but not the long-term. For these and other reasons, ATM performance sensitivity to the weather forecasting uncertainty is difficult to model and evaluate.

ATM performance has several nonlinear dependencies on independent variables such as the weather. Therefore simulation is typically required to model ATM performance. Of course, the simulation must include effects of the weather and its forecast in order to model the sensitivity to the weather forecasting uncertainty. For instance, such effects might include vectoring, rerouting and ground hold decision making models in response to weather forecasts. Such simulations have been constructed at a regional level [HB95,BH98, KPP07] and NAS wide level [RBH06, KD07].

The ATM performance simulations require weather forecasts of varying accuracy in order to evaluate the sensitivity to forecasting uncertainty. This uncertainty variation can be modeled using different approaches. For instance, two broad, and well developed, types of solution to this simulation problem are covariance propagation and Monte Carlo methods [Ge74]. In this problem, covariance propagation varies the forecast uncertainty while Monte Carlo varies the forecast itself. Of course, the covariance propagation requires that the simulation take as input the forecast uncertainty, and not merely the forecast itself. On the other hand, the Monte Carlo method requires a large number of weather forecasts. This can be accomplished with a forecast ensemble, or with forecasts from several different days.

In many problems, simple bounding cases which provide worst and best possible results are quite useful to help guide further research and planning. This is conveniently available for weather forecasts in the form of the persistence (i.e., the current weather is the forecast) and perfect (i.e., the future weather is the forecast) weather forecasts.

For example, in Figure B-12 persistence and perfect convection forecasts were used to compare the effect of the convection forecast with two ATM capabilities: trajectory-based operations traffic flow decision making where the delays and reroutes are assigned to specific flights rather than to flows, and agile decision making where flights can be rerouted or delayed minutes prior to departure [HR07]. For this scenario, these results indicate that NAS performance was most sensitive to the trajectory-based versus flow-based operations. The trajectory-based operations case significantly moved the NAS performance tradeoff curve to lower levels of congestion and delay, compared to the flow-based operations. TFM agility was the next most significant factor influencing ATM performance. The agile TFM moved the NAS performance to lower levels of congestion and delay, compared to the non agile TFM case. Also, the non agile, flow-based operations was the best approximation of the NAS performance as measured by ETMS and ASPM data sources. Finally, the convection forecast uncertainties were the least significant factors influencing ATM performance. Improving these forecasts resulted in second order NAS performance improvement compared to the other factors. These results, however, may not hold for other types of NAS weather or traffic days, which should be explored in future research.

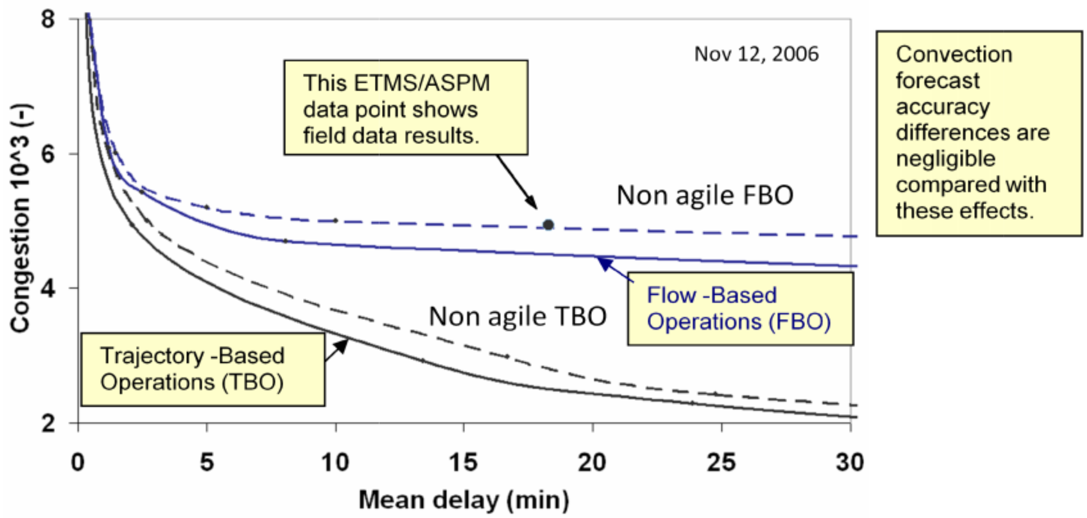


Figure B-12 NAS performance sensitivities of trajectory-based and flow-based operations performance improvements and agile versus non agile decision making.

B-1.14 Use of Probabilistic Convective Weather Forecasts to Assess Pilot Deviation Probability

Probabilistic weather forecasts for convection are being developed today and for NextGen. For instance, the operational 0-6 hour National Convective Weather Forecast (NCWF-6) product provides up to 6-hour forecasts of the probability of convection. Efforts have been made to determine how to use this forecast in ATM automation where probabilities of convective need to be translated to ATM impact. One approach is to determine a correlation between aircraft position and NCWF-6 convective probability values, at the appropriate flight level and relative distance above the echo top [SSM07]. Using the derived correlation, a decision-maker could assess the NCWF-6 probability that aircraft are willing to traverse, and in turn, the risk associated with traveling in the vicinity of forecasted NCWF-6 probability contours. The Probability Cut-off Parameter (PCP) is the maximum NCWF-6 probability contour which correlates with a majority of aircraft positions based on historical analysis. With a 1-hour NCWF-6 forecast, the 80th percentile value (PCP) for all aircraft flying through the probability field across the continental US is around 35% using four months of flight track and weather data [SSM07]. PCP values differ for longer forecast times. Also, PCP values can be established for a local scope, at center and sector levels [SAG09]. Figure B-13 shows the method to create the PCP. A flight traversed an NCWF-6 forecast and the contours it coincided with are recorded. These data can then be aggregated for many flights. The bottom of Figure B-13 shows an aggregation of many flights of similar aircraft to develop a PCP for aircraft type. Future research must address how storm echo tops can be included in the analysis of probabilistic weather forecasts and PCP analysis.

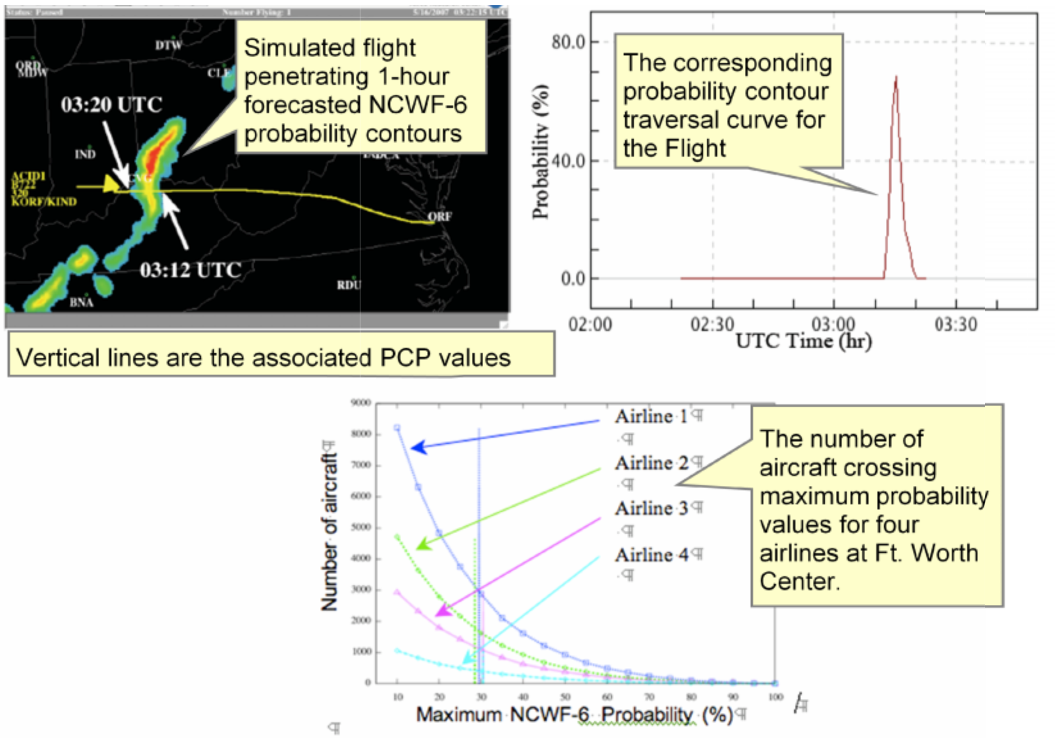


Figure B-13 Transforming a probabilistic NCWF-6 forecast into probability of penetration.

B-1.15 Integrated Forecast Quality Assessment with ATM Impacts for Aviation Operational Applications

The ATM planning process uses specific weather information to develop strategic traffic flow plans. Plans often reroute traffic when hazardous convective weather occurs within the NAS. In order to better understand the application of convective weather forecasts into the ATM planning process, convective forecast products are objectively evaluated at key strategic decision points throughout the day.

An example of how forecasts can be evaluated in the context of ATM strategic planning processes is illustrated in Figure B-14. A sector-based verification approach along with the ATM strategic planning decision points and a measure of weather impact across the NAS [KMM07, MLL08] can be used to evaluate convective weather forecast quality in an operational context. The fundamental unit of measure is applied to super high sectors – the volumes that are used for strategic air traffic planning of en route air traffic. In Figure B-14, a squall line is moving into the Tennessee Valley. The goal is to correctly transform the forecast into sector impacts quantified by the ATM impact model that applies, for instance CWAM model [CRD07, SWG08]. The ATM-impact model may have a flow plan and decision points as an input in order to determine the demand flow direction and quantity. In this example, the northern polygons were false alarms – areas where events were forecast, but did not occur. Convection occurring over the southeast, ahead of the squall line, was not captured by the forecast, and the sectors were considered missed events.

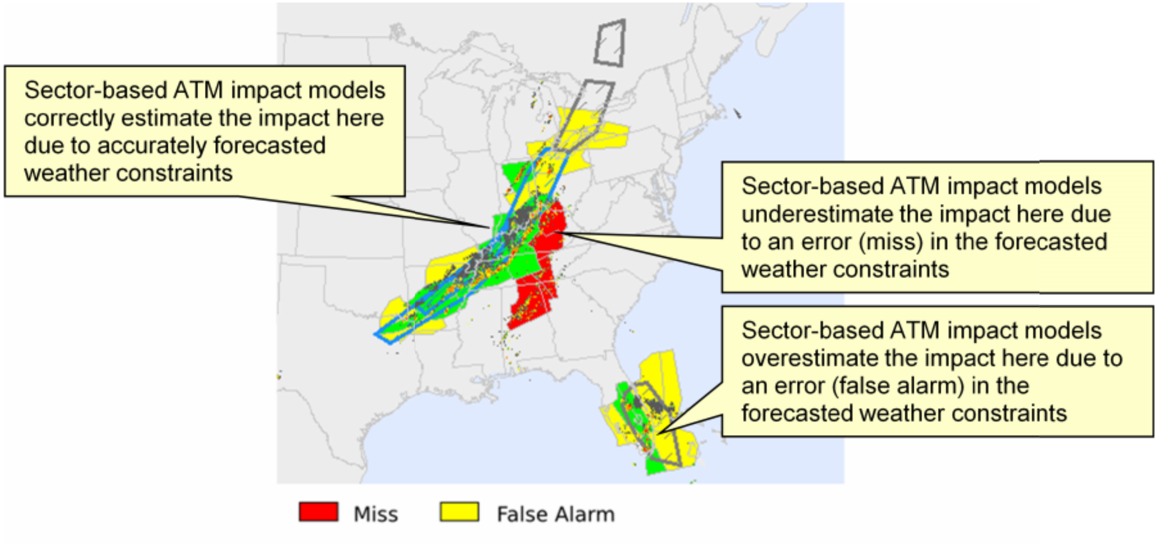
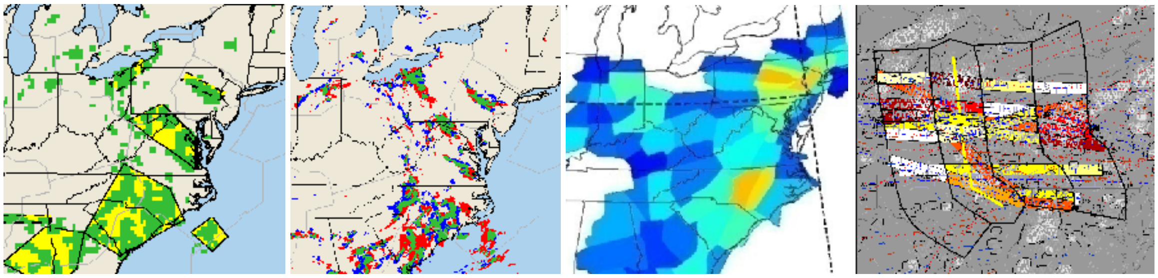


Figure B-14 Sector-based verification of a 2-hour forecast and observations (impacted sectors are color-coded to depict the verification results).

In NextGen, accurate and consistent weather information will be the foundation of the 4-D Wx SAS for ATM operations. User-specific evaluation of weather forecast quality plays a significant role in providing accurate and consistent weather information to the 4-D Wx SAS. ATM impact models must be tied into the evaluation of weather forecast quality in a way that the ATM impact is accurately predicted in measures that are meaningful to the ATM application.

B-1.16 Conditioning ATM Impact Models into User-relevant Metrics

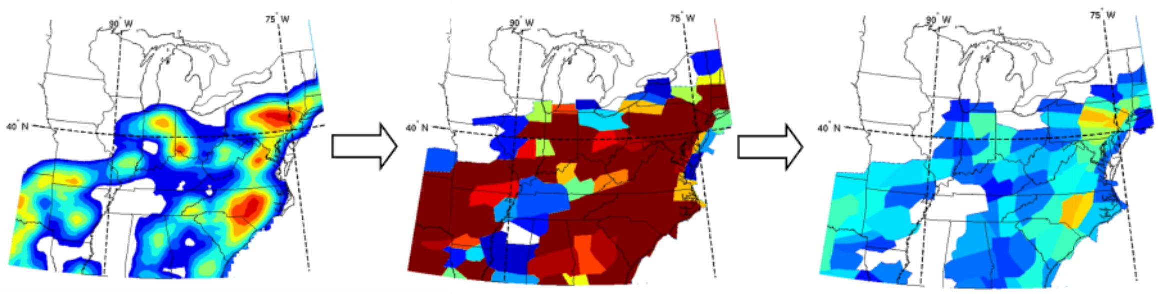
NextGen ATM planners and automated DSTs need useful weather information for efficiently planning, managing, and scheduling the flow of air traffic across the NAS. Significant efforts are currently underway to provide improved forecasts of convective weather for traffic flow managers to help them increase air space usage efficiency during times of convective weather impacts. However, due to the increased workload created by convective weather impacting congested air traffic routes and other factors, increased forecast performance does not always translate directly into more efficient operations. Weather forecasts need to be processed in a way that accounts for the ATM strategic planning procedures making weather information easily digestible for ATM DSTs and their users, in the particular format that is required (e.g., as shown in Figure B-15). In order to translate the weather forecasts into useful information for ATM planners, weather forecasts need to be calibrated, not with respect to meteorological criteria, but with respect to operational planning criteria. Since the airlines participate in the ATM process through Collaborative Decision Making (CDM) processes [BCH08], calibrated ATM-impacts must be expressed in meaningful terms to the airlines (dispatch and ATC coordinators) as well as to the ANSP. When planning and scheduling flows of air traffic to cross the NAS, one must project flight schedules and trajectories and weather forecast information into an ATM impact model to arrive at delay estimates (arrival and airborne delays), cancellation estimates, and cost estimates.



(a) Convective Forecast (b) Pixel-based impact (c) Sector-based impact (d) Route-based impact

Figure B-15 Convective forecast transformed into ATM impact in various formats.

TFM planning requires accurate, consistent, and calibrated impacts, as illustrated in Figure B-16. For instance, weather information (un-calibrated and operationally calibrated) must be ingested into ATM impact models that properly account for sector-to-sector queuing in order to measure delay costs associated with the weather forecast and expected demand on sectors. When operationally calibrated weather information is introduced into ATM impact models, costs must be close to those cost associated with 'perfect' knowledge of the weather [MKL09]. In NextGen, post-process analysis can be used to adjust the bias on ATM impact models so that future ATM impacts best model actual costs. Ultimately, improving the transformation of weather information into ATM impacts will reduce air traffic delay costs. In NextGen, it will be critical that the impacts of weather information be calibrated with respect to ATM operational decisions for effective planning and automated decision support.



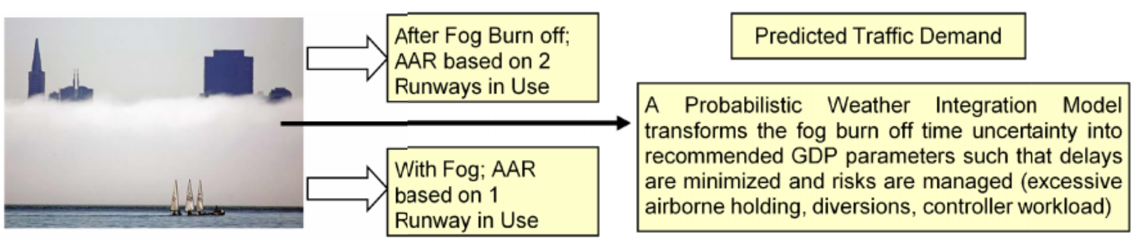
(a) Original Convective Forecast (b) ATM Impact Uncalibrated (c) ATM Impact Calibrated

Figure B-16 Convective forecasts for use by automated ATM planners (impacted sectors are red for high impact and blue no impact).

B-1.17 Integration of the Probabilistic Fog Burn Off Forecast into TFM Decision Making

Convective weather forecasts in the en route environment include uncertainty in multiple dimensions, including time, space, and severity. Attempts at integrating probabilistic weather forecasts into operational decision making in order to address these uncertainties has proven to be challenging – it requires complex models to integrate probabilistic weather forecasts with TFM decision making. The situation at San Francisco (SFO) International Airport provides an opportunity to explore the integration of probabilistic weather forecasts into TFM decision making in a less complex scenario [CW03]. This case involves a forecast of a single weather parameter – the marine stratus (fog) burn off time – at a fixed geographical location (the SFO approach zone). Traffic managers initiate a Ground Delay Program (GDP) to reduce the inflow of aircraft when fog at SFO lingers well into the morning arrival rush, thereby reducing the AAR in half (because only one runway can be used instead of two). One must rate the confidence of each of several forecasts, and use empirical errors of historical forecasts in order to create a probabilistic forecast in terms of a cumulative distribution function (CDF) of clearing time [CIR06].

To address the ATM impact (Figure B-17), a weather translation model must integrate SFO's probabilistic fog burn off forecast in with GDP algorithms [Cl09]. One model uses a Monte-Carlo simulation approach to find the optimal GDP parameters based on objectives of minimizing unnecessary delay and managing the risk of airborne holding [CW09]. The model samples multiple times from the CDF of the forecast of stratus clearing time, calculating the key measures for each possible GDP end time and scope under consideration. The mean value of each metric is calculated over all clearing time samples for each GDP parameters scenario, providing the expected value of each metric given the uncertainty in the clearing time. An objective function uses these key metrics to select the GDP parameters that minimize cost. This model places a high importance on managing the risk of excessive holding if the stratus clears later than anticipated. This is addressed by using an objective function that permits low probabilities of ATM risk, and quickly increases to heavily penalize risky end time decisions.



(a) For Burn off Time Estimate (b) ATM Impact (c) TFM Plan

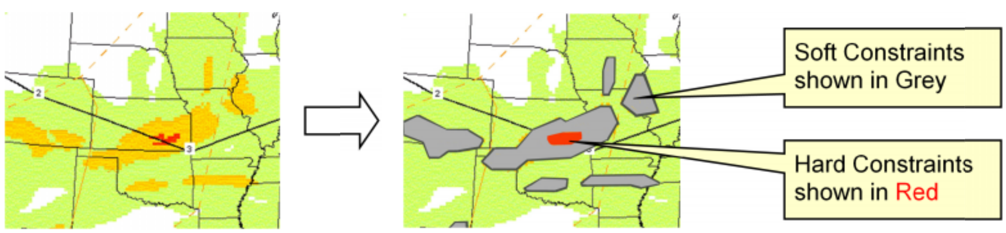
Figure B-17 Integration of a Probabilistic Forecast of Stratus Clearing with TFM.

The planning, implementing, and controlling a GDP under uncertainty in stratus clearance time at SFO is both stochastic and dynamic in nature. Decisions related to airport rates, scope, and flight departure delays require revision in response to updated forecasts. Towards this, a parallel body of research is underway to develop an algorithm for setting AARs and allocating slots to flights, and dynamically revising those decisions based on updated forecasts [MHG09]. The primary input to the algorithm is a set of capacity scenarios and their probabilities, generated from forecasts. Given a distribution of stratus clearing time, one algorithm applies a stochastic optimization model [BHO03] to decide on optimum AARs, following which a slot allocation algorithm is applied to assign landing slots to airlines [HBM07]. After airlines perform substitutions and cancellations, the revised schedule and updated forecasts are fed back to the algorithm, which is re-applied in response to changing conditions.

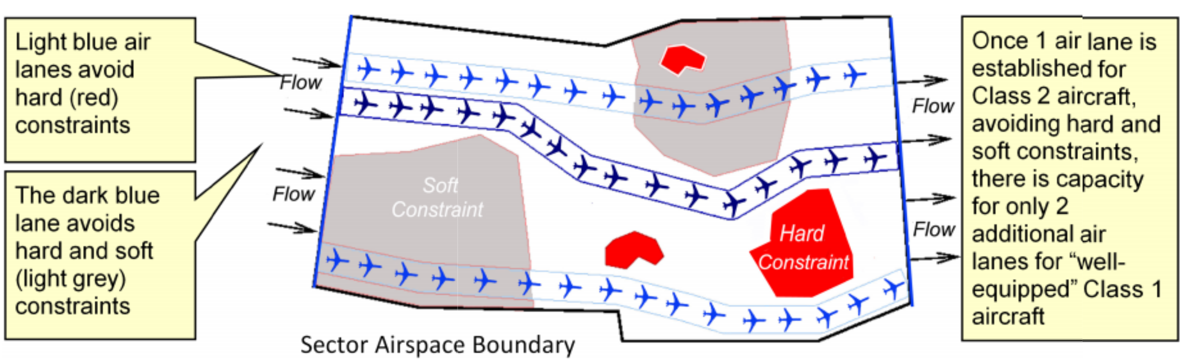
Stochastic dynamic optimization models that simultaneously decide AARs and delays of individual flights require more than just capacity scenarios as input [MH07]. Typically these models apply a wait-and-see policy where certain decisions are delayed until updated information on airport capacity becomes available. Such models could be applied in NextGen if weather forecasts provide a capacity scenario tree whose branching points provide information on when to expect updates in forecasts and the conditional probabilities of scenarios associated with those updates.

B-1.18 Mincut Algorithms given Hard/Soft Constraints to determine Maximum Capacity

While the continuous version of the maximum flow problem [M90, KMP07] is suitable for estimating the maximum throughput across an en route airspace given a traffic flow pattern [SWG08], it assumes that weather hazards are classified in a binary way: traversable or not (hazardous or not). The assumption is that all hazards are hard constraints. However, weather hazards, including the "types" of convection, turbulence, icing, and other weather effects may more generally be classified into hard and soft constraints. Hard constraints are formed by weather hazards that no aircraft can safely fly through (e.g., severe convection, turbulence or in-flight icing). Soft constraints are formed by weather hazards which some pilots or airlines decide to fly through while others do not (e.g., moderate turbulence or icing); these can be characterized as user "business rules". As illustrated in Figure B-18, one can consider two aircraft "classes": Class 1 aircraft that avoid both hard and soft constraints, and Class 2 aircraft that avoid hard constraints but are willing to fly through soft constraints.



(a) Flight Level Turbulence Data (b) Hard and Soft Constraints Model



(c) Some aircraft avoid hard constraints and other aircraft avoid hard and soft constraints.

Figure B-18 Capacity computation for two classes of aircraft among hard and soft constraints.

The problem that arises within this mathematical weather to TFM translation model is that of multi-commodity flow, in which the goal is to determine if there exists a set of air lanes, each with an associated Class of aircraft (the "commodity"), such that each air lane satisfies all constraints from the weather types that impact the Class, and such that the air lanes yield a set of flows that satisfy the demand, or some fraction of the demand. We quantify the capacity of the resulting region of interest in terms of what fraction f of demand is satisfiable, given the multiple types of constraints for various classes of aircraft. The fraction f may be less than 1, indicating that the constraints result in reduced capacity below demand level, or it may be greater than 1, indicating that there is excess capacity available. The problem becomes more complex as both the hard and soft constraint boundaries and the likelihood that airlines will pass through certain hard and soft constraints is modeled with probabilities.

B-1.19 ATM Impact of Turbulence

Unexpected turbulence may injure crew and passengers, and potentially can damage aircraft. The hazard results from several different atmospheric phenomena including jet stream interaction, shear, mountain wave generation, and convection. Two distinct types of turbulence are of concern – Clear Air Turbulence (CAT) and Convective Induced Turbulence (CIT). Turbulence within convection is addressed by avoiding convective storms.

The ATM impact (Figure B-19) [KlK09] results from pilots desiring to avoid or exit turbulent conditions for safety reasons. This may happen tactically or strategically. Alerting to potential turbulence is important so that the cabin can be properly secured prior to an encounter. Exiting an unplanned encounter requires information to identify an acceptable exit strategy (that is, climb or descend to airspace clear of turbulence, or avoid by changing horizontal flight path to a region clear of turbulence). The exit strategy can be determined tactically, essentially as an aircraft is experiencing turbulence, or is warned that it is about to enter it, or strategically, with sufficient planning time to enter into a region of potential turbulence or avoid it altogether. Given a turbulence forecast for advanced warning of potential Moderate-or-Greater (MoG) or of Severe-or-Greater (SoG) turbulence, a pilot or dispatcher can decide to flight plan into a region of potential MoG turbulence if acceptable to the pilot or airlines (a pilot decision or airline policy decision), or in the case of potential SoG, the region should be avoided. This process varies by airline, type of certification, aircraft current altitude, and other factors.

Turbulence is capable of producing both workload and airspace utilization impacts. Tactical information about actual turbulence encounters are conveyed through Pilot Reports (PIREPs or AIREPs). PIREPs are broadcast to controllers and then relayed to other pilots. Today, this occurs by voice communications; in NextGen this process is expected to be automated for many aircraft through electronic PIREPs (e-PIREPs). Processing of PIREPs increases pilot, flight dispatch, and controller workload but does not, strictly speaking, close airspace. MoG turbulence tends to close en route airspace given that passenger comfort and safety is a high priority for many airlines. However, there are some types of aircraft that may fly through MoG turbulence, for instance, cargo aircraft, ferry flights, or some business jets. Forecasted or reported SoG turbulence is an immediate safety hazard which closes airspace and, if encountered, may require diversion due to the likelihood of passenger/pilot injuries and/or required aircraft inspections.

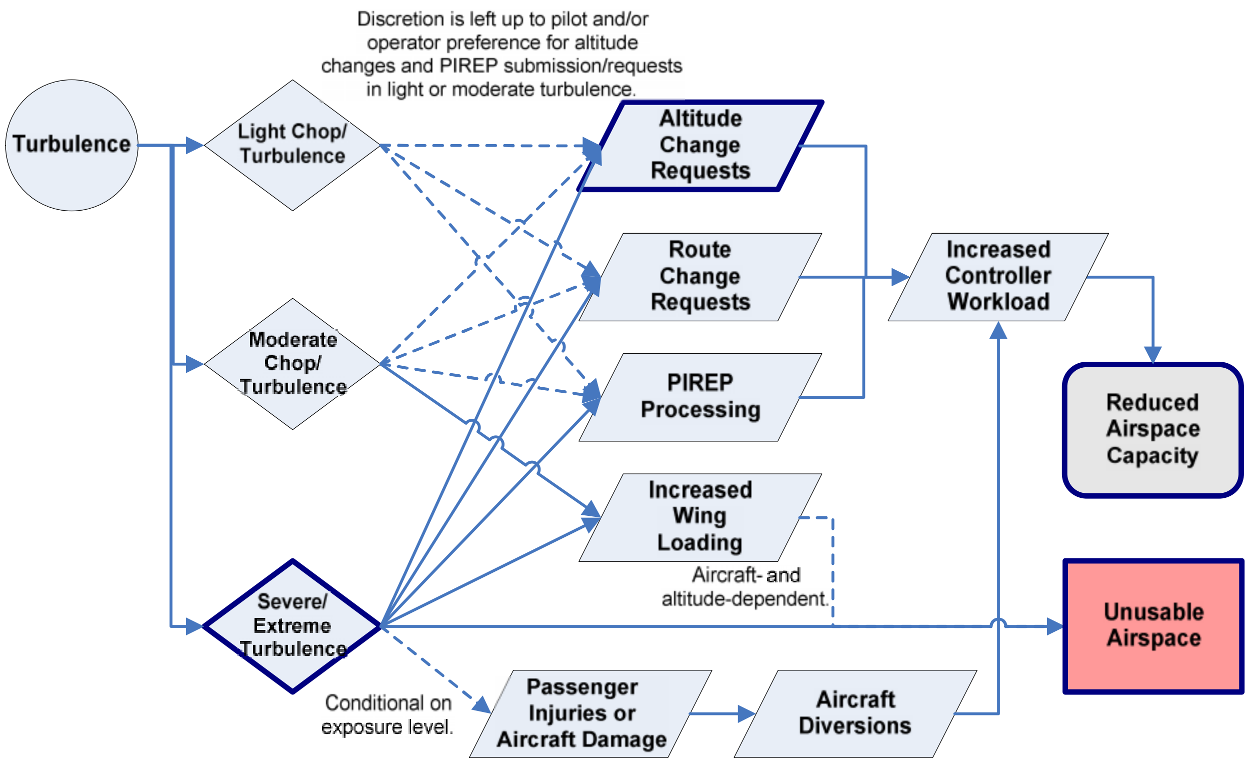


Figure B-19 Causality diagram for turbulence.

Traffic flow impacts are 4-D and temporally sensitive because of the dynamic and random nature of turbulence. Current turbulence forecasts predict the potential for turbulence in a given region of airspace, altitude, at a given time in the future. NWP algorithms use coarse grids that cannot directly model and detect the existence of the "subscale" occurrence of turbulence. While fine grids may offer hope for detailed analysis in small airspace studies (e.g., accident investigations), the ability to have a NAS-wide description of exactly where the boundary of the turbulence hazards reside (space and time) is beyond current technology and perhaps may not be achieved in NextGen. Thus, in NextGen, 4-D representations of hard constraints for turbulence (SoG level – where no aircraft should enter) and soft constraints for turbulence (MoG level – where some pilots and airlines may choose to go through) will be based on probabilistic information for the potential for where MoG and SoG turbulence may exist. DSTs for dispatchers and controllers must then be designed in NextGen to reason about the risk of entering into turbulence, rather than avoiding a well-defined region of turbulence. It is possible in NextGen that a tactical e-PIREP feedback process of quickly communicating to pilots and controllers where turbulence hazards actually exist will complement long term strategic forecasts of the potential for turbulence to exist.

B-1.20 Tactical Feedback of Automated Turbulence electronic Pilot Reports

Currently turbulence encounters are reported from cockpit crews either verbally or by text data link. PIREPs are subjective, late – transmitted only when pilot or controller workload permits, and not easily disseminated to all users. Pilots need to know how turbulence will affect their aircraft in order to make route change decisions. Different aircraft respond to turbulence differently, therefore considerable inference is required on the part of crews to transform turbulence PIREPs from larger or smaller aircraft into the hazard to their own aircraft.

NextGen will likely automate the process of collecting and distributing turbulence (as well as other) PIREP information. Automated e-PIREPs, where human judgment on the magnitude of the turbulence encounter is replaced by an automatic measurement of the turbulence, will automatically and frequently report PIREPs by data link to ATC and to nearby aircraft. Essentially, all e-PIREP equipped aircraft become sensors in the sky for turbulence.

With a collection of e-PIREP information reported at a wide variety of flight levels (null as well as hazard reports), turbulence information can be data linked directly to nearby aircraft or collected and distributed via a centralized database (e.g., NNEW) [KRB09]. Given turbulence data at or above a given threshold (note: the threshold differs based on aircraft type, velocity, altitude, and weight), crews can determine which regions of airspace may be a hazard and which are safe to traverse. Clusters of point e-PIREP data classified as hazardous can be identified (Figure B-20), as well as clusters of clear air data (null or low magnitude reports). Thus, hazardous airspace as well as airspace clear of turbulence can be communicated to nearby aircraft that are soon to pass into such airspace. Since turbulence is a transient hazard, this process needs to be automated, a datalink needs to quickly communicate information to nearby aircraft, and the process must repeat throughout the day for detecting CIT and CAT hazards.

Current turbulence forecasts predict the potential for turbulence in a given region of airspace, altitude, at a given time in the future. NWP algorithms use coarse grids that cannot directly model and detect the existence of the "subscale" occurrence of turbulence. The ability to have a description of exactly where the boundary of the turbulence hazard resides (space and time) is beyond current technology and perhaps may not be achieved in NextGen. However, the tactical feedback process of where turbulence hazards actually exist will complement long term strategic forecasts of the potential for turbulence to exist.

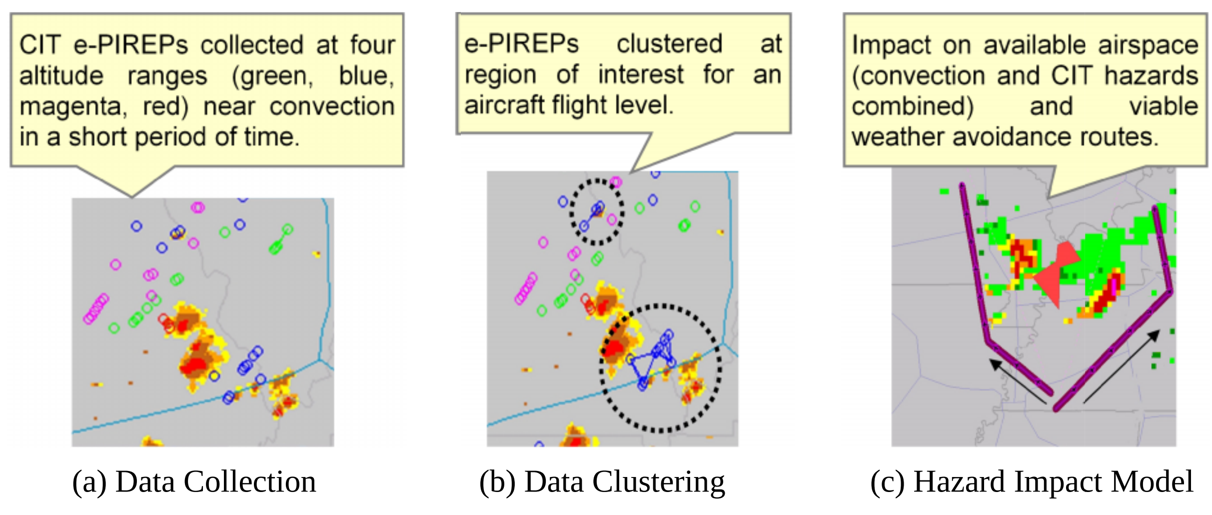


Figure B-20 Feedback of e-PIREP CIT turbulence data transformed into hazard regions.

B-1.21 ATM Impact of Winter Weather at Airports

The accumulation of ice on aircraft prior to take off is a significant safety hazard affecting aircraft. Research [RCM00] indicates that the icing hazard for aircraft directly corresponds to the amount of water in the snow, rather than visibility – the traditional metric used to determine de-icing and take off decisions. Results from field tests of de-icing fluids have identified the liquid-equivalent snowfall rate as the most important factor determining the holdover time (time until a fluid fails to protect against further ice build-up) [RVC99].

Furthermore, winter weather also impacts other areas of the airport, e.g. roads into and out of the airport, parking areas and transportation to the terminals. This adds to the difficulty of loading passengers and cargo for travel.

The ATM impact of decisions made regarding aircraft de-icing holdover times, de-icing fluid types, and application procedures have yet to be defined and integrated into a NextGen gate-to-gate concept of operations. From initial field evaluations using stand-alone DSTs, significant impacts to an airport occur from de-icing operations [RCM00], including airport ground congestion, decreased arrival rates, and decreased departure rates. Metrics affecting severity of impacts include precise timing of the snow event start and stop times, characterization of snowfall in terms of Liquid Water Equivalent (LWE), optimal deicer mix and temperature to maximize holdover times, and precise timing of the sequence of events from pushback, to de-icing, taxi, and takeoff to prevent additional de-icing. NextGen integration needs further decision support requirements for winter weather impact in order to optimize gate-to-gate performance.

B-1.22 Weather Impacts on Airport Capacity

Terminal weather conditions, including C&V, surface winds, precipitation, snow, and convective activity, have significant direct (e.g., available runways) and indirect (e.g., aircraft separation requirements) impact on the available airport capacity. Approaches for estimating airport capacity as function of existing or forecast weather can be roughly divided into two groups: models predicting the impact based on trends observed in historical data [H10,HR08,KJL07,Smi08] and analytical airport capacity models explicitly incorporating weather parameters and their uncertainty into the modeling process [KMC09].

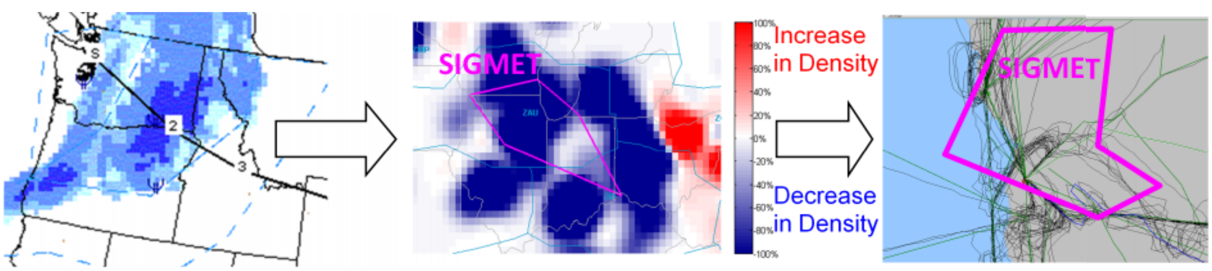
Terminal WITI [KJL07,KKL09] is an example of an airport capacity model utilizing historical trend data to determine the impact of weather on available capacity. It uses airport capacity degradation thresholds determined using historical data for airports to determine estimated capacity reduction as a function of C&V, winds, snow, precipitation, and convection. Weather events are prioritized in terms of severity of their impact on capacity reduction, and if multiple weather events exist or are predicted at the airport, then the estimated capacity reduction is assumed to be equal to the capacity reduction caused by the most severe weather event.

An alternate approach to estimate weather impact on available airport capacity is to use an analytical stochastic model which considers the impact of both terminal airspace and runway system constraints on airport capacity. Probabilistic airport capacity estimates can take into account weather nowcasts and forecasts for C&V, winds, precipitation and echo tops and utilize several weather translation and weather impact models (e.g., WAAF and MaxFlow/Mincut) and runway capacity models [SZ04] to analytically compute probabilistic ranges of estimated airport capacity as a function of forecast terminal weather.

B-1.23 ATM Impact of In-Flight Icing

In-flight icing impacts air traffic flow in complex ways. For aircraft not certified for icing conditions, all known or forecast icing is prohibited airspace and considered a "hard" constraint – these aircraft are not allowed to fly into such an airspace. A SIGMET issued by the National Weather Service (NWS) is considered a hard constraint for all aircraft. Today, SIGMETs are typically valid for up to 4 hours and usually affect a large volume of airspace. Some situations have icing severity and aircraft equipage combined to define a "soft" constraint – some aircraft may penetrate the icing volume for limited exposure times.

In-flight icing is typically a low altitude hazard, generally less than FL200. Major ATM impacts, therefore, are seen for low-end General Aviation (GA) and for all aircraft in the arrival/departure and terminal phases of flight. National ATM impact can be significant when icing affects large airport metroplexes. Figure B-21 illustrates some of the air traffic responses due to SIGMETs issued for severe icing [KrK09]. The traffic density is significantly decreased by a SIGMET when compared to the same day a week before and a week after – the effect is strongest if the SIGMET has a lower altitude that reaches ground level. Holding patterns are established outside of the SIGMET volume to allow aircraft to descend below the SIGMET prior to arrival if the SIGMET does not extend to ground level. Other impacts include increased ground delays until the SIGMET is released, cancellations of flights scheduled to take of when the SIGMET is active, and aircraft forced to fly above or below the SIGMET altitude ranges, thus increasing densities above and below the SIGMET volume and increasing controller workload for those altitudes.



(a) Icing Forecast (b) Decrease in density of Traffic (c) Holding and Delays Impact

Figure B-21 In-flight icing causes significant ATM impacts.

NextGen traffic flow impacts will be 4-D and temporally sensitive. In NextGen, flight data objects representing aircraft and traffic flows will integrate with 4-D representations of hard and soft constraints due to current and forecast icing conditions. NextGen icing forecasts will be automatically generated. The SIGMET for NextGen will likely be a 4-D airspace that is shaped by the 4-D forecasted icing volumetric icing phenomenon. Icing decision support can then be provided to flight crews, air traffic managers and controllers, dispatchers, and automated DSTs in the same spatial and temporal context. A 4-D gridded format will be highly consistent with planned NNEW formats. Future products needed to fully address ATM impacts include calibrated icing probability and icing severity. Further, a better understanding and mathematical model of the in-flight icing ATM impact in both the terminal and en route environments is needed.

B-1.24 ATM Impacts Derived From Probabilistic Forecasts for Ceiling and Visibility and Obstructions to Visibility

The Ceiling and Visibility (C&V), and Obstructions to Visibility (OTV) impacts differ depending on the flight regime (terminal, en route, ground operations) and type of aircraft operation (Part 91 vs. Part 135 or Part 121). Reduced visibility and ceiling rank 3rd and 4th behind convection and winds as factors reducing terminal capacity [NWS04a, NWS04b]. For the en route NAS, ATM impact for IFR equipped aircraft results from reduced AARs and increased MIT restrictions that originate from the impacts of OTV on terminal airspace and airport ground areas. This impact can greatly reduce air route capacity and may propagate from sector to sector as passback MIT restrictions. OTV impact on terminal arrival and departure operations (see Figure B-22) include restrictions on VFR operations, increased MIT requirements on final approach, increased missed approach potential, higher workload for pilots and controllers (e.g., PIREP communications), and restrictions on use of Land And Hold Short Operations (LAHSO). Impacts result from ground fog, low ceiling, low visibility due to precipitation, and smoke and haze. These conditions are further influenced by day/night effects and by viewing angle relative to solar angle. For ground operations, the OTV impacts come from ground fog, low visibility due to precipitation, blowing snow, plus day/night and viewing angle effects as above. For non-IFR equipped GA aircraft, the OTV impact to ATM is minimal; however, the safety impact to inadvertent penetration into IMC during VFR operations is significant.

A number of techniques for probabilistic forecasting of C&V and OTV occurrence are in limited operational use today, but significant improvements in forecast skill, longer-duration forecasts, expansion to NAS-wide coverage, and better linkage to the specific forecast needs of individual terminal areas are required to meet critical NextGen needs. Similarly, models for translation of C&V weather forecasts into ATM impacts are only in limited use, and there exists no real-time system linking state-of-the-art NAS-wide probabilistic C&V forecasts with a calibrated, terminal-specific ATM impact model. So, the core OTV forecast technology, plus translation to ATM impact and decision support dealing with uncertainty, are NextGen technology gaps. The linkage, testing and implementation of these technologies is a critical and achievable NextGen requirement.

NAS decision support systems need realistic system-wide impact assessment models (e.g., [RH07, HR08]) that use current and forecast probabilistic OTV-impacted AARs at individual terminals to forecast resulting composite air route MIT restrictions. The assessment models must represent the system-wide impacts of reduced AARs, ground holds, and departure delays at remote airports where OTV conditions are not present.

B-1.25 Improved Wind Forecasts to predict Runway Configuration Changes

The airport configuration is a primary factor in various airport characteristics such as arrival and departure capacities (AARs) and ADRs) and terminal area traffic patterns. Since the airport configuration is largely dependent on airport wind conditions, an ATM-impact model must translate the wind conditions (and other factors) into AAR, ADR, and other impacts. Today there is poor dissemination throughout the NAS of the airport configurations in use at each airport at any given time, with very little known about expected future configuration changes. AARs, ADRs, and terminal traffic patterns are central to a variety of ATM decisions, such as setting arrival restrictions to avoid airborne holding as well as the effects certain airport configurations have on nearby airport traffic flows and configurations. Consequently, as uncertainty from wind conditions translates into uncertainty about the current or future airport configuration, this results in traffic management decisions that underutilize or overload airports, resulting in unnecessary or inefficient delays.

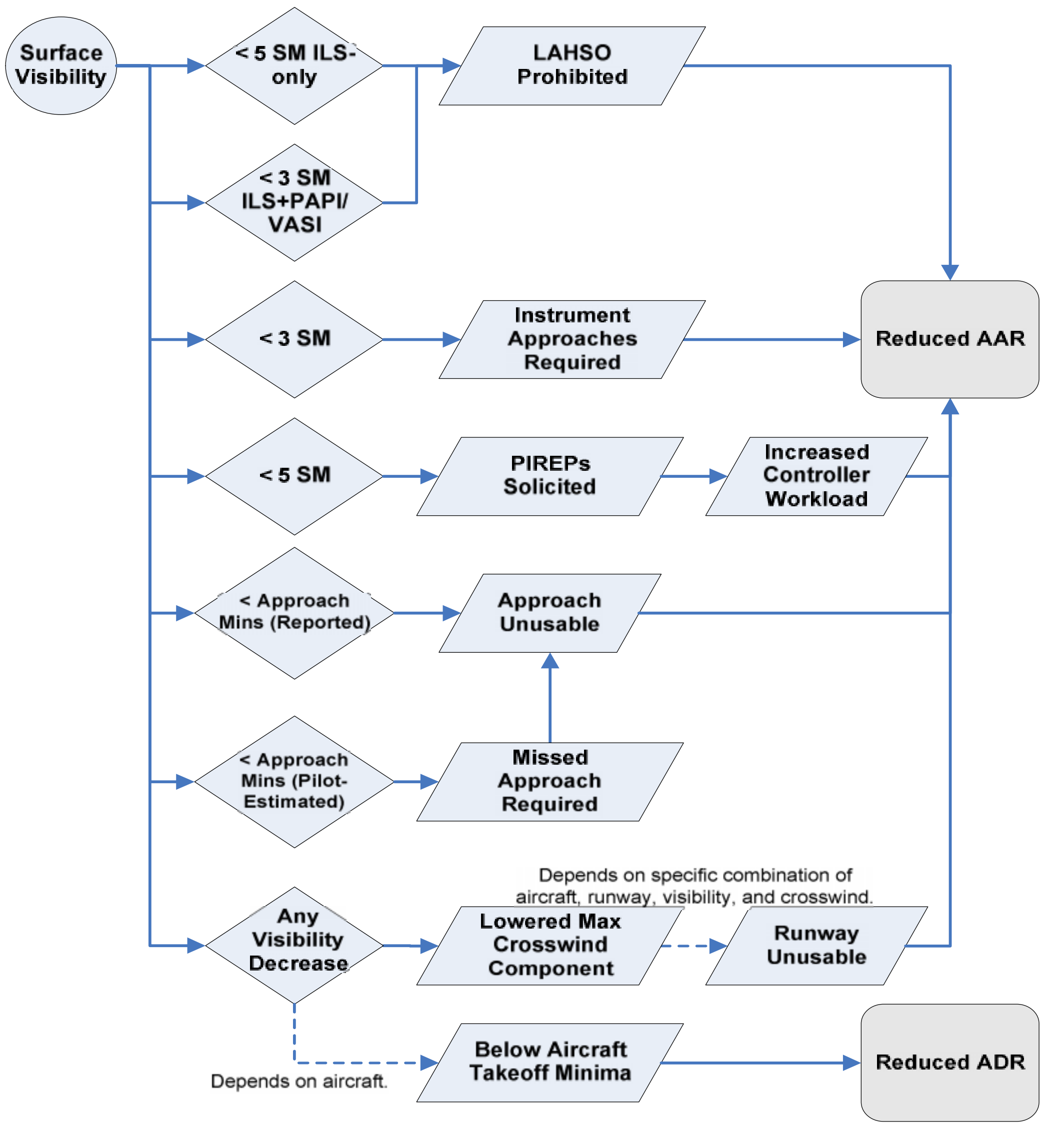


Figure B-22 Causality Diagram for Terminal C&V.

In order to build a model for translating wind conditions into ATM impacts, both meteorological and ATM modeling need to be addressed. The wind speed and direction is essential in determining which runways are feasible. Terminal Aerodrome Forecasts (TAFs) do not currently predict wind conditions precisely enough or accurately enough to enable airport configuration prediction. NextGen weather forecast systems must correct this in order to assimilate weather into DSTs for airport surface operations as well as TFM decision making. Accurately predicting wind conditions at an airport is difficult, and viable automated methods are only now emerging due to recent scientific advances and gains in computer performance. Furthermore, TAFs are intended primarily to provide information for filing flight plans, so they are not required to include certain changes in wind speed or direction that may cause a change in airport configuration.

As for modeling the ATM impact, there is also research needed to establish the relationship between how controllers choose between viable configurations to meet the arrival and departure demands of an airport. Controllers usually have 30 minutes or more leeway in the time at which runway usage can be changed while maintaining safety. This leeway is generally used to choose a time at which to implement a runway configuration change so as to minimize inefficiencies associated with making the change. The timing of the arrival and departure traffic demand, weather (winds as well as possibly convective weather constraints), and other factors need to be modeled. Furthermore, there is generally a preferred configuration that will be used if it is feasible for a sufficiently long period of time. There is a need to build a mathematical model that relates these factors to the forecasted weather (and traffic) conditions.

B-1.26 Improved Wind Forecasts to facilitate Wake Vortex Decision Support

Turbulence associated with aircraft wake vortices pose a potential hazard to other aircraft, especially lighter aircraft following at low altitude. This risk is mitigated by increased separation standards when wake turbulence avoidance is a concern. Historically, these separation standards were established under the assumption that little or no information is available in near real time with regard to the location, severity, or movement of wake vortices. As a result, they are designed conservatively, presuming the existence of a significant wake threat following each Heavy aircraft, and atmospheric conditions that would allow the wake turbulence to persist at a severe intensity for a relatively long duration (several minutes) in a location that encroaches on the flight path of the trailing aircraft.

Knowledge of wake vortex characteristics and behavior in near real time allows the opportunity to safely reduce existing separation standards to increase throughput, particularly within the terminal airspace [LMC03]. Early attempts to develop operational systems to mitigate wake impact focused on detection of vortices, with concurrent meteorological sensing to anticipate wake behavior, particularly wake dissipation rate and vertical displacement [HCB00]. Ground-based systems (e.g. Lidar) have proven extremely effective in local (on-airport) detection; their primary weakness is limited detection range in inclement weather, and they are relatively expensive. Furthermore, prediction of wake behavior based on meteorological measurements of atmospheric stability produced mixed results.

More recent efforts have focused on wind dependent solutions [LTL05, LTD07, RC08]. A very short term wind forecast (20 minutes) is sufficient to determine when persistent transport crosswinds protect specific Closely Spaced Parallel Runways (CSPR) from the threat of a wake vortex moving into the departure flight path, thereby safely allowing reduced separations. Analogous wind dependent solutions currently under investigation for arrival operations have more substantial implications for TFM. Unlike departures, for which a ground queue of aircraft may be immediately available to exploit available capacity, reduced separations for arrivals implies TFM planning to ensure aircraft availability to fill available slots. This puts more rigorous demands on wind forecast performance. First, it requires sufficient forecast lead time to allow for positioning of en route aircraft, which requires additional release of ground held aircraft. Furthermore, the burden of managing the flow of airborne planes (as opposed to a ground queue) requires that the forecast window of opportunity be of sufficient length to provide commensurate benefits, and that the end time of favorable crosswinds be forecast with high reliability to avoid an oversupply of airborne arrivals.

These concepts are illustrated in Figure B-23. (1) The initial forecast of future arrival capacity increase will likely require at least a 1-hour lead time to indicate the potential for increased capacity. (2) When winds are verified as favorable, and the current forecast indicates an expected duration of at least 3 hours of favorable crosswind, ATM can increase upstream throughput, presumably involving the release of additional ground-held aircraft. (3) Additional arrival demand becomes available locally to fully utilize arrival slots made available by reduced separations. Typically this would be expected 60-90 minutes after release of additional aircraft. (4) At some point during the increased capacity window, the wind forecast would indicate an expected end to favorable winds. This would require at least 1 hour lead time to reduce flow of upstream arrivals and absorb existing en route arrivals. (5) Crosswinds no longer favorable for reduced separations. Note that this example represents a minimum acceptable benefits scenario, i.e. a 3-hour wind of favorable crosswinds, during which at least 1.5-2.0 hours could be exploited with a sufficiently increased supply of incoming arrivals. A more aggressive approach to further exploit capacity would be to increase the upstream flow rate immediately upon the initial forecast of favorable conditions occurring within 1 hour. This, of course, adds additional risk of oversupply in the event of an incorrect forecast.

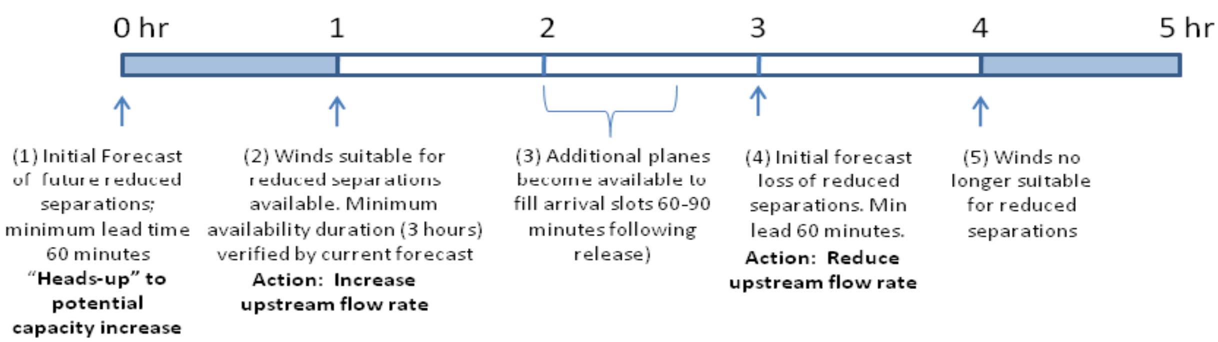


Figure B-23 Conceptual timeline showing traffic flow management in response to reduced wake vortex separations for arrival aircraft.

In NextGen, an increased availability of aircraft meteorological data (e.g. via the Meteorological Data Collection and Reporting System (MDCRS)) and aircraft surveillance technology (e.g. ADS-B) may provide the necessary near real time information for wind dependent solutions without the high cost of more sophisticated ground-based sensors. In particular, flight path observations could be used to validate favorable conditions aloft (nominally up to a few thousand feet) to support the concept. Additionally, continuing advancement in NWP modeling performance and resolution is expected to be of central importance for meeting the wind forecast lead time and precision requirements. Since the capacity impact of wake separation restrictions is highly dependent upon aircraft mix, solutions must also integrate sequence optimization schemes to fully exploit available capacity.

B-1.27 Impact of Winds Aloft on the Compression of Terminal Area Traffic Flows

Strong winds aloft impact an airspace by causing aircraft spacing problems. Generally, when strong winds aloft are present, the wind speed will vary considerably with altitude. This will cause large variations in groundspeeds between aircraft at different altitudes and in trail spacing becomes difficult to maintain. The effect on one flow direction may be very different from the effect in the opposite flow direction, for instance, traffic flying East with the wind will have different effects from traffic flying West into the wind. From an ATM perspective, greater MIT restrictions will be issued to deal with this effect, which controllers refer to as compression. Generally when winds aloft impact the airspace, MIT restrictions have to be increased, and there is also the possibility of impacting performance with a lower AARs with the potential of GDPs and Ground Stops (GS).

Vertical wind information, both observed and forecasted, can be used to manage the impact of compression. Current hourly updated vertical profiles of forecast winds will need to be more frequent in NextGen to facilitate better wind forecasts for this ATM application. The outstanding issue is how to translate this information to determine compression effects on ATM, specifically predicting MIT and any reduced AAR or the need for GDPs or GSs. In NextGen, a larger percentage of traffic will be following Continuous Descent Approaches (CDAs) and tracking Area Navigation (RNAV) routes within a required RNP level, and these procedures will also drive wind forecast accuracy requirements. How the requirements relate to the weather forecast accuracy is an open research question.

B-1.28 Oceanic/Remote Weather Integration

The NextGen Concept of Operations envisions a seamless transition between CONUS, terminal, and oceanic domains. Weather information for oceanic and remote areas will be integrated with ATM at the same level as for CONUS operations. A number of oceanic procedures are already being implemented as wide-spread use of Automatic Dependent Surveillance – Broadcast (ADS-B) expands. For example, airlines are already exploiting the benefits from Dynamic Airborne Reroute Procedures (DARP) which allow airborne aircraft to take advantage of updated atmospheric conditions and cruise-climb more efficiently for better fuel consumption. Oceanic routes integrate with CDAs into gateway terminals to permit idle thrust descents from cruise to short final approach. All of these capabilities depend on timely weather updates on hazards (convection, turbulence, volcanic ash, in-flight icing), winds, and Outside Air Temperature (OAT).

Weather information for remote and oceanic regions is more difficult to create than for the CONUS because data is sparse. This requires creative use of available data from satellites and other limited sources, and is an area of active research. Prototype algorithms have been developed for regional use, but not integrated with ATM procedures.

Studies in the Central East Pacific [GSC06], for instance, demonstrate how wind data can be used to generate wind optimal routes, transitioning away from the fixed Central East Pacific routes to user-preferred routes. While such routing takes advantage of the jet stream, it also must take into account turbulence that can be found near the jet stream, which is an area of future research.

Direct integration of winds and temperature into flight planning systems on the ground, and via data link into flight management systems (FMSs) while airborne, is occurring. Flight plans are optimized prior to departure, and changed as needed en route to take advantage of updated winds and OAT (for cruise-climb). 4-D, flight path specific, descriptions of weather hazards (convection, turbulence, volcanic ash, in-flight icing) are needed to complete the NextGen seamless transition to CONUS and terminal operations. 4-D hazard information needs to be integrated with winds and temperature effects on flight profiles. Airline dispatchers, oceanic air traffic managers, and pilots can then strategically plan flight profiles and, most importantly, pilots can prepare to react to real-time hazard information prior to an encounter.

B-1.29 Translation of Volcanic Ash Plume Hazards onto Airspace and Airport Impacts

Advanced techniques are needed in NextGen that will detect, forecast, and disseminate information on volcanic ash plume hazards and how the hazards will affect ATM resources to aviation operators and users. Airborne volcanic ash constitutes a recognized threat to aviation that can severely damage jet aircraft engines through erosion, corrosion and congestion. Volcanic ash contamination may render large volumes of airspace unavailable, necessitating costly rerouting contingencies, degrades braking action at affected airports, as well as completely closes contaminated airports [KMP08]. Problematic ash-related aircraft encounters have been reported days after an eruption and thousands of miles from the source. There are a number of technical issues that need to be addressed to identify volumes of airspace that should be avoided.

Within the DOD, research on Dust, Smoke, and Aerosols (DSA) modeling is a priority item to support assessments of battlefield obscurants and their impact on operations and surveillance systems. The weather translation model for volcanic ash plume hazards (Figure B-24) requires further advancement of both science and operational modeling. Science issues for NextGen include:

- Timely detection of eruption and resulting ash cloud
- Discrimination of ash from water/ice and sulfur clouds
- Missed detections and false alarms
- Sensor response function, measurement precision, calibration
- Dispersion models
- What concentration and ash particle size constitute a hazard
- How the concentration and ash particle size determined
- Operational issues for NextGen include:
- Timely advice of the mathematical model for eruption / ash cloud
- Dispersion model development and validation, and
- More automation needed for integration of ATM impact with NextGen systems.

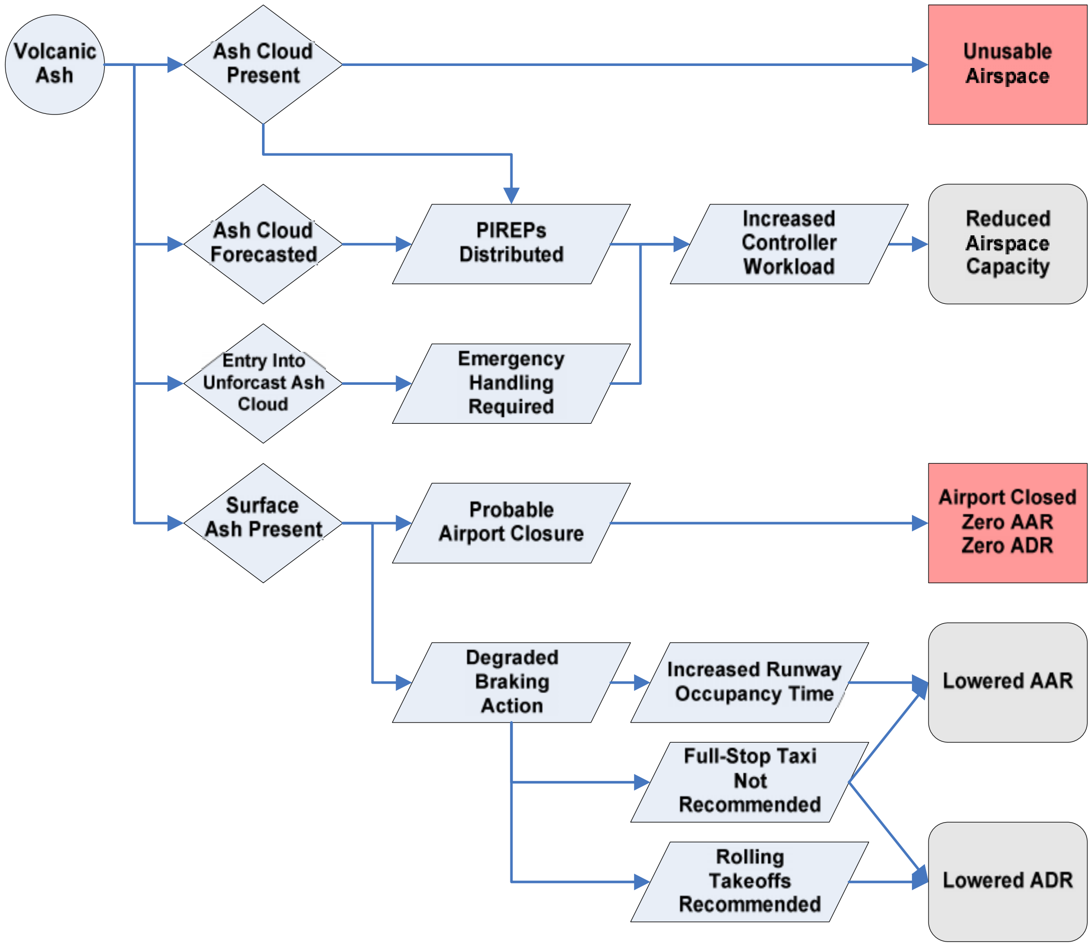


Figure B-24 Causality diagram ATM impacts of volcanic ash.

The ATM impact is so severe that any forecast or actual volcanic ash above a threshold concentration and particle size is considered a hard constraint. A 4-D airspace volume defining the hard constraint is required for NextGen. Application of the constraint would be the same as for any 4-D weather hazard. It represents a no-fly volume that most likely is deterministic versus probabilistic (pending further research on the above technical issues).

B-1.30 Translation of Atmospheric Effects into Environmental and ATM Impacts

The large increase in air traffic associated with NextGen will have a growing impact on the environment. Environmental impacts will be significant constraints on the capacity and flexibility of NextGen unless these impacts are managed and mitigated [GTA09]. The major environmental effects of aviation are:

- Emission of pollutants affecting local air quality, such as NOx, SOx, CO, and particulate matter;
- Emission of greenhouse gases such as CO_2;
- Aircraft noise; and

- Water pollution via de-icing agents, spilled fuel, etc.

Note that the discussion of fuel consumption in the NextGen Concept of Operations is not an environmental impact but is a surrogate for greenhouse-gas and air-pollution impacts. All of the weather-integration applications discussed here, of course, have an impact on fuel consumption as related to ATM efficiency.

Most of the above environmental impacts are affected by the atmosphere and will require the integration of probabilistic weather forecast elements for proper risk management. The weather elements include, but are not limited to: wind and temperature profiles; probabilistic model output of Atmospheric Impact Variables (AIVs); translation of atmospheric conditions to environmental impact; and translation of environmental impact to ATM impact.

Examples of the translation mechanisms coupling atmospheric conditions to environmental impact include:

- Noise intensity on the ground is affected by wind and temperature via their influence on the strength and directionality of acoustic propagation, and also via their influence on aircraft performance (e.g., climb rates).
- Dispersion and mixing of air pollutants is affected by wind, temperature, and humidity via their impacts on atmospheric mixing and chemistry.
- Generation of greenhouse gases is affected by wind, temperature, and humidity via their impacts on engine performance and fuel consumption.

Environmental impacts are translated into ATM impacts via several mechanisms, including:

- Mitigation measures such as specialized departure and arrival procedures and routings, as well as restricted periods of operation;
- Routing and altitude assignments that seek to minimize fuel consumption (and possibly contrail formation); and
- Surface and system management that seeks to minimize taxi times and delays on the ground with engines running.

To the degree that the above change the capacity or throughput of airspace or airport elements, then environmental considerations will impact NAS operations.

B-1.31 ATM Impact of Space Weather

There is a growing threat from space weather as aviation's dependence on space and terrestrial networks vulnerable to space weather continues to grow. The threat also exists within the aircraft, affecting communication and navigation abilities for long-haul polar flights. In addition, there is an increasing need to characterize the radiation environment that changes as a consequence of space weather eruptions. Even relatively minor solar storms can affect communications, navigation, and radiation exposure, and this can cause flights to reroute, divert or not even dispatch over polar regions. Thus, an increase in polar flight activity in NextGen will bring about an increase in NAS delays from space weather impacts during times of high solar activity. We can expect an as-yet undefined impact to the net-centric NextGen infrastructure in the CONUS as well. Moreover, the human exposure to space radiation is significantly higher on polar routes, which poses a potential health risk. Finally, the emerging industry of commercial space tourism and commercial resupply and transportation services to the International Space Station will also necessitate the need for increased situational awareness of the space weather environment and its impacts.

Information on space weather is currently sparse and not well applied to aviation applications. Recent popularity of polar routes has driven the requirement to include adding appropriate space weather information into the normal operating procedures of commercial aviation. This requirement also extends all over the globe, as communication and navigation issues in particular reach far beyond the polar regions. There is currently an effort underway between the FAA and its stakeholders to develop aviation user requirements for RF communication, radiation impacts to humans, and avionics and satellite navigation. These user requirements will help form a baseline as to what type of space weather products will needed to be disseminated to the net-centric system. These space weather products will likely consist of observations, warnings, alerts, and updates First, impact thresholds for both net-centric operations and communications/navigation systems need to be established in terms of the physical units describing solar events. This is an area of active research. Once thresholds are better understood, solar events can be translated into such ATM impacts as alternative communications and navigation methods required for flight; backup net-centric systems for flights through affected regions; support for airline dispatch and air traffic control decisions to close routes and airspace; and restrictions to human exposure to radiation. Forecasts of solar eruptions and their impact time-of-arrival for the Earth’s atmosphere are necessary to mitigate these impacts to aviation in NextGen.

B-1.32 ATM Impact of Weather Constraints on General Aviation Access to the NAS

Although GA aircraft operations make up approximately half of all flight hours in the NAS, quantification of the impact of weather upon their operations in the NAS is complicated due to a number of factors. At one extreme, these GA flights are non-scheduled, and thus cancellation and delay data are not available. When these fights do enter into controlled airspace, then ETMS and other trajectory data sources can be mined to yield statistical models of pilot behavior [DE06] however, it is expected that the results will vary considerably compared to the models that have been emerging to characterize commercial airline pilot behavior. Further, GA aircraft cover a wide spectrum from day VFR-only to extremely weather-capable aircraft matching those in scheduled Part 121 service. This diversity in aircraft capability is matched by that of the pilot qualifications and the airports from which the aircraft operate. This variability will be reflected in the response of these aircraft to weather constraints. These constraints include convective activity, turbulence/wind, flight icing, ground icing, and Ceiling and Visibility (C&V).

One example of this variability is in the behavior of pilots when using datalinked reflectivity data to avoid thunderstorm cells. Some pilots interpret the data tactically and penetrate the convective areas while others interpret it strategically, avoiding the entire region of convective activity [B08]. There is considerable variability in pilot behavior near convective areas, making it difficult to model the diversion probability. Pilot experience and training, as well as aircraft equipment, vary considerably, and these will strongly affect weather avoidance strategies. The evolving nature of onboard weather detection can reasonably be expected to ensure that GA pilot deviation behavior will continue to be nonuniform. Existing simulation methodologies can be rapidly configured to explore pilot response to cockpit weather and traffic displays [HMB06].

Terminal area winds and turbulence will also have varied impacts. The decision of whether or not an aircraft will accept an approach to a given runway can depend more upon pilot skill, runway width, and flow field complexity than upon aircraft type and may be difficult to quantify. This is because most GA aircraft do not have well-defined crosswind limits, although some have a maximum demonstrated crosswind.

En route turbulence will usually result in a request for a higher altitude, although pilots with headwinds may choose to sacrifice ride quality for a higher groundspeed, as headwinds will have a lesser impact at lower altitudes. Orogenic turbulence over major mountain ridges can render some altitudes unusable if downdrafts approach or equal climb rate. Clear air turbulence in the vicinity of jet streams will have similar impacts upon GA jets and air carrier aircraft.

Both in-flight icing and ground icing show high variability in their NAS impacts for GA flights. In addition to having less effective anti-icing provisions, smaller GA aircraft typically operate at altitudes where icing is more frequent, so it is likely that GA aircraft will be more affected by in-flight icing than studies show for larger commercial aircraft [KrK09]. Larger, particularly jet, aircraft will experience icing primarily during ascent or descent from or into terminal areas.

Aircraft are classified as approved or not approved for flight into known icing conditions. This classification does not capture the degree of ice protection possessed by the aircraft. Furthermore, not all aircraft sharing a single type certificate have the same status with regard to icing. This wide spectrum of ice protection is matched by a large variability in pilot strategies to avoid ice. However, regardless of the level of ice protection, pilots will avoid areas of potential or reported icing as much as possible. This can make some altitudes unavailable for holding traffic, resulting in aircraft being spread out over large areas. Most GA airports have limited de-icing services, with hangaring being the most common option. A thin layer of overnight frost can cause cancellation or lengthy delay for all unprotected aircraft, particularly impacting early morning departures.

As for C&V, under Part 91, aircraft may begin an instrument approach even if there are no official visibility measurements or if such measurements are below minimums for the approach. This may lead to a greater probability of missed approach procedures being flown compared to Part 135 and Part 121 operations. Pilots of en route VFR GA aircraft may request IFR clearances in the event of sudden reduction in C&V. Others may require special assistance. Either action adds to ATC workload. New cockpit displays, such as moving map and synthetic vision, have the potential to improve VFR into Instrument Meteorological Conditions (IMC) accident rates but may also increase the proportion of VFR pilots who choose to continue toward the destination rather than diverting or changing to IFR, [JWW06] potentially increasing complexity for controllers managing low altitude IFR operations. Non-towered, non-radar airports are typically “one in – one out” for IFR operations, creating significant delays for both arrivals and departures.

While the number of studies that have been performed to build ATM impact translation models has been increasing over the years, few and possibly none of these have focused on the particular parameters that model GA aircraft in particular, or have quantified the overall impacts to GA pilots in the aggregate.

B-2. Methodologies for ATM Weather Integration

Many of the ATM-impact models will eventually be integrated into DSTs in order to help users reason about the impacts of weather while solving ATM problems. The survey includes approaches for addressing weather-related uncertainty in ATM decision making for strategic look ahead times – risk management processes – as well as approaches that wait until the tactical look ahead times to address deterministic forecasts after the uncertainties diminish. The ATM-weather integration techniques make reference to ATM-impact models as appropriate.

B-2.1 Sequential Congestion Management for addressing Weather Impacts

Flexibility and adaptability in the presence of severe weather is an essential NextGen characteristic. But even at tactical flow management planning times (0 to 2 hours), weather and traffic forecasts contain significant uncertainties. Sequential, probabilistic congestion management [WG08] describes how to incrementally manage en route airspace congestion in the presence of these uncertainties. Note that an alternate, multiple-timescale sequential congestion management approach has also been proposed [GSM08]. This method does not employ probabilistic forecasts, but rather relies on adapting to the observed weather development.

The concept is illustrated in Figure B-25 as a control loop, where congestion management decisions are made continually at regular intervals (e.g., every 15 minutes). The distribution of traffic demand in en route sectors is predicted based on flight plans (or downlinked Flight Management System (FMS) data), track data, wind forecasts, aircraft performance data, and other adapted elements. Several methods of predicting traffic demand distributions have been developed. [WZS05, GS07, WSZ05] Convective weather forecasts, which will include measures of forecast uncertainty, are used to predict the probabilistic capacity of en route sectors. This calculation may include the predicted traffic demand, since the true capacity of sectors is sensitive to the traffic flow patterns and how they interact with the weather. Methods for estimating weather impact on sector capacity have been proposed [KMP07, SWG07, M07], however, none have been developed for estimating the distribution of possible sector capacities based on a probabilistic weather forecast product. The distributions of demand and capacity are convolved to produce a probabilistic congestion forecast, where congestion is simply defined as when demand exceeds capacity.

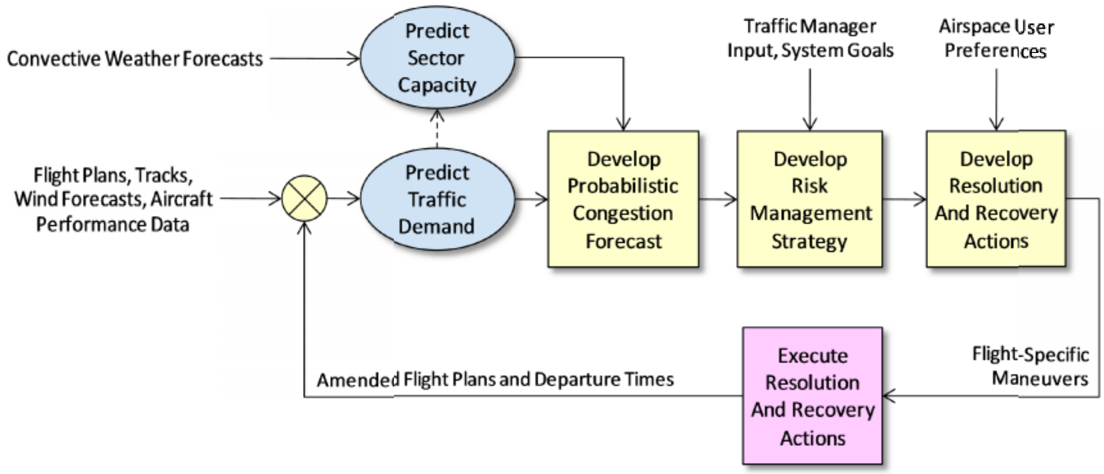


Figure B-25 The sequential, probabilistic congestion management concept as a control loop.

Given a probabilistic congestion forecast, a decision needs to be made. How much control is needed to ensure that the congestion has an acceptable level of risk? This decision is made knowing that the strategy will be modified at the next decision time, and thus it need not be a complete solution to the problem. If too-aggressive action is taken, then some flights will be affected unnecessarily. If insufficient action is taken, then more intrusive maneuvers, such as airborne rerouting, may be required to manage congestion. This is a classic decision-theoretic tradeoff between acting early on uncertain information and waiting for better information. Note that the system goal (congestion risk) and desired types of flight maneuvers can be modified by traffic management personnel at this stage.

Once a congestion management goal has been chosen, specific actions must be developed. If congestion resolution is required, flight-specific maneuvers can be developed in a variety of ways [WG08, TW08, RH06, BS98, SMW07]. If the weather turns out to be less disruptive than predicted, delay recovery actions to undo previous maneuvers may be needed. In both cases, it is anticipated that relatively few aircraft would be maneuvered at any single decision time, as compared to the large-scale traffic flow initiatives commonly used today. At this step, airspace users can collaborate with the ANSP to coordinate resolution or recovery actions with their business needs. This may be via user preferences, or eventually via a 4-D trajectory negotiation process. The final step is to execute the actions such that departure times and cleared flight plans, or the agreed-upon 4-D trajectory, are updated.

Sequential, probabilistic congestion management can take advantage of probabilistic weather forecasts to reduce weather impact on en route airspace. It would also provide an effective "inner loop" to be used in conjunction with strategic flow management initiatives, based on longer-range weather forecasts [HKD07].

B-2.2 Sequential Traffic Flow Optimization with Tactical Flight Control Heuristics

A deterministic sequential optimization approach integrates a strategic departure control model with a fast-time simulation environment to reactively control flights subject to system uncertainties, such as imperfect weather and flight intent information [GSM08]. To reduce the computational complexity of the strategic model, only departure delays are assigned, while tactical en route flight control is accomplished through heuristic techniques. These heuristics rely on a shortest path routing algorithm and an airborne holding model that is used only as a control strategy of last resort.

This closed-loop, integrated optimization-simulation system is illustrated in Figure B-26. System inputs consist of user schedules and flight plans, weather data, and airspace adaptation data. The weather forecast inputs are suitable for establishing CWAM WAFs [DE06].

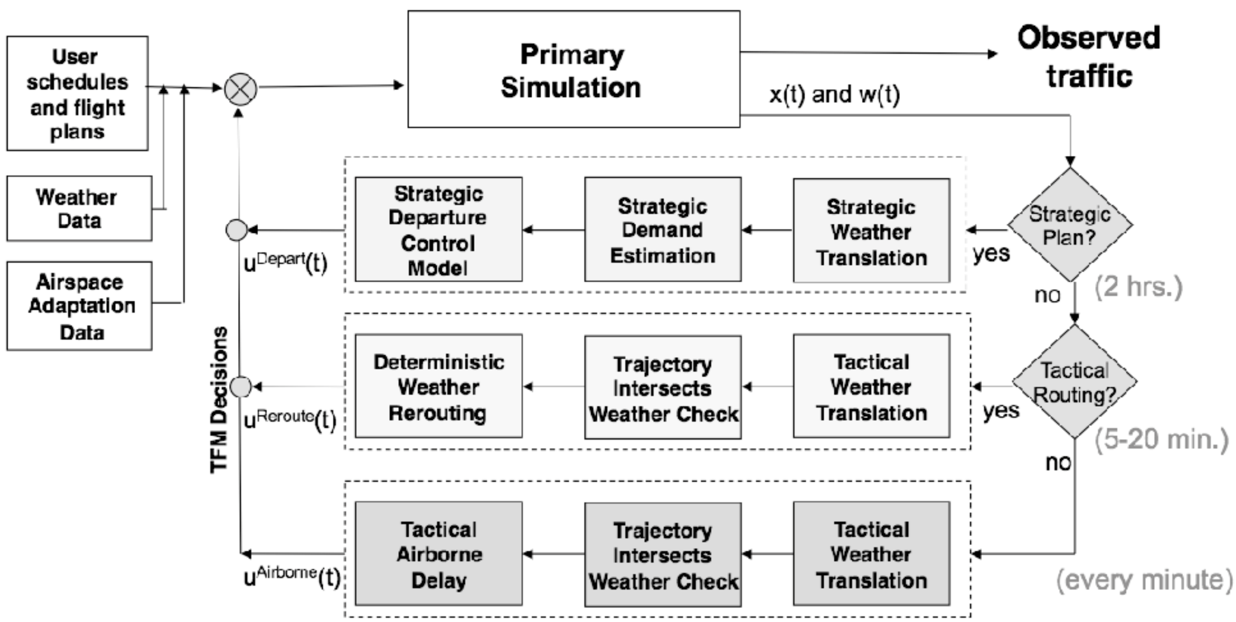


Figure B-26 Sequential optimization with strategic and tactical weather translation.

A Primary Simulation updates state information (e.g., latitude, longitude, speed, altitude, and heading) for all aircraft in the simulation every minute, while updates to the weather forecasts are provided every five minutes. This updated state information is used every two hours to develop and refine deterministic, strategiB-level flow control initiatives, assigning pre-departure delays to flights subject to airport and airspace capacity constraints. The first step in developing these strategiB-level controls is to translate the weather data into reduced sector capacity estimates [KMP07, M07, SWG08]. Subsequently, the predicted positions of all airborne and scheduled flights over a user defined planning horizon is calculated. The forecasted system demand and capacity estimates are used as inputs for strategic departure control, assigning flight specific pre-departure delays.

Refinements to the strategiB-level traffic flow management plan to account for uncertainties in the demand and capacity estimates are accomplished through two tactical control loops. The first is called at a frequency that ranges between 5 and 30 minutes, and assigns tactical reroutes to flights to ensure that aircraft do not venture into regions of significant convective weather. The variable calling frequency is allowed here to account for the confidence in the weather forecast accuracy. Regions of significant convective weather are defined by CWAM WAFs. The trajectories of all flights over a 100 nmi to 400 nmi look-ahead horizon are checked to determine if any flight intersects a WAF. Flights found to intersect these regions are rerouted. The lowest level control loop that is called every minute is a strategy of last resort to immediately assign airborne delay to any flight that will encounter an en route weather hazard within the next minute.

B-2.3 Airspace Flow Programs to address 4-D Probabilistic Weather Constraints

An AFP [Br07, KJP06] is a particular type of Traffic Management Initiative (TMI) that controls traffic flowing into an airspace where demand is predicted to exceed capacity, as illustrated by Figure B-27. A FCA is defined to be the boundary of the region of airspace where demand exceeds capacity – most typically, due to convective weather constraints. Today's AFPs use fixed locations for FCA boundaries used for AFPs, typically a line segment connecting sector boundaries that aircraft cross at they travel toward eastward destinations, and these regions are defined by air traffic control sector boundaries, not the location of the weather constraint itself.

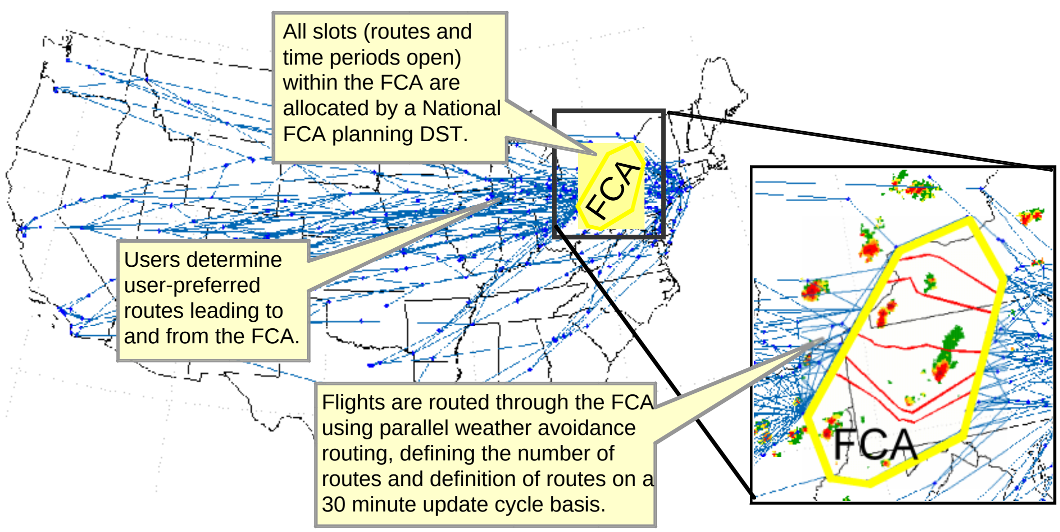


Figure B-27 In an AFP, routes within the FCA are defined by an FCA planning DST to maximize throughput given weather constraints; routes outside the FCA are determined by routing preferences of the user.

In NextGen, the FCA is likely to be a 4-D volume that describes the space-time region where weather constraints (not only convection, but severe turbulence and icing regions as well) cause significant ATM impacts. This 4-D volume is likely to be derived from weather forecast data from the NextGen 4-D Wx Data Cube and from information about the expected demand at a given time and location that reflects user preferences. The FCA is thus a product of the translation of weather into ATM impact; it requires a capacity estimation technique to define the capacity reduction due to the forecasted weather [CRD07, KMP07, SWG06, SWG07, SWG08]. The AFP is a TMI that responds to the ATM impact in terms of a TFM plan that adjusts periodically (e.g., every 30 minutes) as long as the scheduled demand continues to exceed the FCA capacity.

The AFP for NextGen is able to control a number of factors. Strategically, the AFP controls the takeoff time (ground delay) for aircraft heading to the FCA in order to control the flow rate of traffic entering the FCA. Tactically, the AFP defines the entry points into the FCA as a function of time. As aircraft approach the FCA boundary, the AFP defines safe routes (routes that avoid hazardous convection, turbulence, or icing constraints) across the FCA in order to maximize capacity usage within the FCA region subject to the dynamic 4-D weather constraints. One algorithmic solution to the AFP minimizes the sum of all delays experienced by all flights in the AFP [KJP06].

Because the AFP must reason about the effects of weather on airspace capacity for long lookahead times, it is necessary for the AFP to reason about a probabilistic estimate of capacity [MPK06, SB09]. Thus, the FCA boundary is not known precisely, but it represents the general vicinity in 4-D where the constrained airspace is likely to occur. As the time horizon shortens (when most aircraft are en route), the exact boundaries of where the FCA must control traffic flow is known more precisely based on deterministic estimates of capacity. Because the routes across the FCA may not be synthesized until flights are within about 1 hour from entry into the FCA, a datalink is required in NextGen to inform air crews of the routing needed for safe and efficient travel across the FCA. Thus, the AFP is an implementation of strategic TFM plans to continuously adjust the flow rate of traffic entering the FCA in order to match demand with the capacity estimates that were initially set using probabilistic techniques and later refined through deterministic means.

B-2.4 Ground Delay Program Planning under Capacity Uncertainty

Uncertainty in capacity forecasts poses significant challenge in planning and controlling a GDP. There are two main decisions associated with any GDP: (1) setting the AAR, and (2) allocating landing slots to flights, and hence, to the airlines who operate those flights.

The AAR is dependent on uncertain weather conditions; it is not known in advance with certainty. Therefore, when a GDP is implemented, a planned AAR (PAAR) must be set based on stochastic information. A "static" stochastic optimization model for deciding optimum PAAR was presented in [BHO03]. There are other variants of such models [KR06, RO93]. The models require an input arrival schedule, a finite set of capacity scenarios, and their probabilities. A scenario represents time-varying profile of airport capacity. A cost-ratio between ground and airborne delay can be adjusted to penalize excessive airborne delays. Given these inputs, the static optimization model [BHO03] generates the optimum PAAR.

Uncertainty in airport capacity is represented by a set of scenarios in stochastic optimization models. Probabilistic weather forecasts are needed. Past research has addressed this issue for specific airports [Wi04]. Research is currently underway to generate probabilistic weather forecasts at airports and en route airspaces. One methodology generates capacity scenarios by analyzing historical observations of AAR [LHM08]. In the future, a combination of probabilistic weather forecasts and empirical data analysis could be used to generate capacity scenarios for airports.

After setting the PAAR, the next step in a GDP is to assign slots to airlines. In today's system, this is done by executing a Ration-by-Schedule (RBS) algorithm, which is based on first-scheduled-first-served principle. Before RBS is applied, certain flights are exempted from the GDP. The primary reason for exempting flights is to mitigate capacity uncertainty. The RBS algorithm, which lexicographically minimizes the maximum delay of included flights [Vo06], has been accepted as the standard for equitable slot allocation. In a recent study, a new algorithm – Equity-based Ration-by-Distance (E-RBD) – was proposed that considers both equity and efficiency factors in slot allocation [HBM07].

A GDP is a stochastic and a dynamic process. Changing conditions at an airport, for instance due to weather constraints, requires revision of GDP parameters and flight delays. In static optimization models [BHO03, KR06, RO93] decisions are made once and are not revised later based on updated information. This deficiency is overcome by dynamic optimization models [MH07, RO94]. However, it is possible to re-apply static models, and revise decisions, whenever updated forecast becomes available. Figure B-28 presents an algorithm for planning a GDP under uncertainty, and dynamically revising decisions in response to updates in the information on demand and capacity. The steps within the algorithm are similar to how GDPs are planned in today's system under the Collaborative Decision Making (CDM) paradigm

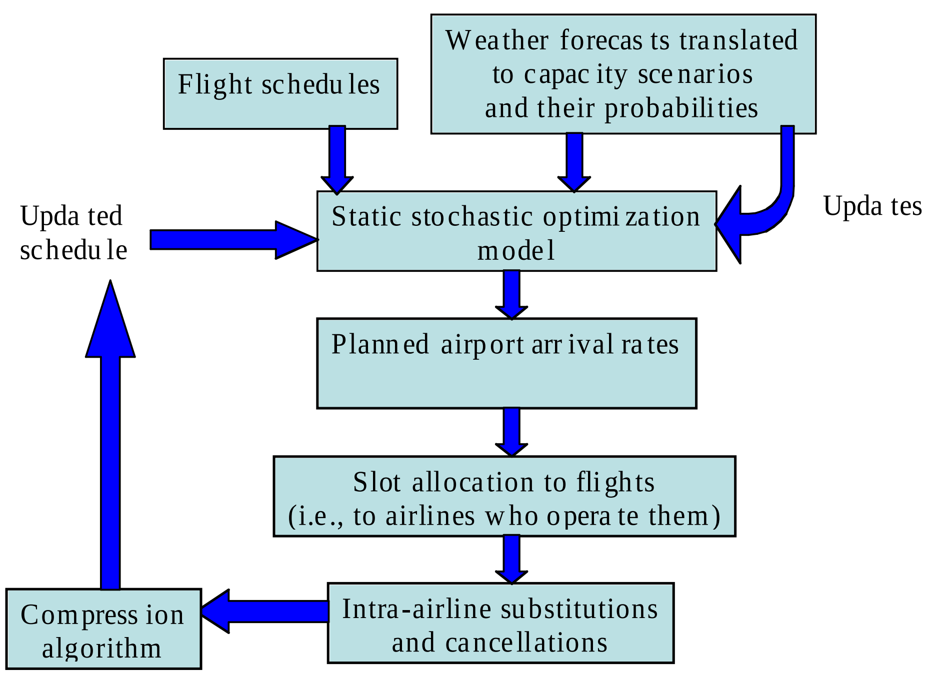


Figure B-28 A dynamic stochastic algorithm for planning and controlling a GDP.

Dynamic stochastic optimization models simultaneously decide PAAR and slot allocation to flights [MH07, RO94]. The dynamic models typically assign scenario-contingent slots to individual flights. These models allow revision of delays based on updated forecasts. Along with a set of capacity scenarios, these models require as input a scenario tree, whose branching points reflect changing AARs. What complicates the applicability of dynamic models is the fact that the branching points in time must be predicted in advance and provided as input to the models. Techniques for generating scenario trees from empirical data were explored in [LHM08]. Performance-wise, however, dynamic models outperform the static models. Application of the dynamic models for GDP planning would require a change in the intra-airline flight substitution process. Unlike in today's system where each flight receives one slot, the dynamic models would assign a portfolio of scenario-specific slots to a single flight. Thus the flight substitutions would also become scenario-specific, and hence, more complex.

Along with capacity uncertainty, there could be uncertainty in flight arrival demand [BVH01]. This could result from flight cancellations, deviation from scheduled or controlled arrival times, and arrivals of un-scheduled flights. Developing models that account for both demand and capacity uncertainty is a potential research topic.

B-2.5 Contingency Planning with Ensemble Weather Forecasts and Probabilistic Decision Trees

Management of the complex interaction between potential weather outcomes and TMIs can be modeled using a collection of potential weather scenarios. These would be retained in an ensemble forecast, which would serve as input to a Probabilistic Decision Tree [DKG04]. Flow planners would make use of this to form a primary plan and contingency flow plans (one for each possible weather scenario) (for instance, strategic two to four hours in the future). This assists in the strategic planning of GDPs, AFPs across FCAs as well as tactical GSs, holding, metering, reroutes, and other plans.

Ensemble weather forecasts aim to represent the spread of possible outcomes of the weather. Since there could be hundreds of different weather scenarios, the secret to this technique is to group the scenarios by general natural and impact on air traffic. Weather organization (e.g. squall line versus popcorn storms) is one such way to group scenarios into a more manageable number. Each representative scenario would have associated with it a likelihood (probability) of occurrence. This technique allows for automated routines to propose hedging strategies. Hedging strategies are a proven way to take a wide range of possible outcomes into account without falling back on an overly conservative (worst-case scenario) strategy. Some weight is given to dire outcomes, but other more optimistic outcomes are considered as well. This leads to a more balanced strategy that performs well on average; cost savings are incurred with repeated use [HKD07]. Probabilistic forecasts and the use of probabilistic decision trees will have failures on a daily review, but over the long-term will show improvement in operations.

The probabilistic decision tree manages the ATM impacts and probabilities of occurrence. As illustrated in Figure B-29, the decision tree is set up to reason about the general dimensions of forecast error that are possible in the future, and how these should be linked to strategic and tactical TMIs that will address those scenarios. The tree is mainly for benefit of the human users. It provides a map of key TMI and flow planning decisions that need to be made. Decision makers and other stakeholders can follow along to see which critical decisions must be made, when, and ATM-impact costs associated with the course of action.

First, the ensemble captures potential variations in weather types that may emerge, and associated probabilities. Errors in timing, coverage, echo tops, and translational errors may be considered in the tree. In order to process such errors, the appropriate weather to ATM impact models must be invoked, requiring potentially a wide range of ATM impact models from capacity estimates, route blockage probabilities, affects of weather on AARs, or other impacts. Associated with each branch of the tree is a set of TMIs that would be used if the future evolves to that state.

For NextGen, the use of probabilistic decision trees to manage traffic in the NAS requires both ATM impact models to mature as well as the understanding of how to best assemble TMIs into a probabilistic decision tree that meet the objectives of a strategic plan of operations. Given that the amount of weather forecasts in an ensemble is likely to be large, and the space-time dimensions of potential uncertainty further expand the number of scenarios, NextGen will require research on how to best manage probabilistic decision trees using computers as the number of possible futures is far larger than humans could cognitively grasp

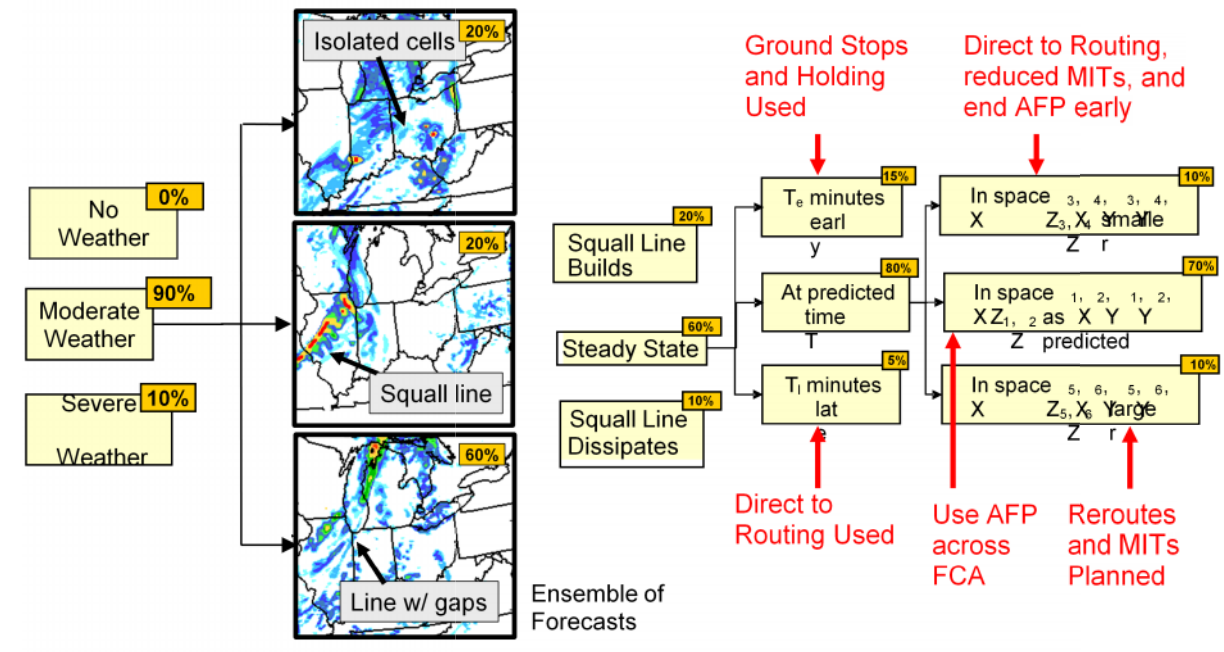


Figure B-29 Probabilistic decision tree reasoning with an ensemble of weather forecasts.

B-2.6 Probabilistic Traffic Flow Management

An important goal of TFM is to ensure that traffic loadings do not exceed system capacities. TFM problems often involve time horizons extending to one or more hours into the future. This strategic TFM problem is inherently stochastic since both the traffic loadings and system capacities are difficult to forecast precisely over such long time horizons [WSZ05]. Strategic TFM solutions need to account for forecasting uncertainties.

The strategic TFM problem is difficult even in the absence of forecasting uncertainties [BS98]. This difficult problem is solved mainly by human operators in today's NAS. A strength of human decision making is its intuitive ability to rapidly assess and approximately account for uncertainties. Such powerful intuition will be a challenge to replace in automated strategic TFM solutions in NextGen. These future TFM solutions hold the promise of significantly improving NAS performance and repeatability, but first they must match the robustness inherent in human decision making.

Any strategic planning activity within the NAS requires forecasts which contain uncertainties since all forecasted quantities are random variables. For instance, surveillance reports, navigation data, communications, user intent and conformance, weather, and the possibility of anomalous events all introduce uncertainty into NAS forecasted quantities. These processes could be modeled and their random variables estimated in a classic covariance propagation [Ge74]. But this is difficult due to the magnitude of the problem and the substantial modeling effort required. Perhaps the biggest drawback to the approach, however, is the difficulty in accounting for the substantial human-in-the-loop decision making that critically affects these processes. In fact, in the absence of such an accounting, the variances of many random variables (e.g., aircraft position) can rapidly grow. In this case distributions flatten and the strategic TFM problem reduces to a non problem due to an absence of information.

An alternative to the classic covariance propagation approach is to identify the key random variables in the strategic TFM problem and model them with aggregate uncertainty models, based on system domain knowledge and historical data. In this rational-empirical approach, one (i) constructs mathematical models describing the random variable uncertainty as a function of the relevant independent variables and (ii) fits these models to the historical data [WSZ05, H07a, HR08, HW08]. This approach also has the advantage that many random variables can be ignored as irrelevant. For instance, though surveillance error should be accounted for in a classic covariance propagation approach, it becomes irrelevant in the aggregate model of traffic loading uncertainty [WSZ05].

In the strategic TFM problem, forecasted traffic loadings and system capacities are the most important random variables that need to be estimated. Since loading and capacity are typically expressed as integers, these random variables can be expressed as discrete distributions, known as probability mass functions (PMFs). Properly constructed, these PMFs faithfully represent the forecast accuracy. They are neither less accurate (wider) nor more accurate (thinner) than the forecast accuracy. Given PMFs that faithfully represent the forecast accuracy, the probabilistic TFM solution can then use them to account for the uncertainties that are unavoidable at the planning stage.

A misconception is that a probabilistic TFM solution is limited to probabilistic, or multiple, solutions. Such solutions would be difficult to implement but are easily avoided. Probabilistic TFM solutions can use probabilistic forecasts to produce a deterministic solution. An obvious approach is to compare the traffic loading and system capacity PMFs to evaluate a congestion cost (e.g., by convolving the PMFs). Such a metric can be forecasted for NAS elements, such as airports and regions of airspace, and for flights. Figure B-30 shows an example of the distribution of flight costs in a day [H07a].

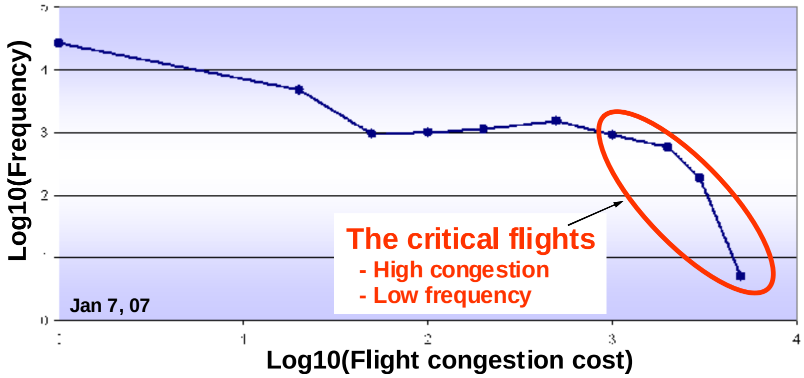


Figure B-30 Example histogram of flight congestion costs.

Such congestion forecasts, by flight or by airspace / airport, are crucial in the probabilistic TFM solution. They can be used to guide flight selection, for delaying or rerouting. And they can be used to manage system congestion to acceptable levels. And this approach is well-suited to the NextGen principles of trajectory-based operations and user involvement.

The specific solution method can take several forms. One is a resource allocation solution involving a combination of rerouting and ground delay. This probabilistic TFM concept has a high maturity level, as it has been defined, analyzed and verified at various levels. Also, it has been simulated for several different types of traffic and weather days, and has been tested in a real-time system testbed [H07a, H07b, H08].

B-2.7 A Heuristic Search for Resolution Actions in Response to Weather Impacts

Uncertainties present in demand, weather, and capacity, create a need to resolve congestion in an efficient and flexible manner. In both the strategic and tactical time frames, the methods utilized to resolve congestion should provide metrics to measure the quality of the proposed solutions. As it is desirable to have flight-specific resolution actions, there are many potential solutions and the challenge is to find a good solution quickly. A Generalized Random Adaptive Search Procedure (GRASP) can address this problem through a computationally-efficient heuristic optimization approach. GRASP finds feasible solutions quickly and evaluates proposed solutions against defined metrics to determine the set of resolution maneuvers that best satisfies the objectives.

Figure B-31 illustrates the decision loop. The process creates an ordered list of flights and then examines each flight individually to determine if it can remain on its original path or if it must be delayed and/or rerouted. Weather information is used to predict sector capacities in and around the congested area, and flight options that violate the congestion resolution goal are less desirable. The flight list is ordered probabilistically, using specified priority criteria such as first-come first-served (FCFS), to determine the likelihood of placement in the sort order. This is useful because it exploits the fact that the chosen prioritization criteria may not fully capture the best situation and therefore minor modification in the ordering may be beneficial [FR95].

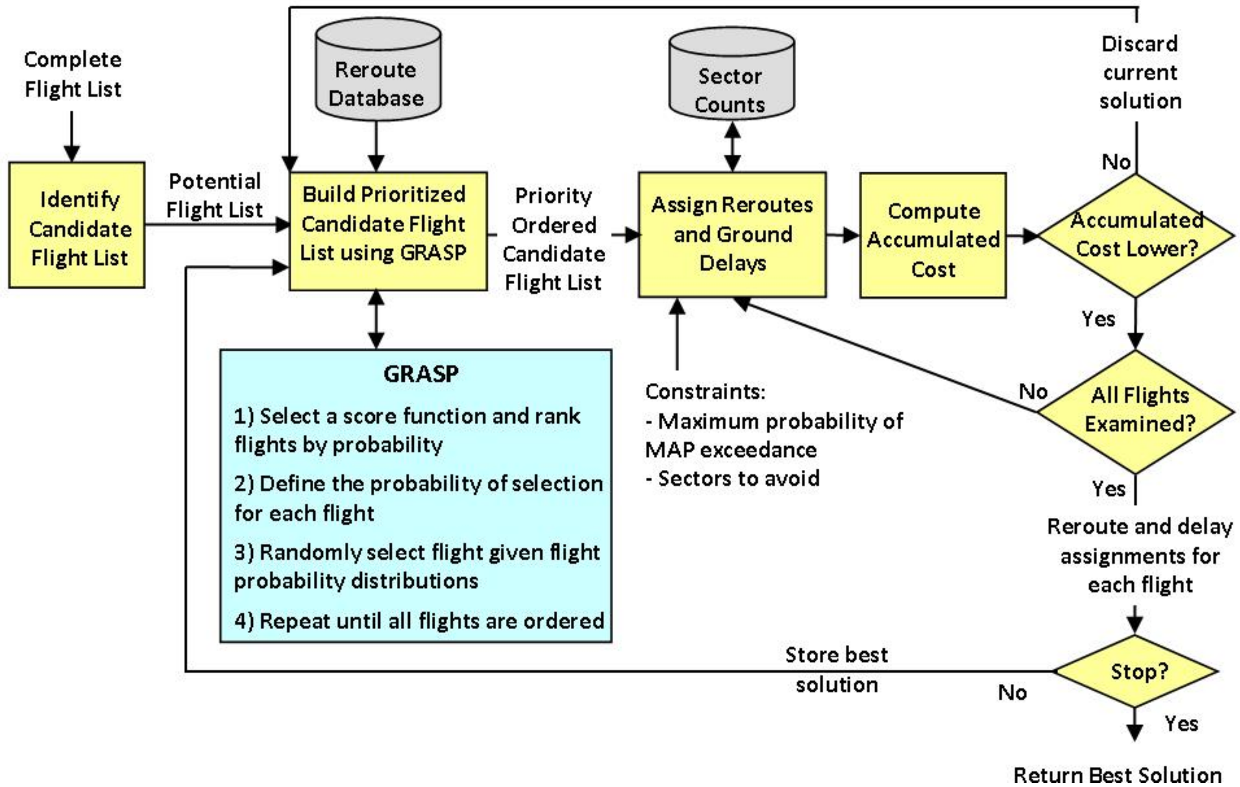


Figure B-31 Congestion management algorithm flow diagram.

Once all flights are examined, an objective function is used to measure solution quality against a variety of goals. Objective functions are formulated to evaluate the quality of the solution as a whole, such as congestion resolution effectiveness, total delay, or the equitable distribution of resolution actions among users. After iterating, the algorithm returns the best solution found.

This process for air traffic congestion provides a flexible and computationally efficient alternative to more traditional heuristic optimization algorithms [MWG06, SMW07]. Given its computational efficiency, GRASP could be employed within a larger decision making process, such as sequential probabilistic congestion management [WG08], to optimize the resolution maneuvers at each stage of the decision process.

Another useful application is to evaluate quantitative measures of the impact on a policy objective that result from implementing a given prioritization criteria. For example, by choosing a FCFS prioritization, the impact on delay and equitable distribution can be compared to the results obtained from the choice of an alternative prioritization (e.g., sort flights by the number of congested sectors they currently are planned to traverse). This type of analysis can provide feedback as to which choice of prioritization criteria is desirable, based on the trade-offs obtained in the policy objectives considered.

B-2.8 Integrated Departure Route Planning with Weather Constraints

NextGen will require an Integrated Departure Route Planning (IDRP) capability in order to handle departure traffic efficiently and safely. The IDRP capability must integrate departure route and en route sector congestion information, especially when weather constraints are present and traffic demand must dynamically adjust to predicted downstream capacity fluctuations. This concept also applies to downstream weather constraints such as convection, turbulence, or icing. The IDRP capability reduces the time needed to coordinate and implement TMIs and supporting departure management plans.

A variety of TMIs such as reroutes, MIT restrictions, and GDPs are generated to control the NAS when air traffic demand on specific resources – sectors, routes, and fixes – is predicted to exceed capacity. This is especially crucial when system capacity is reduced by severe weather. In current operations, with limited automation support, traffic managers must mentally integrate the traffic, weather, and airspace resource information and project that information into the future. This process is difficult, time consuming, and inaccurate. In NextGen, in order to maximize airspace capacity while maintaining safety, it is desirable to minimize the impact of TMIs on operations and to implement only those TMIs necessary to maintain system integrity.

Route availability [DRT08] feedback helps traffic managers determine the specific departure routes, altitudes, and departure times that will be affected by significant convective weather, turbulence, or icing. NextGen DSTs will assist users in deciding when departure routes or fixes should be opened or closed and to identify alternative departure routes that are free of weather constraints. DSTs need to help traffic managers answer the questions:

- If a route is impacted by the weather constraint during a particular time window, which and how many aircraft are affected?
- What alternative departure routes are free of weather constraints during a particular time window, and how many aircraft can the route handle?

The IDRP concept (Figure B-32) translates weather constraints into ATM impacts, and thus helps decision makers evaluate and implement different TMIs [MBD08] in response to the projected ATM impacts. The concept takes into account multiple factors that can have significant effects on departure management when weather constraints are present. In evaluating the impact of congestion and downstream weather constraints on departure operations and potential actions to mitigate those impacts, traffic managers must consider filed flight plans and acceptable alternatives, surface departure queues, predicted weather impacts (route availability) along both departure and arrival routes in the terminal area and nearby en route airspace, the current state of departure routes (open, closed, MIT, etc.), predicted congestion and flight times along weather-avoiding reroutes, and the weather forecast uncertainty. By bringing all of these factors into an integrated environment, IDRP can reduce the time needed to make departure management decisions and coordinate their implementation. If it is integrated with surface and arrival management systems, IDRP can improve efficiency over the NAS considerably.

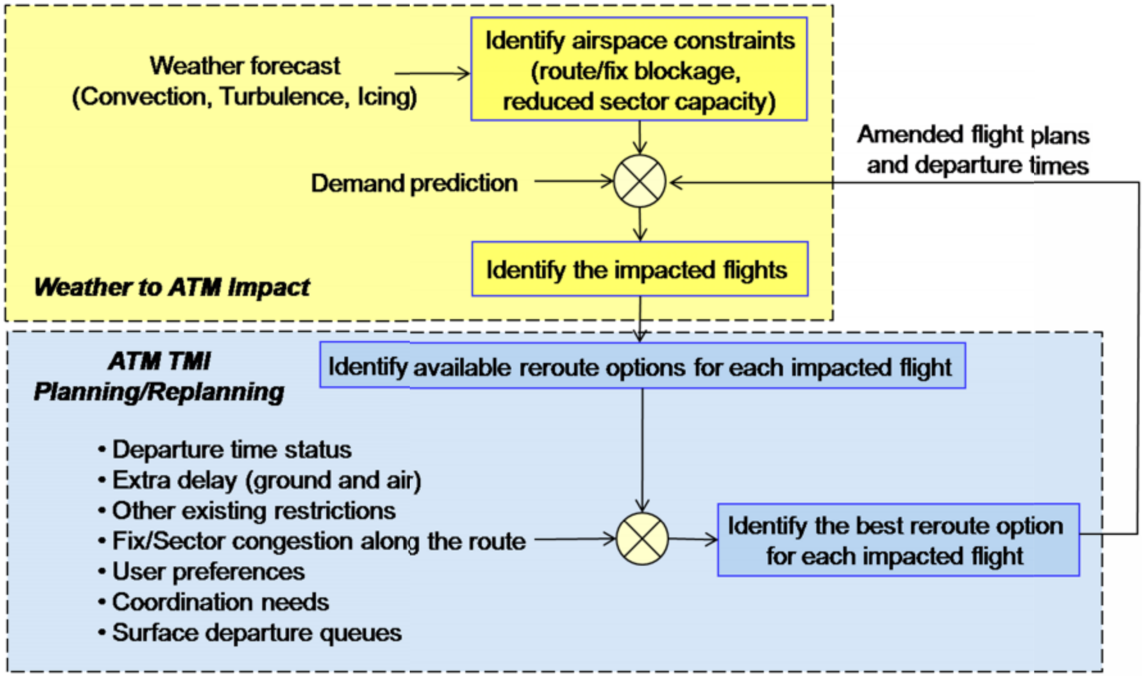


Figure B-32 Integrated Departure Route Planning Concept.

B-2.9 Tactical Flow-based Rerouting

This concept for rerouting air traffic flows around severe weather is for a tactical timeframe (0 to 2 hours out) and requires an ATM-impact model for route blockage, as illustrated by Figure B-33. In this timeframe, weather predictions are relatively good, so the reroutes can be closer to the weather than strategic reroutes and thread through smaller gaps between weather cells. Automated solutions makes tactical rerouting easier, increasing the ability of traffic managers to implement them. Moving this activity from controllers to traffic managers will reduce controller workload, thereby safely increasing airspace capacity during severe weather.

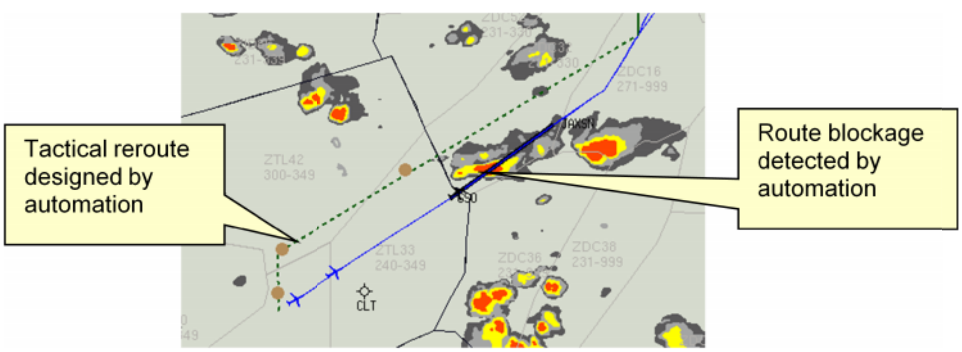


Figure B-33 Example flow reroute.

A Flow-based Tactical Rerouting DST identifies flights that are likely to need deviations from their current routes to avoid severe weather. The flights considered can be limited to the flights in a Flow Evaluation Area (FEA) flight list [CDM04] to narrow the focus to particular flows or areas. To determine severe weather encounters, predicted 4-D trajectories are probed against a WAF [DRP08] that is based on a dynamic 4-D weather forecast, including echo tops. Parameters are provided to allow the traffic manager to adjust the sensitivity of the probe.

The DST groups the flights identified with WAF encounters into flows according to weather impacted route segment, arrival airport, sectors traversed, or some other manner, and presents those to the traffic manager. The traffic manager can select one or more flows to examine in more detail in a flight list or on a map display, and advance time to view the predicted future situation. The traffic manager can select one or more of the impacted flows and request reroutes from the DST. The DST can then generate reroutes that avoid the WAF. It may achieve this based on historical routes, a network algorithm, or both. A ground delay can also be used with the current route to allow the weather to move off of the route. The resulting clear routes are ranked and filtered based on a number of criteria such as delay, required coordination, consistency with existing traffic flows, sector congestion, and closeness to weather.

Traffic managers determine the best reroutes for each flow. The reroutes go into a list with all the information necessary to implement them, including identification of air traffic managers (external facility or internal area) that need to approve them. After coordination, an air traffic manager in a rerouted flight's controlling facility can accept and implement the reroute.

B-2.10 Tactical On-Demand Coded Departure Routes (CDRs)

This concept for rerouting air traffic flows around severe weather is based on moving today's static, fixed Coded Departure Route (CDR) framework for rerouting traffic on jet routes during severe weather events into a dynamically defined "On Demand" CDR framework [KPM06] for NextGen for routing 4-D trajectories in a tactical timeframe (0 to 2 hours out). The method requires an ATM-impact model for route blockage to identify ahead of time when On-Demand CDRs are needed, as previously illustrated by Figure B-33, and the ability to design space-time reroutes between city pairs with a 1-2 hour look ahead time (Figure B-34). The purpose of On-Demand CDRs is to move the rerouting decision as close to the tactical time horizon as possible to eliminate the uncertainty in rerouting – eliminating the potential for several weather outcomes, as is the case in ensemble weather forecasts, and focusing in on one projected weather outcome in the tactical time frame.

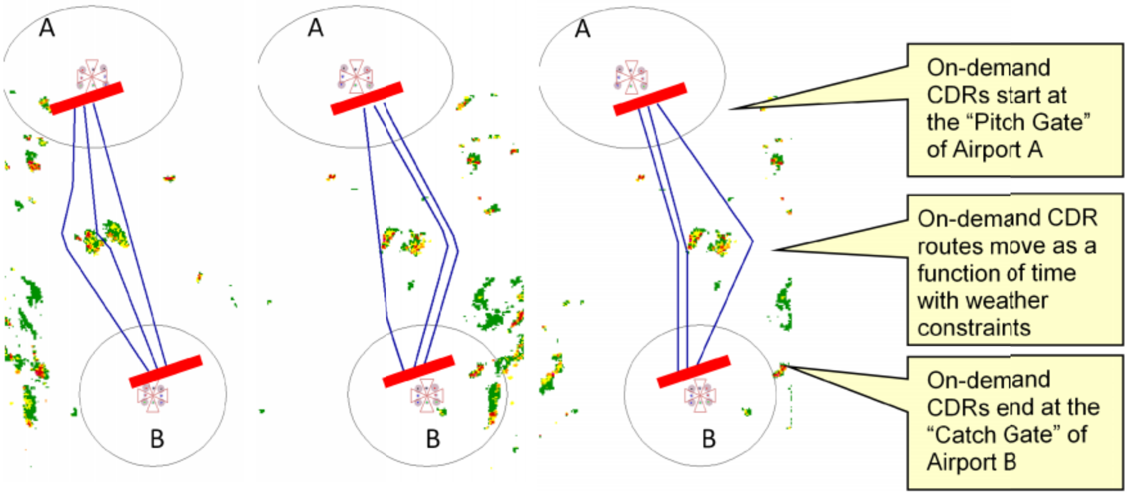


Figure B-34 On-Demand CDRs between pitch and catch gates from Airport A to B.

Today, CDRs are generated far in advance of the day that they are implemented. The routes are maintained in a database and distributed between the ANSP and the users (airlines). If the weather forecast is highly predictable, the ANSP selects the CDR that best solves a weather avoidance problem, given other TFM constraints. For less predictable weather, the ANSP identifies CDRs that could be used to avoid multiple weather constraint scenarios, asks the NAS users to prepare for this full set of contingencies (alternative CDRs), and then assigns the actual route to the flight as it departs. However, today's CDRs often take aircraft far out of the way as they do not shape the weather avoidance route to the actual movement of the weather constraint.

The On-Demand CDR concept dynamically generates CDRs approximately 1-2 hours in advance of take off time based on the latest deterministic weather forecast. The benefit of generating CDRs as needed to meet the constraints imposed by the weather forecast is that the routing solution adapts and best fits both the emergent weather pattern and latest traffic flow requirements. Such weather avoidance routes can be generated with a space-time weather avoidance algorithm [P07] that takes into consideration the weather forecast, CWAM WAF [DE06, CRD07] or other weather avoidance constraints, and relevant human factors (see C-5) and domain knowledge requirements [KPM06]. The weather avoidance routes do not have to be based on today's jet routes and Naviads, since in NextGen, RNAV routing and RNP performance will allow routes to be defined anywhere in the sky.

B-3. Technology Evaluation Criteria and Ranking

Technology Name	Class (TRA, IMP, DST)	Time horizon (TAC, STR)	Airspace domain (ARR, DEP, ENR, OCE)	ATM app. (ATC, TFM)	Decision support (PRE, ANA)	Supported weather events	Weather events frequency	Weather events duration	Weather events scale	Weather inputs (DET, PROB, ENS)	Captured disruption - Impact on traffic	Output dimensionality	Output spatial resolution	Output temporal resolution	Output accuracy	Reliability (Type I error, Type II error)	Portability	Output versatility	Real-time support
B-1.1 En route Convective Weather Avoidance Modeling	TRA	TAC, STR	ENR, OCE	ATC, TFM	PRE, ANA	convective		Minutes to Hours	local, regional, NAS	DET		4D	weather input dependent	dynamic, weather input dependent	65%	25%, 10%	Y	N	Y
B-1.2 Terminal Convective Weather Avoidance Modeling	TRA	TAC	ARR, DEP	ATC, TFM	PRE, ANA	convective		Minutes to Hours	local	DET, ENS		3D	weather input dependent	dynamic, weather input dependent			Y	N	Y
B-1.3 Mincut Algorithms to determine Maximum Capacity for an Airspace	IMP	TAC, STR	ARR, DEP, ENR, OCE	ATC, TFM	PRE	convective		Minutes to Hours	local, regional	DET, ENS		4D	weather input dependent	dynamic, weather input dependent			Y	Y (turbulence, icing, volcanic ash)	Y
B-1.4 Weather-Impacted Sector Capacity considering CWAM and Flow Structure	IMP	STR	ENR, OCE	TFM	PRE	convective		Minutes to Hours	local, regional	DET		4D	weather input dependent	dynamic			Y	Y	N/A
B-1.5 Route Availability in Convective Weather	TRA, IMP	TAC, STR	ARR, DEP, ENR, OCE	ATC, TFM	PR	convective		Minutes to Hours	local, regional	DET		4D	weather input dependent	dynamic, weather input dependent			Y	Y	Y
B-1.6 Directional Capacity and Directional Demand	IMP	TAC	ARR, ENR, OCE	TFM	PRE	convective		Minutes to Hours	local to regional	DET		3D	weather input dependent	dynamic, weather input dependent			Y	Y	Y
B-1.7 ATM Impact based on the Weather Impacted Traffic Index	IMP	STR	ARR, DEP, ENR, OCE	TFM	ANA	convective, ceiling, visibility, snow, wind		Hours	regional, NAS	DET, PROB		3D	weather input dependent	static			Y	Y	N/A
B-1.8 Weather-Weighted Periodic Auto Regressive Models for Sector Demand Prediction	IMP	TAC	ARR, DEP, ENR, OCE	ATC	PRE	convective		Hours	local, regional, NAS	DET, PROB	improved sector demand predictions, better airspace utilization	3D	sector size dependent	dynamic, 15 min, 30min-2hrs	23%-43%		Y	Y	Y, near-real-time
B-1.9 ATM Impact in terms of a Stochastic Congestion Grid	TRA	STR	ARR, DEP, ENR, OCE	TFM	PRE	convective, turbulence, icing		Hours	local, regional, NAS	PROB		4D	weather input dependent	dynamic			Y	Y, for any stochastically modeled constraints	Y
B-1.10 ATM Impact in terms of Network Flow Adjustments	IMP	STR	ENR	TFM	PRE	convective		Hours	local, regional, NAS	DET	adaptation of traffic flows due to weather constraints	3D	grid cell size dependent	dynamic			Y	Y, turbulence, icing, volcanic ash	Y
B-1.11 Translation of Ensemble Weather Forecasts into Probabilistic ATM Impacts	IMP	TAC, STR	ARR, DEP, ENR, OCE	TFM	PRE	convective		Minutes to Hours	local, regional, NAS	DET, ENS		3D, 4D	weather input dependent	dynamic			Y	Y, turbulence, icing, volcanic ash	N/A
B-1.12 Translation of a Deterministic Weather Forecast into Probabilistic ATM Impacts	N/A	TAC, STR	ARR, DEP, ENR, OCE	ATC, TFM	PRE	convective		Hours	local, regional, NAS	DET		3D, 4D	weather input dependent	dynamic			Y	Y, turbulence, icing, volcanic ash	Y
B-1.13 Sensitivity of NAS-wide ATM Performance to Weather Forecasting Uncertainty	IMP	STR	ARR, DEP, ENR, OCE	TFM	ANA	convective		Hours	local, regional, NAS	DET		3D		Static			N	Y, for any weather events	N/A
B-1.14 Use of Probabilistic Convective Weather Forecasts to Assess Pilot Deviation Probability	TRA	TAC, STR	ENR, OCE	ATC, TFM	PRE	convective		Hours	local, regional, NAS	PROB		3D, 4D	weather input dependent	dynamic			Y	Y, for any stochastically modeled constraints	Y
B-1.15 Integrated Forecast Quality Assessment with ATM Impacts for Aviation Operational Applications	N/A	STR	ARR, DEP, ENR, OCE	ATC	PRE	all		Minutes to Hours	NAS	DET, PROB		4D	weather input dependent	static			Y	Y, for any weather events	Y
B-1.16 Conditioning ATM Impact Models into User-relevant Metrics	TRA	STR	ENR, OCE	TFM	PRE	convective		Minutes to Hours	local, regional, NAS	DET		3D	weather input dependent	static			Y	Possibly, but so far only convective	Y
B-1.17 Integration of the Probabilistic Fog Burn Off Forecast into TFM Decision Making	TRA, IMP	STR	ARR	TFM	PRE	ceiling, visibility		Minutes to Hours	local	PROB		2D		dynamic, 30 minutes			Y	N	Y

Technology Name	Class (TRA, IMP, DST)	Time horizon (TAC, STR)	Airspace domain (ARR, DEP, ENR, OCE)	ATM app. (ATC, TFM)	Decision support (PRE, ANA)	Supported weather events	Weather events frequency	Weather events duration	Weather events scale	Weather inputs (DET, PROB, ENS)	Captured disruption - Impact on traffic	Output dimensionality	Output spatial resolution	Output temporal resolution	Output accuracy	Reliability (Type I error, Type II error)	Portability	Output versatility	Real-time support
B-1.18 Mincut Algorithms given Hard/Soft Constraints to determine Maximum Capacity	IMP	TAC, STR	ARR, DEP, ENR, OCE	TFM	PRE	convective, turbulence, icing		Hours	local, regional	DET		4D	weather input dependent	dynamic, weather input dependent			Y	Y	Y
B-1.19 ATM Impact of Turbulence	TRA, IMP	TAC, STR	ENR	ATC	PRE	clear-air turbulence	hourly / daily	Minutes to Hours	local	DET, PROB	safety	4D	20 km	dynamic, hourly updates			Y	N, clear-air turbulence-specific	Y
B-1.20 Tactical Feedback of Automated Turbulence electronic Pilot Reports	TRA, IMP	TAC	ENR	ATC	PRE	convective induced turbulence (CIT)	hourly / daily	Minutes to Hours	local	DET	safety	4D	unlimited, down to ~km scale	dynamic, minute scale updates			Y	Y, based on PIREPs in case of volcanic ash, icing	Y
B-1.21 ATM Impact of Winter Weather at Airports	TRA	TAC, STR	DEP	ATC	PRE	snow, icing	hourly, daily	6-48 hours	local	DET		2D, 3D	point location - at airport	dynamic			Y	N	Y
B-1.22 Weather Impacts on Airport Capacity	IMP	TAC,STR	ARR, DEP	TFM	PRE	convective, ceiling, visibility, snow, wind	continuous	Minutes to hours	local	DET	more accurate AAR, ADR = reduced delay	2D, 3D	point location - at airport	dynamic			Y	Y, Possibly other types of weather	Y
B-1.23 ATM Impact of In-Flight Icing	TRA, IMP	STR	ARR, DEP	ATC	PRE	airborne icing	occasionally from Oct - April	Minutes to Hours	local, regional	DET, PROB	cost to airlines (cancellation, delays), cost to NAS (delay propagation, uncertainty)	4D	weather input dependent	dynamic			Y	Y	Y
B-1.24 ATM Impacts Derived From Probabilistic Forecasts for Ceiling and Visibility and Obstructions to Visibility	TRA, IMP	STR	ARR, DEP, ENR	TFM	PRE	ceiling, visibility	frequent	Hours	local, regional, NAS	DET, PROB		2D		static			Y		Y
B-1.25 Improved Wind Forecasts to predict Runway Configuration Changes	TRA, IMP	TAC, STR	ARR, DEP	ATC, TFM	PRE	wind, convective	100%	24 hours	local	DET	more accurate AAR, ADR = reduced delay	2D		dynamic			Y	N	
B-1.26 Improved Wind Forecasts to facilitate Wake Vortex Decision Support	TRA	TAC	ARR, DEP	ATC	PRE	wind		Minutes to Hours	local	DET	reduced aircraft separation but only when sufficiently strong cross-winds and when pilots decide to accept reduced separations	3D	13, 20, 40 km (RUC grid dependent)	dynamic			Y	N	Y
B-1.27 Impact of Winds Aloft on the Compression of Terminal Area Traffic Flows	TRA, IMP	TAC, STR	ARR, DEP	ATC, TFM	PRE	wind		Minutes to Hours	local	DET		4D		dynamic			Y	N	Y
B-1.28 Oceanic/Remote Weather Integration	TRA, IMP	TAC, STR	OCE	ATC, TFM	PRE	convective, turbulence, icing, volcanic ash	frequent	Hours	global	DET		4D					Y		
B-1.29 Translation of Volcanic Ash Plume Hazards onto Airspace and Airport Impacts	TRA, IMP	TAC, STR	ARR, DEP, ENR, OCE	ATC, TFM	PRE	volcanic ash	very rare	Hours to Weeks	regional	DET, PROB	over $1.2 billion recently in Europe	4D					N	N	N
B-1.30 Translation of Atmospheric Effects into Environmental and ATM Impacts	IMP	TAC, STR	ARR, DEP, ENR, OCE	ATC, TFM	PRE	wind, temperature, humidity		24 hours	local, regional, NAS	DET, PROB	environmental impact	4D					Y		
B-1.31 ATM Impact of Space Weather	TRA, IMP	TAC, STR	ENR, OCE	ATC, TFM	PRE	radiation	very rare	Hours to Days	polar regions	DET, PROB		4D					Y	N	
B-1.32 ATM Impact of Weather Constraints on General Aviation Access to the NAS	IMP	TAC, STR	ARR, DEP, ENR	ATC, TFM	PRE	convective, turbulence, ceiling, visibility, icing, wind		Minutes to Days	local, regional, NAS-wide	DET		4D					Y		
B-2.1 Sequential, Probabilistic Congestion Management for addressing Weather Impacts	DST	TAC	DEP, ENR	TFM	PRE	convective			regional	PROB	Congestion management over factoring in time/cost impacts	4D	weather input dependent	dynamic, 30 minutes	90%		Y	N, restricted to short-term resolutions on a tactical basis	Y
B-2.2 Sequential Traffic Flow Optimization with Tactical Flight Control Heuristics	DST	TAC	DEP, ENR	TFM	PRE	convective, ceiling			regional	DET		4D		dynamic, minutes scale updates	90%		Y	N, restricted to short-term resolutions on a tactical basis	Y
B-2.3 Airspace Flow Programs to address 4D Probabilistic Weather Constraints	DST	TAC	ENR	ATC, TFM	PRE	convective	hourly		regional	PROB	increased throughput	4D	weather input dependent	dynamic	90%		Y	Y, icing, turbulence	Y

Technology Name	Class (TRA, IMP, DST)	Time horizon (TAC, STR)	Airspace domain (ARR, DEP, ENR, OCE)	ATM app. (ATC, TFM)	Decision support (PRE, ANA)	Supported weather events	Weather events frequency	Weather events duration	Weather events scale	Weather inputs (DET, PROB, ENS)	Captured disruption - Impact on traffic	Output dimensionality	Output spatial resolution	Output temporal resolution	Output accuracy	Reliability (Type I error, Type II error)	Portability	Output versatility	Real-time support
B-2.4 Ground Delay Program Planning under Capacity Uncertainty	DST	TAC	ARR	TFM	PRE	convective, ceiling, visibility, snow, wind	high		local	PROB	increased throughput	2D	weather input dependent	dynamic			Y	Y, for any weather events	Y
B-2.5 Contingency Planning with Ensemble Weather Forecasts and Probabilistic Decision Trees	DST	STR	ARR, DEP, ENR, OCE	TFM	PRE	convective			regional	ENS		2D	weather input dependent	dynamic			Y	Y, visibility, ceiling, wind	Y
B-2.6 Probabilistic Traffic Flow Management	DST	STR	ARR, DEP, ENR, OCE	ATC, TFM	PRE	convective, turbulence, ceiling, visibility, icing, wind													
B-2.7 A Heuristic Search for Resolution Actions in Response to Weather Impacts	DST	STR	ENR	TFM	PRE, ANA	convective	Upon demand based on MAP values		regional	DET	increased throughput	2D	MAP dependent	dynamic			Y	Y, turbulence	Y
B-2.8 Integrated Departure Route Planning with Weather Constraints	DST	TAC	DEP, ENR	ATC, TFM	PRE	convective	high		regional	DET	increased throughput, predictability	3D, 4D		dynamic	80%		Y	Y, turbulence	Y
B-2.9 Tactical Flow-based Rerouting	DST	TAC	ENR	ATC, TFM	PRE	convective	high		regional	DET	reduced controller workload, increased throughput	3D, 4D	input parameter	dynamic	80%		Y	Y, turbulence	Y
B-2.10 Tactical On-Demand Coded Departure Routes (CDRs)	DST	TAC	DEP, ENR	ATC, TFM	PRE	convective	high	Hours	local	DET		4D	hundreds of km	dynamic			Y	N	Y

	Maturity							Cost					Dependencies		
Technology Name	Stage of development (STAT, CONC, IMPL, DEPL	Theoretically valid?	Empirically valid?	Operationally valid?	Benefit studies conducted?	Estimated benefits	Number of publications	Cost of finishing technolog	Cost of completing mathematical mode	Cost of infrastructure for the supplie	Cost of implementation for the governme	Cost of implementation for airlines/use	Required NAS adaptation	Dependencies and interdependencies	Dependence on obsolete technology
B-1.1 En route Convective Weather Avoidance Modeling	IMPL	Y	Y	Y	Y		25+						N	determinisitc weather input data, long look-ahead convective forecasts for strategic use	
B-1.2 Terminal Convective Weather Avoidance Modeling	IMPL (departures), CONC (arrivals)	N	N	N	N		0						N	determinisitc weather input data, long look-ahead convective forecasts for strategic use	
B-1.3 Mincut Algorithms to determine Maximum Capacity for an Airspace	CONC	Y	N	N	N		15+						dynamic routing	datalink communication	
B-1.4 Weather-Impacted Sector Capacity considering CWAM and Flow Structure	CONC	Y	Y	N			5+						N	Dependent on pattern match against historical flow patterns	N
B-1.5 Route Availability in Convective Weather	CONC (Mincut), DEPL (Route Blockage)	Y	Y	N (Mincut), Y (Route Blockage)			15+						Y (Mincut), N (Route Blockage)		
B-1.6 Directional Capacity and Directional Demand	CONC	Y	N	N	N		5+						Y, for terminal version, flexible fix locations, flexible sectorization and routing	datalink communication, dynamic airspace configuration at the terminal level, RNP equipage	
B-1.7 ATM Impact based on the Weather Impacted Traffic Index	IMPL	Y	Y	N			10+								
B-1.8 Weather-Weighted Periodic Auto Regressive Models for Sector Demand Prediction	IMPL	Y	Y	N	Y		3						N	3D weather data w/storm location and echo tops; ETMS data feed, historical traffic flow data	
B-1.9 ATM Impact in terms of a Stochastic Congestion Grid	CONC	N	N	N	N		1						Grid-based rather than Sector-based analysis	Depends on TFM control strategy affecting demand patterns	N
B-1.10 ATM Impact in terms of Network Flow Adjustments	IMPL	Y	N	N	Y		1								
B-1.11 Translation of Ensemble Weather Forecasts into Probabilistic ATM Impacts	STAT	N	N	N	N		3						N	probabilistic weather ensemble forecasts	N
B-1.12 Translation of a Deterministic Weather Forecast into Probabilistic ATM Impacts	IMPL	N	N	N	N		2								
B-1.13 Sensitivity of NAS-wide ATM Performance to Weather Forecasting Uncertainty	IMPL	Y	Y	N	Y		1								
B-1.14 Use of Probabilistic Convective Weather Forecasts to Assess Pilot Deviation Probability	CONC	Y	Y	N	N		2								
B-1.15 Integrated Forecast Quality Assessment with ATM Impacts for Aviation Operational Applications	IMPL	Y	Y		N										
B-1.16 Conditioning ATM Impact Models into User-relevant Metrics	IMPL	Y	N	N	N		2+								
B-1.17 Integration of the Probabilistic Fog Burn Off Forecast into TFM Decision Making	IMPL	Y	Y	N	Y										

	Maturity							Cost					Dependencies		
Technology Name	Stage of development (STAT, CONC, IMPL, DEPL)	Theoretically valid?	Empirically valid?	Operationally valid?	Benefit studies conducted?	Estimated benefits	Number of publications	Cost of finishing technology	Cost of completing mathematical model	Cost of infrastructure for the supplier	Cost of implementation for the government	Cost of implementation for airlines/users	Required NAS adaptation	Dependencies and interdependencies	Dependence on obsolete technology
B-1.18 Mincut Algorithms given Hard/Soft Constraints to determine Maximum Capacity	CONC	Y	N	N	N		3+								
B-1.19 ATM Impact of Turbulence	CONC	Y	N	N	N		1						N	datalink	
B-1.20 Tactical Feedback of Automated Turbulence electronic Pilot Reports	CONC	Y	N	N	N		5							datalink (future model may depend on aircraft installed sensors)	
B-1.21 ATM Impact of Winter Weather at Airports	STAT	N	N	N	N										
B-1.22 Weather Impacts on Airport Capacity	IMPL	N	N	N	N		3						N		
B-1.23 ATM Impact of In-Flight Icing	CONC	N	N	N	N		1								
B-1.24 ATM Impacts Derived From Probabilistic Forecasts for Ceiling and Visibility and Obstructions to Visibility	DEPL	Y	Y	Y											
B-1.25 Improved Wind Forecasts to predict Runway Configuration Changes	STAT	N	N	N	N										
B-1.26 Improved Wind Forecasts to facilitate Wake Vortex Decision Support	DEPL	Y	Y	Y			5+						Y, attitude towards wake vortex prediction accuracy will need to change, pilots may not accept the technology	high-accuracy cross-wind forecasts	
B-1.27 Impact of Winds Aloft on the Compression of Terminal Area Traffic Flows	STAT	N	N	N	N										
B-1.28 Oceanic/Remote Weather Integration	STAT														
B-1.29 Translation of Volcanic Ash Plume Hazards onto Airspace and Airport Impacts	STAT														
B-1.30 Translation of Atmospheric Effects into Environmental and ATM Impacts	STAT														
B-1.31 ATM Impact of Space Weather	STAT														
B-1.32 ATM Impact of Weather Constraints on General Aviation Access to the NAS	STAT	N	N	N	N										
B-2.1 Sequential, Probabilistic Congestion Management for addressing Weather Impacts	CONC	Y	Y	N									N	Capacity metrics based on weather	N
B-2.2 Sequential Traffic Flow Optimization with Tactical Flight Control Heuristics	CONC	Y	Y	N									Y, 4D weather cube	4D weather cube	N
B-2.3 Airspace Flow Programs to address 4D Probabilistic Weather Constraints	CONC	Y	N	N									Y, 4D weather cube	4D weather cude, AFP/FCA Constuction, Capacity Estimator	N

	Maturity							Cost					Dependencies		
Technology Name	Stage of development (STAT, CONC, IMPL, DEPL)	Theoretically valid?	Empirically valid?	Operationally valid?	Benefit studies conducted?	Estimated benefits	Number of publications	Cost of finishing technology	Cost of completing mathematical model	Cost of infrastructure for the supplier	Cost of implementation for the government	Cost of implementation for airlines/users	Required NAS adaptation	Dependencies and interdependencies	Dependence on obsolete technology
B-2.4 Ground Delay Program Planning under Capacity Uncertainty	CONC	Y	N	**N**									Y, FSM modifications	FSM, weather input	N
B-2.5 Contingency Planning with Ensemble Weather Forecasts and Probabilistic Decision Trees	CONC	Y	Y	Y									**N**	weather ensembles	N
B-2.6 Probabilistic Traffic Flow Management	CONC														
B-2.7 A Heuristic Search for Resolution Actions in Response to Weather Impacts	CONC	Y	Y										**N**	MAP values	N
B-2.8 Integrated Departure Route Planning with Weather Constraints	IMPL	Y	Y	Y									Y, override PDAR limitations with HOST/ERAM	URET/ERAM files for arr/dept gates, unpublished PAR/PDR/PDAR trigger points	
B-2.9 Tactical Flow-based Rerouting	IMPL	Y	Y	Y									Y, electronic negotiation within TFM/intrafacility		N
B-2.10 Tactical On-Demand Coded Departure Routes (CDRs)	STAT	Y												better aircraft equipage (datalink, RNAV)	

B-4. References

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C. INTEGRATION PLAN TRACEABILITY WITH PREVIOUS STUDY GROUPS

C-1. REDAC Recommendations and Response

Note: The integration plan has been reviewed for alignment with the REDAC recommendations. A few items remain to be addressed and are so noted in the table below. This alignment process will be on-going as the execution of this overall plan proceeds.

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
Overarching Requirements		
Crosscutting Research Program		
1) Initiate and fund a crosscutting research program in ATM/Weather integration and insure that weather aspects are an integral part of all new ATM initiatives from the beginning. 2) Establish Senior Leadership over-sight.	2.3.3 Integrate Weather Information into ATM Decision Support Tools 6 Aligning the Weather Integration Plan with Previous Findings and Recommendations. 6.1 Weather-ATM Integration Working Group of NAS Operations Subcommittee of FAA REDAC. 5.2.1 Weather Leadership Team	
Leadership		
3) Establish REDAC monitoring.	6.3 Integration Teams Approach to Tracking the Status on the Previous Findings and Recommendations	No reference in NAWIP to REDAC Monitoring however some REDAC members part of writing team for the NAWIP document.
4) Revitalize joint advisory committee reviews of FAA and NASA joint research such as weather – ATM integration. FAA and NASA should hold joint meetings of their advisory committees and include the identification of current and future	1.3.2.2 NASA 5.2.1 Weather Leadership Team 5.2.2.2 Weather Integration Techniques Team	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
cross agency research opportunities in support of integrating advanced aviation weather and air traffic management tools. Furthermore, a Memorandum of Understanding (MOU) or Agreement of Understanding (AOU), between FAA and NASA, and encompassing weather and ATM research, may be needed to clearly elucidate the needed connection between these agencies.	A-1.2 Trajectory Management A-4.3.1 Trajectory Flight Data Management	
Requirements Process		
5) Develop requirements for weather ATM integration participation within the AWRP.	5.4 Relationship of Integration with Aviation Weather Programs.	
Research Recommendations: Near Term - IOC 2010		
Assessment of Avoidable Delay		
6) Research is needed to identify and quantify avoidable delay. Quantitative research studies of “avoidable” delay, should be conducted each year, based on significant summer or winter storm events, to identify opportunities to reduce delay and to evaluate the performance of weather – ATM integration capabilities as they are developed and fielded. 7) ATM/TFM/AOC/FOC involvement is needed.	Executive Summary 1.1 Background 2.1 Problem Statement 2.3.2 Improve Weather Products to Enhance Usability by ATM. B-1.7 ATM Impact Based on the Weather Impacted Traffic Index. 3 NextGen Weather Integration: Decision Support Tools A-3.4.2 Enhanced Surface Traffic Operation	
Translating Weather Data into ATC Impacts		
8) Expand research on the translation of convective	4.1 Survey of ATM-Weather Impact Models and	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
weather impacts into ATC impacts so that this information can be used to effectively support decision making. Research should be conducted to address the following elements:	Related Research	
	B-1 Survey of ATM-Weather Impact Models and Related Research	
a. Improve the models for convective weather impacts, e.g., route blockage and airspace capacity.	4.1 Survey of ATM-Weather Impact Models and Related Research	
b. Determine if pilot thresholds for weather conditions that lead to deviations can be reduced, since unexpected deviations around storm regions in high density airspace can lead to prolonged, unnecessary route closures.	4.1 Survey of ATM-Weather Impact Models and Related Research 5.4 Relationship of Integration with Aviation Weather Programs – Weather Technology in the Cockpit (WTIC)	
c. Determine if the data link transfer of ground derived weather and ATC domain information (spatial boundaries acceptable for maneuvering) to the pilot achieve a more consistent pilot response to convective weather.	B-1.30 ATM Impact of Weather Constraints on General Aviation Access to the NAS. A-4.1.1 Continuous Flight Day Evaluation, - Route Blockage and Route Congestion Prediction	
d. Determine if the airspace usage differs between various en route facilities [e.g., the Jacksonville Center (ZJX) appears to have very different procedures for convective weather ATM than many of the ARTCCs in the northeast].	A-4.1.1 Continuous Flight Day Evaluation, - Weather Integration into Automated Airspace Congestion Resolution	
e. Develop models for storm impacts on arrival and departure flows in both en route and terminal airspace.	4.1 Survey of ATM-Weather Impact Models and Related Research	
Improved Weather Input into Collaborative Traffic Flow Management		
9) Develop a six-eight-ten hour convective forecast for strategic flow management decisions with automatically generated and updated forecasts of	3.4 Flight and State Data Management, Provide full flight plan constraint evaluation with feedback. A-4.1Flight Contingency Management, Resource	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
flow impacts. This should be a joint program between the AWRP and the TFM R & D programs with involvement by representatives of the CDM Weather Team.	Capacity Prediction. A-4.3.1 Trajectory Flight Data Management, Departing Aircraft Weather Constraints.	
10) Improve the Traffic Management interaction with AOC/FOC's during weather impacts. Develop collaborative TFM systems that allow operators to better manage risks in meeting their own business objectives. Specifically, collaborative TFM systems should be developed that give operators the following capabilities: - Enable visibility into probabilistic TFM weather mitigation strategies through robust TFM data feeds for integration into their own internal systems via CDMnet and eventually System Wide Information Management (SWIM). - Electronically pre-negotiate multiple trajectory options with Traffic Managers. - Select viable route/altitude/delay options during severe weather impacts. - Integrate and ingest ATC-approved trajectories onto the flight deck for execution consistent with their own corporate infrastructure, business objectives and regulatory requirements. - Expand collaboration to include flight deck capabilities and decision making tools consistent with NextGen and within the corporate infrastructure, business objectives and regulatory requirements of the operator.	A-1.1 Separation Management 4.3 Survey of ATM-Weather Integration Technologies, Probabilistic Traffic Flow Management. B-2.6 Probabilistic TFM A-4.3.1 Trajectory Flight Data Management B-1.7 ATM Impact Based on Weather Impacted Traffic Index. 5.4 Relationship of Integration with Aviation Weather Programs - AWRP. A-1.1.1 Delegated Responsibility for Separation A-2.4.8 Mid-Term Weather Needs Analysis A-4.2.1 Improved Management of Airspace for Special Use A-4.3.1 Trajectory Flight Data Management 2.2 Weather Impact on Solution Sets 3 NextGen Weather Integration: Decision Support Tools 5.4 Relationship of Integration with Aviation Weather Programs - AWRP	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
	- Weather Technology in the Cockpit (WTIC)	
Weather Information and Pilot Decision Making		
11) Initiate a research program to develop procedures and guidance on the integration of weather and airspace congestion information for preflight and in-flight decision making tools. The program should include the following objectives: Develop appropriate rule sets for weather avoidance decision making in both non congested and, highly congested airspace. Develop ways to incorporate the same rule set into preflight, cockpit, AOC/FOC, and ATM decision support tools. Develop methods to integrate or display current and forecast weather impact to flight profile, airspace congestion information, and weather decision support information in preflight and cockpit systems to enable greater shared situational awareness and improved collaborative decision making. Conduct research on the direct, machine to machine, information transfer among cockpit, AOC/FOC, and ATM computing systems and determine whether this will facilitate consistent and expeditious decision making. This will place the users more “over the loop” than “in the loop” with	Executive Summary 1.2 Purpose 2.4 Recommended Solution: Integrate Weather into ATM Decision Support Tools. A-4.3.1 Trajectory Flight Data Management A-2.2.7 Mid Term Operational Scenarios A-2.4.2 Mid Term Operational Needs/Shortfalls. 2. NextGen Weather Integration Overview and Concept B-1.14 Integrate Forecast Quality Assessment with ATC Impacts for Aviation Operational Applications Executive Summary 1.2.2 Integration Goal 2. NextGen Weather Integration Overview and Concept 2.4 Recommended Solution: Integrate Weather into ATM Decision Support Tools 5.4 Relationship of Integration with Aviation Weather Program – Weather Technology in the Cockpit (WTIC)	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
respect to weather decision making.		
Integrating Weather Impacts with Airport Surface and Terminal Management Systems		
12) Expand the use of route availability tools to integrate airport and terminal area weather data and ATM tools. Expand the deployment of integrated tools, such as route availability, to additional airports and terminal regions to improve NAS performance at the largest airports impacted by convective activity.	A-3.4.1 Provide Full Surface Situation Information, REDAC Review. A-4.1 Flight Contingency Management, Route Blockage and Route Congestion Prediction. A-4.3.1 Trajectory Flight Data Management	
13) Conduct research on enhancing the Traffic Management Advisor (TMA) to achieve a weather sensitive arrival planning tool.	A-4.3.1 Trajectory Flight Data Management	
14) Integrate RAPT, ITWS, DFM, and TMA with surface management systems to provide a singular terminal management tool spanning departures, arrivals, and surface movement. Consider common use by air traffic and operators for collaborative decisions.	A-3.4.1 Provide Full Surface Situation Information A-4.3.1 Trajectory Flight Data Management	
15) Support CDM and other efforts to provide meaningful and integrated terminal and TRACON specific weather forecast information.	A-3.2.1 Use Optimized Profile Descent A-4.3.1 Trajectory Flight Data Management, Arrival/Departure Management Tool	
Research Recommendations: Mid Term - IOC 2015		
Adaptive Integrated ATM Procedures for Incremental Route Planning		
16) Develop Weather Impact Forecasts versus Time (for different planning horizons). Develop weather forecasting capabilities that incorporate	3.2.3 Capacity Management 3.4.3 Flight and State Data Management	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
representations of the uncertainties associated with different weather phenomenon for different planning horizons. This should be included in the research recommended in Section 6 B, translating weather into ATM impacts.	4.1 Survey of ATM-Weather Impact Models and Related Research - Mincut Algorithms to Determine Maximum Airspace Capacity -Translation of Ensemble Weather Forecasts into Probabilistic ATM Impacts	
17) Develop Adaptive ATM/TFM Procedures. Develop TFM procedures that are adaptive, and that take advantage of changes in uncertainty over time. These procedures should incorporate distributed work strategies that match the focus of control for a specific decision with the person or group that has access to the knowledge, data, motivation and tools necessary to effectively make that decision. Such adaptive procedures require an integrated approach to strategic planning and tactical adaptation.	2.3.3 Integrate Weather Information into ATM Decision Support Tools. 4.1 Survey of ATM-Weather Impact Models and Related Research - A Heuristic Search for Resolution Actions in Response to Weather Impacts 6.1 Weather-ATM Integration Working Group (WAIWG) of the National Airspace System Operations Sub-Committee of the FAA REDAC A-4.1 Flight Contingency Management, Route Blockage and Route Congestion Prediction. B-2.7 A Heuristic Search for Resolution Actions in Response to Weather Impacts	
18) Manage at the Flight Level Take advantage of trajectory-based management so that control actions and their impacts can be more directly and precisely localized at the points in the system where they are required to deal with a given scenario. In particular, this means that tools and procedures need to be developed to adaptively	3.1.2 Trajectory Management (TBO) 3.2.2 Trajectory Management, High Density Airports 3.3.2 Trajectory Management, Flexible Airspace in Terminal Area A-1 Initiate Trajectory Based Operations A-1.1.3 Automated Support for Mixed	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
manage at the flight level instead of traffic flows, and that the air traffic management user does not need detailed meteorology experience.	Environments.	
19) Translate weather information and forecasts to parameters relevant to decision support tools. Develop decision support tools that translate the implications of probabilistic weather forecasts into the decision parameters that are relevant to the application of particular TFM procedures and in a way that the air traffic management user does not require significant meteorological training.	2. NextGen Weather Integration Overview and Concept. 2.1 Problem Statement 2.2.3 Integrate Weather Information into ATM Decision Support Tools.	
20) Develop human-centered designs. Develop human-centered designs for these decision support tools that enable their users to understand the current state of the relevant parts of the NAS, and that support these users in understanding the basis and implications of recommendations generated by their decision support tools that automatically generate options for users to consider.	1.2.1 Integration Definition 2 NextGen Weather Integration Overview and Concept B-1.10 Translation of Ensemble Weather Forecasts into Probabilistic ATM Impacts. B-2.5 Contingency Planning with Ensemble Weather Forecasts and Probabilistic Decision Trees	
21) Develop tools and automation enabling operations and implementation. Develop computer-supported communication tools and automated decision support tools that enable effective coordination and collaboration in this distributed work system, and that enable timely implementation of the decisions that are made.	2.1 Problem Statement 3. Nextgen Weather Integration: Decision Support Tools 4. Technology and Methodology Concepts 5. Weather Integration Plan Execution A-2.1.6 Linkage to Near and Far Term A-4.3.3 On-Demand NAS Information, Weather	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
	Involvement Preliminary Review, MITRE Initial Evolution Analysis for Mid-Term Operations and Capabilities.	
Weather Impacts and Tactical Trajectory Management		
22) Implement Tactical Trajectory Management with integrated weather information. Develop a highly automated advanced Tactical Trajectory Management (TTM) decision support capability integrated with convective weather and turbulence to decrease controller and pilot workload, and increase safety. This would be a mostly automated system. This capability would assist the controller in a shared severe weather separation responsibility with the pilot.	3. NextGen Weather Integration Decision Support Tools, Solution Set Representation. 3.1.2 Trajectory Management (TBO) 3.2.2 Trajectory Management (High Density Airports) 3.3.2 Trajectory Management (Flexible Airspace in Terminal Area) A-1 Initiate Trajectory Based Operations A-1.1.3 Automated Support for Mixed Environments A-1.2 Trajectory Management	
23) Investigate the human factors (see C-5) issues (communication, information display, safety nets, cognitive complexity, and mental workload) associated with new paradigms for tactical trajectory management.	5.4 Human Factors Considerations	
Airspace Designs for Weather Impacts		
24) Airspace designs should enable route flexibility during adverse weather conditions. If the vision of 4-D trajectories is to become a reality, the airspace must be designed to support seamless adjustments of the route of flight in all four dimensions, as required by weather impacts.	A-2.1.3 Mid-Term Planned Capabilities A-2.1.7 Mid-Term Operational Scenarios 3.3.2 Trajectory Management A-3.2.1 Use Optimized Profile Descent	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
The development of ATM decision support tools must be done jointly with the weather research community so that decisions will adequately address impacts of adverse weather. Foundational efforts that reach across the disciplines of airspace design, weather translation into ATM impact and ATM decision support are required to achieve effective integration.	2.33 Integrate Weather Information into ATM Decision Support Tools B-1.7 ATM Impact Based on WITI B-1.9 ATM Impact in terms of Stochastic Congestion Grid B-1.10 Translation of Ensemble Weather Forecasts into Probabilistic ATM Impacts B-1.11 Translation of Deterministic Weather Forecasts into Probabilistic ATM Impacts	
25) Investigate the human factors (see C-5) issues associated with the dynamic reconfiguration of airspace, including issues associated with information display, training, and cognitive complexity.	5.4 Human Factors Considerations	
Research Recommendations: Far Term - IOC Post 2015		
Advanced Weather-ATM Integration Concepts		
26) Develop methods which combine the use of both probabilistic and deterministic forecasts and observations, to maximize throughput using multiple dynamic flight lanes or “tubes” in weather impacted areas.	4.1 Survey of ATM-Weather Impact Models and Related Research 5.1.2 Step 2: Weather Integration Insertion Determination B-1.5 Route Availability in Convective Weather B-1.9 ATM Impact in Terms of Stochastic Congestion Grid.	
27) Develop methods to transition from a probabilistic trajectory or flight envelope to a 4-D	4.1 Survey of ATM-Weather Impact Models and Related Research	Biannual review of this specific area not planned.

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
trajectory which is useable for separation and safety assurance. Establish an independent bi-annual review of this work to determine the potential benefits and costs to aviation.	- Stochastic Congestion Grid B-1.9 ATM Impact in Terms of Stochastic Congestion Grid.	
28) Conduct research into replacement of surrogate weather indicators such as radar reflectivity with reflectivity with actual indicators such as turbulence, icing, lightning, or wind shear, and an estimate of ATM impact. For example, radar reflectivity can be translated to ATM impact by estimated airspace pilots will avoid and the associated airspace capacity loss.	A-1.1 Separation Management 2) Weather Requirements of TBO and Separation Management b) TBO Specific Mid-Term	
29) Develop methods to use gridded and scenario based probabilistic weather data for ATM decision making. Develop methods to translate deterministic and probabilistic convective forecasts to ATM impact for use in network based capacity estimate models. Determine the reduction in capacity of an airspace region due to convective weather using a network model.	2.1 Problem Statement B-1.10 Translation of Ensemble Weather Forecasts into Probabilistic ATM Impacts B-1.16 Integration of Probabilistic Fog Burn Off Forecast into TFM Decision Making B-1.2.1 ATC Impact of In-flight Icing 4.3 Survey of ATM-Weather Integration Technologies B-2.4 Ground Delay Program Planning under Capacity Uncertainty.	
30) Investigate the human factors (see C-5) issues associated with the integration of such probabilistic modeling into decision support tools.	B-2.6 Probabilistic Traffic Flow Management 5.4 Human Factors Considerations	
Human Factors Considerations for Integrated Tools		
31) Develop advanced information sharing and	2.5 Anticipated Benefits and Impact	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
display concepts for the design of integrated decision- support tools. Develop strategies for information representation and display that enable people to maintain situation awareness regarding weather and traffic impacts, develop shared mental models, and evaluate inputs to the decision process provided by technology. Of particular importance is the need to conduct research on strategies for representing integrating and displaying probabilistic information about uncertainty regarding weather and traffic constraints and its predicted impacts as a function of look-ahead time. Equally important is the need to research new strategies for risk management that make use of such information. Research on the effective use of probabilistic information by ATC, TFM, and AOC/FOCs is a major challenge that needs to commence in the near term in order to obtain short term benefits and to enable more powerful solutions in the longer term. This research need to consider human factors (see C-5) as well as technology development challenges.	3.1.1 Separation Management 3.3.3 Flight and State Data Management 5.4 Human Factors Considerations 5.7 Relationship of Integration with Aviation Weather Programs - AWRP - Weather In the Cockpit (WTIC) A-2.1.6 Linkage to Near and Far Term A-2.2.6 Linkage to Near and Far Term A-4.1.1 Continuous Flight Day Evaluation - Weather Integration into Automated Airspace Congestion Resolution A-4.3.3 On-Demand NAS Information - Weather Involvement- Preliminary Review: MITRE Initial Evolution Analysis for Mid-Term Operations and Capabilities. B-2.6 Probabilistic TFM	
32) Develop new approaches and strategies for effective distributed decision making and cooperative problem solving. Develop effective strategies and technologies (decision support and communication tools) to enable distributed decision making to address the	4.3 Survey of ATM-Weather Integration Technologies B-2 Methodologies for ATM-Weather Integration	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
interaction of weather and traffic constraints, and to adaptively respond to situations as they evolve. This requires consideration of cognitive complexity, workload, and the ability of people to develop and maintain necessary levels of skill and expertise. It requires consideration of the need to design a resilient system that provides effective safety nets. And it requires system engineering decisions concerning when to design the system to provide coordination as a result of the completion of independent subtasks and when to design the system to support collaboration in order to ensure that important interactions occur. Develop technologies that support cooperative problem solving environments that allow people to work interactively with decision support technologies and with each other to assess situations as they develop, and to interactively generate and evaluate potential solutions.	B-2.6 Probabilistic Traffic Flow Management	
33) Develop methods for implementing human-centered designs for decision support tools. Develop effective procedures and technologies to ensure effective communication and coordination in the implementation and adaptation of plans in this widely distributed work system that includes meteorologists, traffic managers, controllers, dispatchers, ramp controllers and pilots.	2.3.3 Integrate Weather Information into ATM Decision Support Tools 2.4 Recommended Solution: Integrate Weather into ATM Decision Support Tools. 2.5 Anticipated Benefits and Impact	
34) Proactively enable new training on integrated tools. The FAA and aviation industry should proactively	5.1.4 Step 4: Integration of Weather Technology into Traffic Flow Management Tools.	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
develop training curricula for controllers, traffic managers, pilots, dispatchers, and weather personnel which cover - The new roles and responsibilities in the use of supporting technologies. - The roles, responsibilities and expectations of other decision makers with whom each group must interface. - The training doctrine, developed in concert with the integrated tools development, leveraging that real-world experience to maximize early benefits and refinements. - The training cadre, deployed to all major new facilities as the tools are deployed to both assist in training and to maximize early benefits and identify problems. The resulting procedures and rules must be translated into controlling documents such as the Federal Air Regulations (FARs), the Airman Information Manual (AIM), Air Traffic Manuals, Flight Manuals, and Aircraft Manuals.	5.2.2.1 Weather Integration Customer Team	
35) Identify best weather practices of air traffic facilities and train these practices system wide. Identify facilities with superior performance and develop best practices guidance for use by other facilities. Do not limit benchmarking to NAS facilities only. Seek global examples and new visions of innovative weather management	5.1.1 Step 1: Team Alignment and Analysis 5.1.4 Step 4: Integration of Weather Technology into Traffic Flow Management Tools. 5.4 Relationship of Integration with Aviation	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
techniques. Develop and train ARTCC and TRACON ATC and TFM staff on "best practices" during the introduction and first five years of all new weather and weather-ATM integrated tools. Establish metrics which compare alternative processes.	Weather Programs, Weather In The Cockpit (WTIC)	
Implications on Airline Operations Centers		
36) Ensure strong industry participation in CDM and NextGen concept development and implementation and consider expanding industry participation on review boards. Industry must have voice and buy-in to future developments to ensure that internal corporate infrastructure and business systems can support, blend with and interact effectively with the NAS service provider systems. Joint development of these systems is possibly the key component of a successful future capability.	3. NextGen Weather Integration Decision Support Tools. 4.1 Survey of ATM-Weather Impact Models and Related Research - Conditioning ATM Impact Models into User-Relevant Metrics. 5 Weather Integration Plan Execution 6.2 NextGen Conference on Integrating Weather, Airports, and Air Navigation Services.	
Implications on FAA and NextGen Enterprise Architectures		
37) Ensure that direct ATM automation-weather integration is a key focus of the development of OEP/NAS Enterprise Architecture operational and technical views for the transition to NextGen. To achieve the capacity and safety goals for NextGen, weather and ATM automation developments must become aligned and focused to	2. NextGen Weather Integration Overview and Concept 2.3.3 Integrate Weather Information into ATM Decision Support Tools	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
define the operational and system views for the evolution to highly automated weather impact analysis and solution-generation system, where the human operators are no longer the "glue" for trajectory level decisions. This is a necessary and fundamental shift from today where weather display and human interpretations the norm. The resultant operational and technical views must be reflected in the OEP and companion NAS EA in order to enable timely investment decision on deploying these needed integrated automation-weather capabilities. This information must also be (constantly) coordinated with NextGen concept and EA development to ensure consistency.	5.1.1 Team Alignment and Analysis	
Implications on FAA Aviation Weather Research Program		
38) Support for the AWRP should be increased beyond previous levels. Support for the AWRP should be increased to enable further improvements in the 0-8 hour forecast time frame, and to allow the weather research community to enter into joint collaborations with the automation research community in integration of weather information into ATM DSS. Additionally, the FAA ATO-P organization should reexamine the R&D goals for AWRP in light of the needs of NextGen. Support for the National Ceiling and Visibility Program should be restored. Related efforts to support and benefit individual	5.4 Relationship of Integration with Aviation Weather Programs. A-4.3.2 Provide Full Flight Plan Constraint Evaluation with Feedback. - Weather Involvement – Preliminary Review: MIT/LL Weather Integration Roadmap. B-1.22 Probabilistic Forecasts for Ceiling and Visibility and Obstructions to Visibility. B-1.30 ATM Impact Of Weather Constraints on General Aviation Access to the NAS.	

REDAC Recommendation	Integration Plan Alignment	Comments (if applicable)
sectors of the industry should be prioritized and addressed. For example: 1. Development of the Helicopter Emergency Medical Evacuation System (HEMS) tool. 2. Rewriting FAR 121 limitations regarding Ceiling and Visibility such as FAR 121.619 (also known as the "1, 2, 3 Rule" for alternate fuel specifications		
39) Conduct research to develop improved methods of sensing turbulence taking advantage of a multi-sensor approach using radar, profilers, anemometers, satellite imagery, GPS, and instrumented aircraft to improve the forecasting and now casting of convective and non-convective turbulence.	A-4.3.2 Provide Full Flight Plan Constraint Evaluation with Feedback. - Weather Involvement – Preliminary Review: MIT/LL Weather Integration Roadmap. B-1.1 En Route Convective Weather Avoidance Modeling B-1.19 Tactical Feedback of Automated Turbulence	

C-2. Integration Plan Alignment with Weather ATM Integration Conference Recommendations

Note: blank spaces in this table will be addressed as the plan is executed.

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
NextGen Weather Group		
Policy Issues		
1) Develop an information paper that describes the 4-D Wx SAS and 4-D Wx Data Cube and their relationship.		
2) A dedicated team needs to focus on the scope and content of the 4-D Wx SAS.		
Research and Development		
3) Encourage industry to participate in NextGen Weather IOC development team efforts to identify domain authority, standards, catalogs, ontologies, etc.		
4) Work with non-federal organizations to identify how to incorporate their sensor information into the 4-D Wx Data Cube.		
Simulations and Demonstrations		
5) Accomplish a demonstration to see if we can collect additional weather data from on-board and ground sensors and transfer it to government system(s) in a net-centric manner.		
6) Have the NEO, Aircraft, and Weather Working Groups sponsor a team to identify options of how		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
we get information into the cockpit		
Performance Metrics		
7) Have weather SMEs review how the reliability of the cube can be demonstrated to operational users		
8) Task the Airport and Air Navigation Services Working Groups to set DST quality and reliability as they identify new tools that will be developed.		
Airport Operations Group		
Policy Initiatives		
9) Data sharing agreements need to be reviewed and updated. Effective communication and information/data sharing, across all levels, is critical.		
10) Weather information needs to be translated into impact information specific to user needs.		
11) Operational users need to be involved in the entire requirements process		
12) Use liquid equivalent water instead of visibility to determine deicing needs and holdover times.		
Research and Development		
13) Legacy system integration is very important. Prioritize legacy system value according to NextGen requirements		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
14) Improve runway forecasts accuracy and reliability. Address runway sensors that are non-representative of actual conditions.		
15) Need to take into account an integrated approach to weather impacts on airport parking, terminal and ramp areas, surface maneuvering of all vehicles, as well as aircraft. Develop and validate a requirements matrix to address user needs for weather as integrated with various surface movement operations.		
Simulations and Demonstrations		
16) Investigate use of the "Theory of Serious Games" for simulation development.		
17) Demonstrate integrated weather for winter operations at ORD		
18) Derive and validate metrics from operational users. Determine metrics of value from operational personnel		
Trajectory Operations Based Group		
Policy Issues		
19) Establish a weather data standard that is compliant with ICAO standards and use this standard in TBO.		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
20) Bring stakeholders together early in the development of TBO implementation roadmap to ensure weather integration at the inception. Do not follow the path of treating weather as an "add-on" in later phases of TBO development, as this will delay or negate the value of a fully-integrated solution that assimilates weather information.		
21) Establish policy that allows flexible trajectory re-negotiation as weather information is updated throughout the NAS.		
22) There is a need to establish policies that encourage NextGen users to incorporate capabilities that meet or exceed new performance-based standards. Develop an agency policy for user performance capabilities in parallel with policy that supports incentives across all stakeholders to meet or exceed performance standards.		
23) Develop agency policy that is adaptive to system performance increases as equipage evolves.		
24) Support efforts (including funding) devoted to the development of the single authoritative source concept, implementation, human factors (see C-5) and governance to enable NextGen TBO.		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
25) Existing policies are inadequate to support TBO including a number of factors such as the use of probabilistic weather forecasts, conflict resolution and data sharing. Develop policy for the use of probabilistic weather as it pertains to decision support tools and NextGen system users.		
26) Develop appropriate precedence and procedures to determine proper course of action an operator must make when conflicting weather information is presented.		
27) Make ATM data available to the research community at large to facilitate research and development efforts supporting NextGen.		
28) Find ways to test and implement new science and innovation into the NAS in an expedient manner to incorporate the latest technology.		
29) Carefully consider the affects of implementing NextGen concepts in terms of organizational changes. Identify "cross boundary" issues that affect more than one organization, and determine whether a new division of responsibilities is necessary prior to implementing NextGen concepts and systems.		
30) Define a transition strategy, but do not perpetuate traditional organizational responsibilities and relationships unless they clearly benefit the governance and operation of		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
NextGen.		
31) There is a need to establish a certification or validation process for weather information that will be used in TBO. Develop a certification or validation process for weather information and forecasts used in the 4-D Wx SAS that test for reliability and recognized safety and traffic flow management conventions.		
Research and Development		
32) Human reaction, response and risk of product use that contain integrated weather must be examined. Human factors (see C-5) research is needed to quantify the effects of inherent human conservatism and caution and the effect of inconsistent forecast skill on operational decision making.		
33) Conduct human factors (see C-5) research to understand how controllers will handle air traffic in a TBO world – specifically their reactions to weather that affects sector loading, controller workload, transition to dynamic sectors and delegation of separation responsibilities to the flight deck.		
34) Continue research to quantify predictions of pilot/controller actions when faced with current weather impacts.		
35) Understand the human-machine interface role for each stakeholder, including weather information		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
integrated into a single display. Related research should eventually embrace the transition to complex technological systems designed for use with NextGen constructs.		
36) There is a need for research into how forecast uncertainty can be 'partitioned' into spatial and temporal elements as a possible way to quantify and reduce risk and impact of uncertainty and forecast errors.		
37) There is a need to determine who has the authority to take the risk and what are the allowed levels of action for both systemic approaches Traffic Management Initiative and individual trajectory negotiations (e.g., go/no go, red/green, or shades such as red/yellow/green, etc.).		
38) A weather translation model could be developed to select different convective forecast and now-cast products and assess how they help achieve a more accurate airspace capacity estimate – separately and as an ensemble forecast. Additional research would be needed to determine how to validate and to determine the granularity (e.g., ARTCC/Sector/Flow/Airway/Gate/Fix).		
39) There is a need for operationally relevant research that translates and integrates weather forecast probability into language (e.g., triggers or sliding scales or time smears, etc.) that can be used by ATM tools.		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
40) There is an overall need to determine weather performance requirements/characteristics for all stakeholders and decision support tools. There is a need to conduct applications research to identify and then match the performance of the weather information with user functional needs for TBO		
41) There is a need to conduct research that identifies the weather performance requirements for the entire environment in which TBO-based systems act (e.g., TBO performance changing triggers, how they change and by how much).		
42) There is research needed to quantify how to develop higher fidelity and standardized trajectory predictions with lower fidelity weather (i.e., what is good enough weather for a trajectory prediction and how does such fidelity change from operation to operation).		
43) There needs to be research conducted to determine if there are significant benefits (consistent with 5.2.6) in obtaining more accurate weather forecasts. There is a further need to identify tools, models (e.g., Numerical Weather Prediction), techniques, etc., that validate and measure the real or perceived improvements.		
44) There is a need to conduct TBO and weather research (e.g., time-based research) that overlaps with airport surface movement and weather research to understand and categorize wheels off departure/wheel on arrival times. This could be		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
enhanced through the combined use of ground vehicles and aircraft sensors to determine position.		
45) Research is needed to establish a set of agreed-upon thresholds that are not based on operations as described earlier, but based on aircraft performance and requirements for safe operation for weather phenomena such as icing for deicing, lightning for refueling, etc. Similar issues as previously identified emerge, such as what are the risk factors, who have authority to take the risk, levels of action (go/no go) or can there be shades (red/yellow/green).		
46) In the first (departure) or final (arrival) stages of TBO, research is needed to quantify the affects of weather on aircraft performance in 4-DT SDO with regard to trajectory and arrival times in space and the ability to penetrate weather when there are the fewest options available for safe flight.		
47) Research is needed to understand the capabilities of the aircraft with respect to weather factors to reduce the uncertainty of meeting TBO objectives. In the worst-case weather scenarios, research is needed to define airspace which cannot be accessed based on high weather impact phenomena.		
48) In the (legacy) en route portion of TBO, research is needed to quantify the effects of aircraft trajectory performance based on convective		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
(especially) and other (e.g., icing) weather characteristics. There is a need to know what aspects (echo tops, storm tops, cloud/visibility tops, turbulence, vertical impact altitudes, etc) most significantly affect aircraft performance from meeting time and space TBO objectives. There is a need to determine how much equipage and differing agency operations (civil vs. military) will play a role in meeting this objective.		
49) Research is needed to identify how weather forecast uncertainty and associated operational risks change over the entire course of the trajectory		
50) There is a need to conduct fundamental weather research regarding specific weather phenomena, over specific areas, occurring or lasting over a range of times, and achieving and/or maintaining specific levels of magnitude that can impact TBO		
51) Applications research is additionally needed to identify important weather thresholds that trigger trajectory-based operation changes.		
Simulations and Demonstrations		
52) CDM between all decision makers (pilots, dispatchers, controllers) needs to be simulated under varied weather conditions and varied TBO activities to quantify relative workload on each, quantify response differences/reactions, and to quantify the relative flexibility (or not) to combined operations/impacting weather scenarios.		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
53) Conduct simulations to explore information overload		
54) Simulations are needed to quantify TBO sensitivity to weather. This should include modeling or simulating the value of DST's over a range of weather fidelity or outcomes		
55) This also includes the simulation of weather probability translation upon TBO constructs (i.e., how each probability 'level' is translated and weighted within the DST components).		
56) The value of the integrated weather needs to be simulated and measured in terms of the metrics highlighted in question 6 or from a cost/benefit perspective. In this regard, the value of continued 'improvement' in weather information fidelity needs to be modeled against real or perceived 'improvement' in DST outputs.		
57) Simulations of NAS users operating in a mixed equipage mode need to be conducted to determine consequences and relative sensitivity of continued mixed equipage towards achieving TBO objectives.		
58) The cost/benefit of optimal or minimal equipage needs to be simulated		
59) There needs to be simulations performed that describe the cost to benefit of further improvements in weather products and forecasts beyond those so matched in informational integrity to TBO constructs. In this regard, there may be, for		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
example trending routines that could be designed that allow more frequent weather updates to be time-based averaged before integrating.		
60) Simulate value of integrated weather with TBO by simulating various NAS performance measures (e.g., route timing, fuel savings, operational options, etc.) to determine sensitivity to weather.		
61) An approach to initial transition in general is to capture the experience of successful recent trials (e.g., ADS-B in Alaska) and extrapolate or leverage to achieve perceived NextGen benefits.		
62) There is a need to demonstrate both tactical and strategic use of probabilistic convective impacts under various levels of uncertainty		
63) There is a need to demonstrate the operational effectiveness of weather integrated DST's under various levels of uncertainty.		
64) There is a need to demonstrate operational value (tactical) to using predicted convection locations rather than planning based on current convection locations		
65) For more strategic assessment, there is a need to demonstrate effective risk management both for strategic TFM approaches and at the individual flight or trajectory level		
66) In the spirit of leveraging from current operations, demonstrations could be designed to use existing systems and begin rolling in new		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
'numeric' systems for integration of convective uncertainty forecasting.		
67) There is a need to demonstrate automation of dispatcher/controller/pilot/traffic manager actions – especially to demonstrate the optimization of routing around a weather obstruction. This could be demonstrated using a variety of weather information to determine the most optimal set for final integration.		
68) There is a need to separately demonstrate then integrate the value of specific weather information – not just convection – as integrated into automated tools. The demonstrations needs to be separate for each stakeholder – cockpit, AOC/FOC, ATC, etc		
69) There is a need to demonstrate a sufficient number of off-nominal (bad weather) scenarios to test the boundaries of NextGen system adaptability		
70) There needs to be demonstrations that incorporate scenario-based research initiatives to help quantify, in a more strategic way, the potential risks prior to entering into these more tactical scenarios		
71) Related to both tactical and strategic focus, there needs to be follow-on demonstrations to illustrate what kinds of safety nets (i.e., fall back or alternative operations) are available when weather reaches such triggers (tactically) – or in a more strategic sense, at what point is the commitment made to continue a TBO given an availability of		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
alternate (operational) options that will exist in the future.		
72) There needs to be various demonstrations that highlight the relative effects of weather forecast errors with trajectory prediction studies. This could be performed using canned wind forecasts having increasing degrees of error.		
73) There is a need to demonstrate the viability of the 4-D Wx Data Cube and 4-D Wx SAS and to show the risks (costs/safety) associated with *not* having "NextGen Weather".		
74) Trajectories in the NAS should ultimately satisfy two objectives: - Separation from other trajectories by the minimum separation standard of the occupied airspace. Satisfaction of this objective is generally best defined by the ANSP. - The user-preferred trajectory provides optimum cost and satisfaction of other operator defined objectives such as safety of flight, passenger comfort and emissions. These are generally objectives best defined by the system user.		
Super Density Operations		
Policy Issues		
75) Re-examine the ADS-B 'IN' timeline. It may need to be accelerated if we are going to more fully realize NextGen benefits, including NextGen		

Wx ATM Integration Conference Recommendation	Integration Plan Alignment	Comments (if applicable)
Weather integration, by 2025.		
Research and Development		
76) Perform analysis/research to determine SDO weather and weather translation requirements for NextGen. Near-term efforts should include: - Analyze all NextGen SDO operational improvements to see how weather impacts them - Analyze sensitivity of NextGen SDO procedures and decision support tools to winds aloft in order to establish weather observation and forecast requirements - Determine how SDO differ with location (e.g., major airports, Metroplexes) in order to better understand their unique NextGen requirements		
77) Send weather integration researchers into the field to learn current deterministic SDO strategies, so that they are better able to develop more strategic SDO weather integration concepts/capabilities.		
Simulations and Demonstrations		
78) Establish a mechanism to solve SDO problems (through joint community involvement). This could include the use of integration laboratories (to include weather integration) and computer simulations to better understand the problems we need to address in implementing NextGen.		

D. CURRENT ATM TOOLS

Tool		Description	Tool Weather Interaction	Current Plans	Future Plans
AIR TRAFIC MANAGEMENT					
TFM-S TDS CCSD WSD	(Replaced ETMS) Includes: Traffic Situation Display, Common Constraint System Display, Web Situation Display	It is the principal component of the TFM infrastructure used by the FAA and NAS stakeholders to predict demand, identify constraints, mitigate delays and maintain common situation awareness. TFMS is based on an open architecture platform supporting the integration of TFM subsystems, facilitating integration with other domains, and supporting responses to new initiatives. In addition to improving development bandwidth, TFMS establishes a platform that is sustainable and scalable for the next decade and beyond.	Upper wind forecast are used to predict A/C en-route and arrival times.	TFMS displays certain weather products (CCFP, NCWF, and WSI Radar mosaic) onto the Traffic Situation Display function of the TFMS. Additionally NWS METAR and TAF data is available for most airports.	TFM-S will incorporate CIWS in 2011. NextGen Weather Processor WP2 will replace CIWS's function in 2017.
FSM GDP AFP GS	Flight Schedule Monitor Includes: Ground Delay Program, Airspace Flow Program, and Ground Stops	FSM displays the Aggregate Demand List (ADL) information for both airports and airspace data elements for its users. FSM creates a common situational awareness among all users and service providers in the National Airspace System. All parties need to be aware of NAS constraints in order to make collaborative air traffic decisions. Designed to effectively interact with existing FAA systems	Upper wind forecast are used to predict A/C en-route and arrival times. Additionally NWS METAR and TAF data is available for most airports	FAA and airlines use FSM to monitor airport AR/DR demand, updated every 5 minutes. FSM constructs "what if" scenarios for best options (i.e., best parameters) prior to making a GDP, AFP, or GS decision.	Software upgrades with no weather integration through 2025
UDP	Unified Delay Program	The goal behind UDP is to merge the algorithms for Delay Assignment (DAS) GDPs and General Aviation Airport Program (GAAP) GDP into a single set of algorithms that apply to any GDP. Same algorithm is used for AFPs.	Upper wind forecast are used to predict A/C en-route and arrival times. Additionally NWS METAR and TAF data is available for most airports.	Testing 2010	Software upgrades with no weather integration through 2025.
TMA	Traffic Management Advisor	Traffic Management Advisor (TMA) analyses traffic approaching an airport from hundreds of miles away and can calculate scheduled arrival times in order to maximize arrival capacity.	Upper wind forecast are used to predict A/C en-route and arrival times	Current plans are for multi-center integration of TMA and for weather integration so TMA can work re-routes due to convection.	Transition to Time Based Flow Management (TBFM)
TBFM	PM/A	Program will include instrumentation embedded in the deployed software code for data collection that will support post-processing and data analysis.	N/A	N/A	TBD
ARMT	Airport Resource Management Tool	The ARMT gathers additional flight information from the Atlanta Common Automated Radar Terminal System (CARTS) IIIE and the manual scanning of bar coded paper flight strips at the Atlanta Airport Traffic Control Tower (ATCT). This manual bar code scanning is used to produce a near real-time recording of taxi clearance and takeoff clearance times. The ARMT also captures the traffic flow management (TFM) constraints, airport configuration and weather conditions currently in effect. The ARMT prototype system is also in the Potomac TRACON and the Chicago TRACON.	ARMT captures the weather conditions currently in effect.	Begin decommissioning of ARMT in 2010 with complete decommissioning in 2017. The purpose of decommissioning is so that it can be incorporated into the Tower Flight Data Manager.	TBD
C-TOP	Collaborative Trajectory Options Program (formerly known as SEVEN) (Under development by CDM)	Allows NAS customers to submit a prioritized list of alternative routing options for their flights. C-TOP provides traffic managers with a tool that algorithmically takes these customer preferences into consideration as it assigns reroutes and delays to flights subject to traffic flow constraints	Weather is not a function of the tool at this time, C-TOP's goal is for an impact value of weather on normal traffic flows.	Phase 1 will be deployed in a selected geographic area for testing/evaluation. Phase 2 will expand Phase 1 functions throughout the NAS 2011 timeframe. (Phase 1 functionality still not fully defined.)	Will transition to CACR development in the future
RAPT	Route Availability Planning Tool	The Route Availability Planning Tool (RAPT) addresses an urgent need to increase the airport departure capacity in convective weather. In busy metroplexes such as New York, airways are tightly clustered and the proximity of adjacent arrival flows means that deviations around thunderstorms by departures cause serious disruptions to arrivals. As a result the departure flows are often shut down. The RAPT is a weather-assimilated decision support tool (DST) that supports the development and execution of departure management plans that more fully utilize the available departure capacity during Severe	The RAPT integrates 3-dimensional (3-D) convective weather forecasts from the Corridor Integrated Weather System (CIWS) Specifically the RAPT algorithms are dependent on CIWS convective	Test and evaluation in C90	TBD

Tool		Description	Tool Weather Interaction	Current Plans	Future Plans
		Weather Avoidance Plans (SWAP).	and echo tops forecast products.		
IDRP	Integrated Departure Route Planning (under development MITRE/MIT-LL)	IDRP builds on the RAPT infrastructure and integrates traffic demand into the DST. MITRE in collaboration with MIT/LL are developing a departure route decision aid that provides guidance of route / fix blockage as in RAPT; but adds the function of traffic demand and capacity of the departure airspace/ fix.	Utilizes the weather avoidance field (WAF) from CIWS converted to WAAF in order to determine route / fix blockage	During 2010 the IDRP prototype will be evaluated in the New York operational environment. This initial evaluation phase utilizes the Route Availability Planning Tool (RAPT) infrastructure that is already installed in the evaluation locations.	Phased evaluation
EFPT	Enroute Flow Planning Tool (under development MITRE/MIT-LL)	A flow-based tactical re-routing DST identifies flights that are likely to need deviations from their current routes to avoid severe weather. The flights considered can be limited to the flights in a Flow Evaluation Area (FEA) flight list to narrow the focus to particular flows or areas. To determine severe weather encounters, predicted 4D trajectories are probed against a WAAF that is based on a dynamic 4D weather forecast, including echo tops.	MITRE working with MIT/LL are working to develop a new weather model that can provide a 3D display of convection and its impact on traffic flows.	Prototype development to provide operational concept demonstration Under development MITRE Concept Exploration (CE)	Enhance functionality based on derived requirements
Future Traffic Display		Under development by Volpe 2010 - 2011 timeframe. A function of the TFMS system giving the traffic manager the ability to move the traffic along its filed flight path and view the systems impact.	NONE	TBD	TBD
Reroute Impact Assessment (RRIA)		This will allow traffic managers to perform “What If” analyses for proposed reroutes and associated MITs to determine possible impacts.	NONE	Planned to deploy 2010	TBD
DSP	Departure Spacing Program (ZNHY, N90 and Towers only)	DSP enables air traffic controllers to work more efficiently with traffic management coordinators to better use existing capacity for departing aircraft by reducing departure sequencing delays and minimizing terminal-area ground, airspace and telephone congestion. DSP also reduces the need for voice communication between air traffic control facilities by providing dynamic flight plan information and reports, via data transfer through the DSP network, to air traffic control towers, terminal radar approach control facilities and air route traffic control centers.	NONE	TBD	TBD
KVDT	Keyboard Video Display Terminal	A tool which allows air traffic controllers to amend flight plans	NONE	TBD	TBD
DSR	Display System Replacement	Provides controller workstation displays and input/output devices and a communications infrastructure to connect the DSR with external processing elements of the en route air traffic control automation system.	Since this is a display system only, any weather integration will be associated with the ERAM system that it supports.	Currently in a technology refresh 2005 - 2020 with and end of service of 2022.	TBD
ERAM	En Route Automated Modernization	ERAM will replace HOST and will increase capacity and improve efficiency in the nation’s skies. En route controllers will be able to track 1,900 aircraft at a time, instead of the current 1,100. Coverage will also extend beyond facility boundaries, enabling controllers to handle additional traffic more efficiently, made possible by processing data from 64 radars instead of the current 24. Controllers will be able to share and coordinate information seamlessly between centers, making the use of three-mile (rather than five-mile) separation. Flight plan processing will also improve, and hand-offs performed when planes divert from their planned course will be done automatically rather than manually. This will improve operational efficiency during weather and congestion.	ERAM will be delivered in multiple releases and varying capability improvements will occur with each release.	Weather data integration: Air traffic controllers will use information from weather systems to help pilots route away from storms, avoid turbulence, and give passengers smoother flights.	TBD
URET	User Request Evaluation Tool	combines real-time flight plan and radar track data with site adaptation, aircraft performance characteristics, and winds and temperatures aloft to construct four dimensional flight profiles, or trajectories, for pre-departure and active flights. For active flights, it also adapts itself to the observed behavior of the aircraft, dynamically adjusting predicted speeds, climb rates, and descent rates based on the performance of each individual flight as it is	TBD	RUC Winds and Temperature	The future plans call for integrating URET into ERAM.

Tool		Description	Tool Weather Interaction	Current Plans	Future Plans
		tracked through en route airspace, all to maintain aircraft trajectories to get the best possible prediction of future aircraft positions. URET uses its predicted trajectories to continuously detect potential aircraft conflicts up to 20 minutes into the future and to provide strategic notification to the appropriate sector. URET enables controllers to "look ahead" for potential conflicts through "what if" trial planning of possible flight path amendments. URET enables controllers to accommodate user-preferred, off-airway routing to enable aircraft to fly more efficient routes, which reduce time and fuel consumption.			
NTML	National Traffic Management Log	The National Traffic Management Log (NTML) was developed to provide a single system for automated logging, coordination, and dissemination of traffic management initiatives throughout the National Airspace System.	NONE	TBD	TBD
VSCS	Voice Switching and Communications System	VSCS allows air traffic controllers to establish all air-to-ground and ground-to-ground communications with pilots and other air traffic controllers. The system offers unprecedented voice quality, touch-screen technology, dynamic reconfiguration capabilities to meet changing needs, and an operational availability of 0.9999999.	NONE	TBD	TBD
ESIS Displays	Enhanced Status Information System	ESIS is a display system which is coupled with NTML to provide controllers and NAS managers with pertinent information	NONE	TBD	TBD
ERIDS	En Route Information Display System	ERIDS provide real-time access to air traffic control information not currently available from the Host Computer System (HCS) and makes this auxiliary information readily available to controllers. ERIDS is installed at various positions, including the Traffic Management Units (TMU), Center Weather Service Units (CWSU), and ARTCC Monitor and Control (M&C) Centers. ERIDS is integrated into the display system consoles at each sector, uses the center's airspace configuration for sector assignments, and allows changes in sector assignments. ERIDS displays graphic and text data products, including air traffic control documents, Notices to Airmen (NOTAMS), and general information.	NONE	TBD	TBD
IDS – 4	Information Distribution System, Model 4	Integrates several National Airspace System (NAS) data weather sensors and operational data onto a single display platform. The information is used by several thousand air traffic controllers.	IDS is a general weather information display.	Decomissioning of IDS-4 (Systems Atlanta Information Display System - SAIDS) is scheduled for 2009 - 2015.	TFDM (Tower Flight Data Management System) will be replacing the SAIDS and IDS-4 system beginning in 2010 and will continue through 2030.
HOST		Facility located at the ARTCC which operates user application software, as well as certain peer network layer protocols required to communicate with adjacent ATN routers.	Host displays NEXRAD weather data.	TBD	TBD
STARS	Standard Terminal Automation Replacement System	STARS is a joint Federal Aviation Administration (FAA) and Department of Defense (DoD) program to replace capacity-constrained, older technology systems at FAA and DoD terminal radar approach control facilities and associated towers. Controllers use STARS to provide air traffic control services to pilots in the airspace immediately around many major airports. These air traffic control services include the separation and sequencing of air traffic, the provision of traffic alerts and weather advisories, and radar vectoring for departing and arriving traffic.	Displays are specially developed for air traffic control and are capable of displaying six distinct levels of weather data	Currently in 49 FAA facilities and 50 DOD facilities, FAA is evaluating future deployment based on possibly combining smaller facilities.	TBD
WEATHER TOOLS					
RAPT	Route Availability Planning Tool	The Route Availability Planning Tool (RAPT) addresses an urgent need to increase the airport departure capacity in convective weather. In busy metroplexes such as New York, airways are tightly clustered and the proximity of adjacent arrival flows means that deviations around thunderstorms by departures cause serious disruptions to arrivals. As a result the departure flows are often shut down. The RAPT is a weather-assimilated decision support tool (DST) that supports the development and execution of departure management plans that more fully utilize the available departure capacity during Severe	The RAPT integrates 3-dimensional (3-D) convective weather forecasts from the Corridor Integrated Weather System (CIWS) with the National Airspace System (NAS) airspace structure information	Test and evaluation in NY metropolitan area	Using CIWS weather information to determine route availability and using automation to select best flight/flights to operate on the available route. i.e. Working to improve the modeling capabilities.

Tool		Description	Tool Weather Interaction	Current Plans	Future Plans
		Weather Avoidance Plans (SWAP).	(including aircraft trajectory information) to predict the availability of the filed departure route and, specifically designated coded alternative departure routes for an aircraft. Specifically the RAPT algorithms are dependent on CIWS convective and echo tops forecast products.		
ITWS	Integrated Terminal Weather System	The Integrated Terminal Weather System (ITWS) is a recent technology that helps make air traffic flow more efficient in periods of adverse weather at NAS pacing airports. The ITWS is an air traffic management (ATM) tool that provides terminal air traffic managers and controllers plus airline dispatchers with highly accurate, easily understood and immediately useable graphical weather information and hazard alerts on a single, integrated color display. The ITWS provides aviation-oriented weather products via situation displays to air traffic control (ATC) personnel in Airport Traffic Control Tower (ATCT), Terminal Radar Approach Control (TRACON), and some Air Route Traffic Control Center (ARTCC) facilities, as well as in the FAA's Air Traffic Control System Command Center (ATCSCC). These products are immediately usable without further meteorological interpretation. In addition, the ITWS subsumes the functionality of Terminal Weather Information for Pilots (TWIP) [from TDWR] and provides depictions of impacting weather to jetliner flight decks via a communications service provider (ARINC).	The ITWS uses highly sophisticated meteorological algorithms to integrate and analyze data from multiple FAA and National Weather Service (NWS) sources, including data from the Terminal Doppler Weather Radar (TDWR), Airport Surveillance Radar Model 9 (ASR-9) weather channel, the Next Generation Weather Radar (NEXRAD) or WSR-88, the Low-Level Windshear Alert System (LLWAS), Automated Weather Observing System (AWOS) Data Acquisition System (ADAS), aircraft observations from Meteorological Data Collection and Reporting System (MDCRS), and NWS gridded model data to display current and near-term forecasts of weather conditions and hazards in the terminal area. The ITWS gets 1-minute ASOS data and ground stroke lightning data from ADAS.	TBD	TBD
CIWS	Corridor Integrated Weather System	CIWS is a web-based, Nation-wide operational decision support tool to improve traffic flow management. It is envisioned that the CIWS will be implemented at the FAA's Tech Center to provide traffic flow managers with comprehensive convective weather information needed for tactical modifications (0-2 hours). CIWS provides information on the current convective weather situation as well as fully automated forecasts of convection and attributes, e.g., Echo Tops, out to 2 hours.	The CIWS collects various data, then processes, generates, displays, and distributes convective (thunderstorm) weather products to traffic managers at the FAA David J. Hurley Air Traffic Control System Command Center	CIWS will be operational through 2017.	CIWS is a developmental prototype for COSPA and will be integrated with the TSD in 2011

Tool		Description	Tool Weather Interaction	Current Plans	Future Plans
			(ATCSCC), numerous Air Route Traffic Control Center (ARTCC) facilities, large Terminal Radar Approach Control (TRACON) facilities, and some large airports. By concentrating its two-hour forecast product over busy National Airspace System (NAS) corridors, CIWS would enable traffic managers to plan for routing/re-routing due to impacts on the airspace from major thunderstorm disruptions. The CIWS receives weather data from multiple sensors (primarily radars) and distributes processed information to NAS traffic managers via situation displays, and later via the System Wide Information Management (SWIM) network.		
WARP	Weather and Radar Processor	The primary purpose of the WARP system is to improve the timeliness and quality of weather information provided to Air Traffic Control (ATC) and Traffic Flow Management (TFM) specialists at the Air Route Traffic Control Center (ARTCC) facilities and at the David J. Hurley Air Traffic Control System Command Center (ATCSCC) in order to support the tactical and strategic decision-making process. WARP has an interface to the Display System Replacement (DSR) in order to provide mosaics of Next Generation Weather Radar (NEXRAD) data to air traffic controllers. It also provides imagery depicting traffic-impacting thunderstorm activity to the traffic management unit (TMU) and weather coordinator on briefing terminals.	The Weather and Radar Processor (WARP) system provides the capability to simultaneously and continuously receive, process, generate, store, and display aviation-related weather information and radar products from external sources and to disseminate this information to other National Airspace System (NAS) subsystems.	TBD	TBD
TOWER					
DBRITE	Digital Bright Radar Indicator Tower Equipment	Provides tower controllers with radar workstation displays and input/output devices and a communications infrastructure to connect the DSR with external processing elements of the en route air traffic control automation system.	NONE	End of Service 2012 replaced by Remote Automated Radar Terminal System Color Display End of service 2014	TBD
TDLS PDC FDIO ATIS	TBD	The Tower Data Link System (TDLS) automates tower-generated information for transmission to aircraft via data link. The TDLS interfaces with sources of local weather data and flight data and provides pilots with Pre-Departure Clearance (PDC), Digital-Automatic Terminal Information System (D-ATIS), and emulated Flight Data Input/Output (FDIO). The PDC helps tower clearance delivery specialists compose and deliver departure clearances. The Digital Automatic Terminal Information Service (D-ATIS) provides high reliability messages of runway and taxiway instructions, information on avionics equipment, frequency outages, and local weather conditions worldwide. The TDLS data is transmitted in text form via the Aircraft	TBD	TBD	TBD

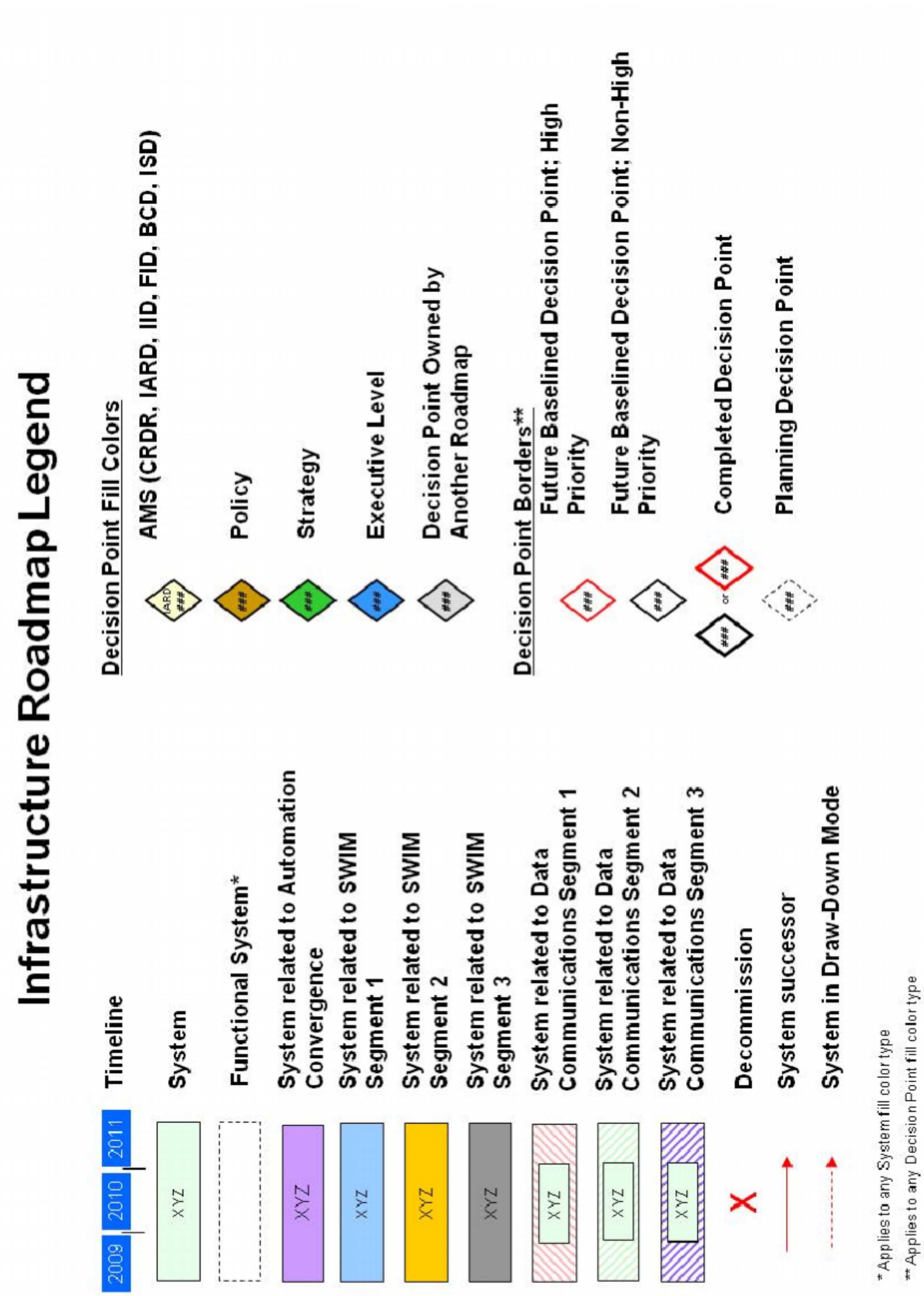
Tool		Description	Tool Weather Interaction	Current Plans	Future Plans
		Communication and Reporting System (ACARS) to an ACARS-equipped aircraft for review and acknowledgment by the flight crew.			
IDS-4 (5)	(see above)	TBD	TBD	TBD	TBD
DSM	TBD	TBD	TBD	TBD	TBD
AMASS	TBD	The Airport Movement Area Safety System (AMASS) with Airport Surface Detection Equipment (ASDE) provides controllers with automatically generated visual and aural alerts of potential runway incursions and other potential unsafe conditions. AMASS includes the Terminal Automation Interface Unit (TAIU) that processes arrival flight data from the Terminal Approach Control (TRACON) automation system and beacon target data from the Airport Surveillance Radar (ASR) and generates a track. The track is compared with the movement of aircraft and ground vehicles on the airport surface based upon surveillance data from the Airport Surface Detection Equipment (ASDE-3). AMASS adds to the ASDE-3 by presenting alarms to the tower controllers when evasive action is required. AMASS integrates and displays data from ASDE-3 and the ASR. The FAA has installed AMASS at the nation's top 34 airports.	TBD	TBD	TBD
ETVS	TBD	The ETVS (installed in the ATCT) provides the air traffic control (ATC) operational ground-to-ground (G/G) voice communications intra-connectivity between controllers within an ATCT (intercom), interconnectivity between controllers in separate ATCTs (interphone), and interconnectivity between ATCT controllers and TRACON controllers/Air Route Traffic Control Center (ARTCC) controllers/Flight Service Station (FSS) specialists/David J. Hurley Air Traffic Control System Command Center (ATCSCC) specialists. Air-to-ground (A/G) radio connectivity between ATCT controllers and pilots is also supported by the ETVS.	TBD	TBD	TBD
TOWER WEATHER					
	Wind and Wind Shear Equipment	TBD	TBD	TBD	TBD
ASOS / AWOS	Automated Surface Observation System /Automated Weather Observation System	The Automated Surface Observing Systems (ASOS) program is a joint effort of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD). The ASOS systems serves as the nation's primary surface weather observing network. ASOS is designed to support weather forecast activities and aviation operations and, at the same time, support the needs of the meteorological, hydrological, and climatological research communities.	REPORTS BASIC WEATHER ELEMENTS: Sky condition: cloud height and amount (clear, scattered, broken, overcast) up to 12,000 feet Visibility (to at least 10 statute miles) Basic present weather information: type and intensity for rain, snow, and freezing rain Obstructions to vision: fog, haze Pressure: sea-level pressure, altimeter setting Ambient temperature, dew point temperature Wind: direction, speed and character (gusts, squalls)	With the largest and most modern complement of weather sensors, ASOS has significantly expanded the information available to forecasters and the aviation community. The ASOS network has more than doubled the number of full-time surface weather observing locations. ASOS works non-stop, updating observations every minute, 24 hours a day, every day of the year.	TBD

Tool		Description	Tool Weather Interaction	Current Plans	Future Plans
			Precipitation accumulation Selected significant remarks including- variable cloud height, variable visibility, precipitation beginning/ending times, rapid pressure changes, pressure change tendency, wind shift, peak wind.		
RVR	Runway Visual Range	Runway Visual Range (RVR) systems provide support to precision landing and takeoff operations in the NAS. RVR is a system that will measure visibility, background luminance, and runway light intensity to determine the distance a pilot should be able to see down the runway. RVRs consist of visibility sensor, ambient light sensor, runway light intensity monitor, and processing units. The RVR interfaces with the ASOS system as well which enhance safety, increase system capacity, and improve maintenance with in CONUS.	TBD	TBD	TBD
TDWR	Terminal Doppler Weather Radar	The Terminal Doppler Weather Radar (TDWR) system detects hazardous weather conditions such as wind-shear, micro-bursts and gust fronts, tornadoes, winds, heavy precipitation (inferring thunderstorms at an airport). This weather information is generated by the Radar Product Generator (RPG) and provided to air traffic on displays at terminal facilities. In addition, a TDWR provides alerts (both aural and textual) of detection wind shear/microburst activity in the approach/departure corridors. The TDWR also provides a 10- and 20-minute prediction of gust front location and movement using a Machine Intelligent Gust Front Algorithm (MIGFA).	TBD	TBD	TBD
METAR	TBD	TBD	TBD	TBD	TBD
OPERATORS					
	Flight Planning Systems	TBD	TBD	TBD	TBD
	Flight Following Systems Includes: CCSD, Flight Explorer (vendor tools), Internet Weather	TBD	TBD	TBD	TBD
AIRCRAFT					
FMS	Flight Management System	A flight management system is a fundamental part of a modern aircraft in that it controls the navigation. The flight management system (FMS) is the avionics that holds the flight plan, and allows the pilot to modify as required in flight. The FMS uses various sensors to determine the aircraft's position. Given the position and the flight plan, the FMS guides the aircraft along the flight plan. The FMS is normally controlled through a small screen and a keyboard. The FMS sends the flight plan for display on the electronic flight instrument system (EFIS), Navigation Display (ND) or Multi-Function Display (MFD).	TBD	TBD	TBD
RADAR					
MDCRS	Meteorological Data Collection and Reporting System	The system collects and organizes up to 28,000 real-time, automated position and weather reports per day from participating aircraft. The data is then forwarded in BUFR format to the National Weather Service World Area Forecasting Center in Maryland, USA, where it's used as input for their predictive weather models.	TBD	TBD	TBD
EFB	Electronic Flight	It is an electronic information management device	TBD	TBD	TBD

Tool		Description	Tool Weather Interaction	Current Plans	Future Plans
	Bag	that helps flight crews perform flight management tasks more easily and efficiently with less paper. It is a general purpose computing platform intended to reduce, or replace, paper-based reference material often found in the Pilot's carry-on Flight Bag, including the Aircraft Operating Manual, Aircrew Operating Manual, and Navigational Charts (including moving map for air and ground operations). In addition, the EFB can host purpose-built software applications to automate other functions normally conducted by hand, such as performance take-off calculations.			

E. Weather Capability Availability

The following pages contain the latest version of the NAS Enterprise Architecture, Weather Infrastructure Roadmap, Version 4.0a dated May 26, 2010. These pages show the planned evolution and improvement of the FAA weather support system.


Infrastructure Roadmap Legend
2009
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2011
Timeline
XYZ
System
Functional System*
System related to Automation Convergence
System related to SWIM Segment 1
System related to SWIM Segment 2
System related to SWIM Segment 3
System related to Data Communications Segment 1
System related to Data Communications Segment 2
System related to Data Communications Segment 3
Decommission
System successor
System in Draw-Down Mode
* Applies to any System fill color type
** Applies to any Decision Point fill color type
Decision Point Fill Colors
IARD
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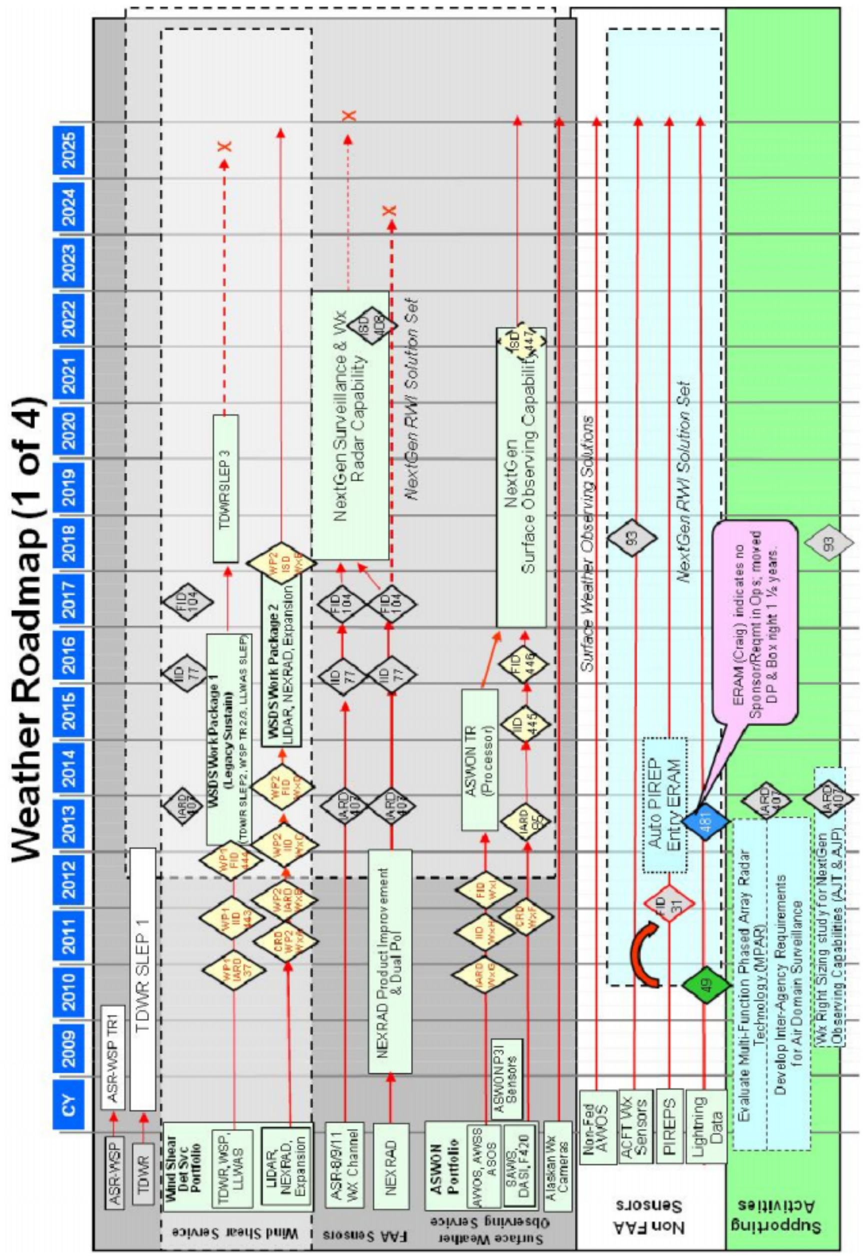
AMS (CRDR, IARD, IID, FID, BCD, ISD)
Policy
Strategy
Executive Level
Decision Point Owned by Another Roadmap
Decision Point Borders**
Future Baselined Decision Point; High Priority
Future Baselined Decision Point; Non-High Priority
or
Completed Decision Point
Planning Decision Point


Weather Roadmap (1 of 4)
CY
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2024
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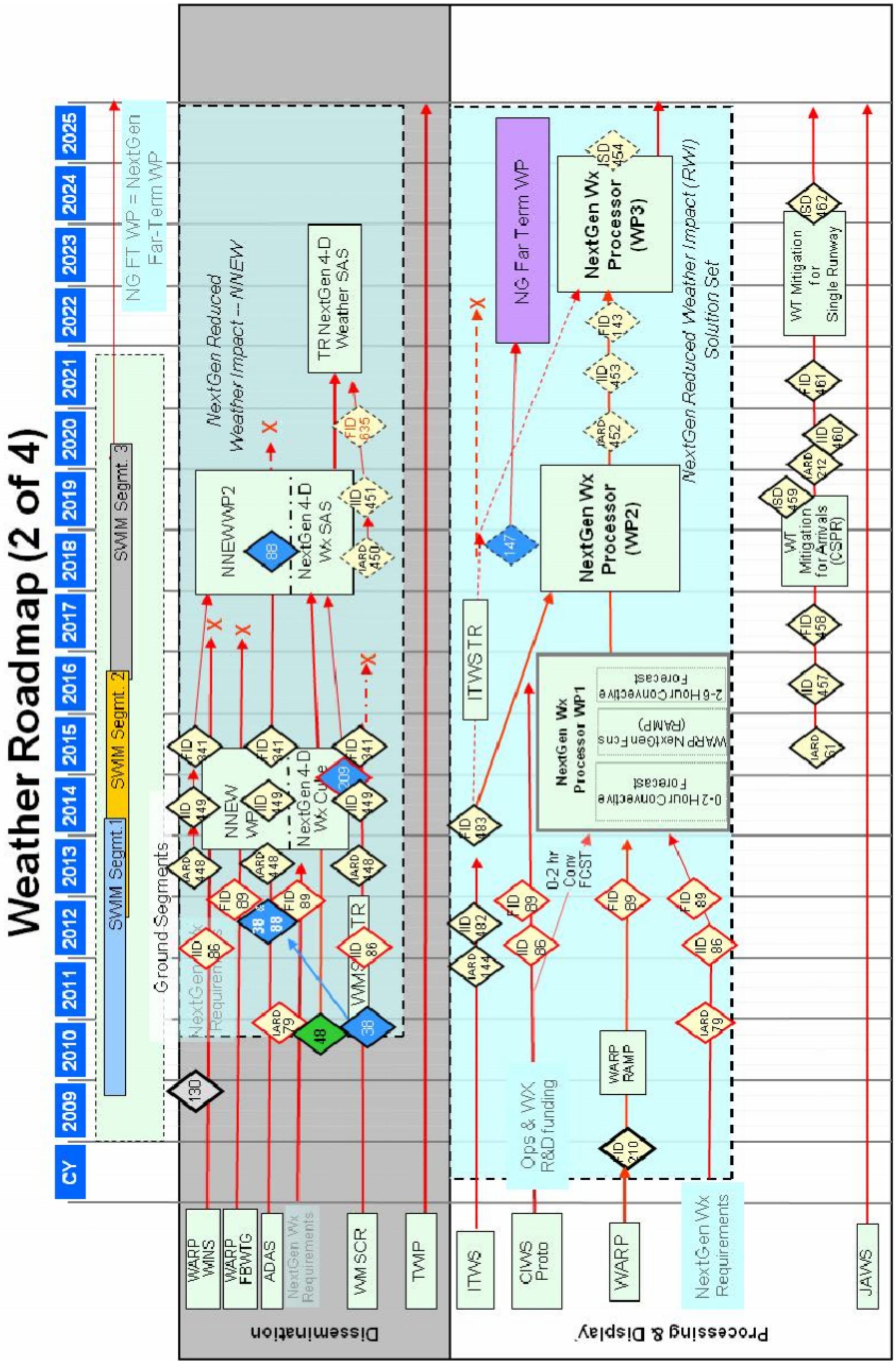
ASR-WSP
ASR-WSP TR1
TDWR
TDWR SLEP 1
Wind Shear Det Svc Portfolio
TDWR, WSP, LLWAS
LIDAR, NEXRAD, Expansion
WSDS Work Package 1 (Legacy Sustain)
WSDS Work Package 2
TDWR SLEP 3
ASR-8/9/11 WX Channel
NEXRAD
NEXRAD Product Improvement & Dual Pol
NextGen Surveillance & Wx Radar Capability
NextGen RWI Solution Set
ASWON Portfolio
AWOS, AWSS ASOS
SAWS, DASI, F420
ASWON P3I Sensors
ASWON TR (Processor)
NextGen Surface Observing Capability
Alaskan Wx Cameras
Surface Weather Observing Solutions
Non-Fed AWOS
ACFT Wx Sensors
PIREPS
Lightning Data
Auto PIREP Entry ERAM
ERAM (Craig) indicates no Sponsor/Reqmt in Ops; moved DP & Box right 1 ½ years.
Evaluate Multi-Function Phased Array Radar Technology (MPAR)
Develop Inter-Agency Requirements for Air Domain Surveillance
Wx Right Sizing study for NextGen Observing Capabilities (AJT & AJP)
Wind Shear Service
FAA Sensors
Surface Weather Observing Service
Non FAA Sensors
Supporting Activities



Weather Roadmap (2 of 4)
CY
2009
2010
2011
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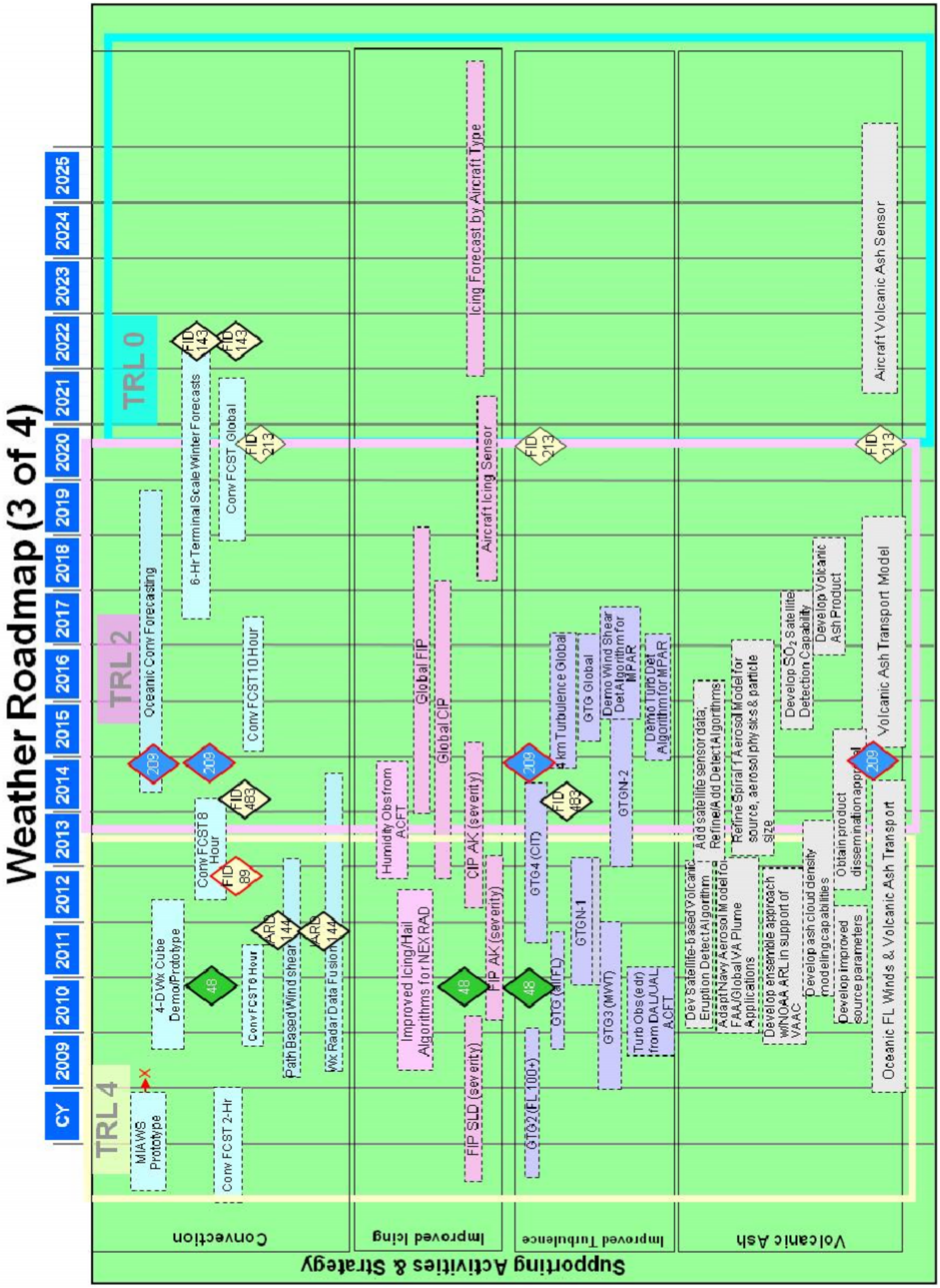
2018
2019
2020
2021
2022
2023
2024
2025
Dissemination
Processing & Display
WARP WINS
WARP FBWTG
ADAS
NextGen Wx Requirements
WMSCR
TWIP
ITWS
CIWS Proto
WARP
NextGen Wx Requirements
JAWS
SWIM Segmt. 1
SWIM Segmt. 2
SWIM Segmt. 3
NG FT WP = NextGen Far-Term WP
Ground Segments
NextGen Reduced Weather Impact -- NNEW
NNEWWP2
NextGen 4-D Wx SAS
TR NextGen 4-D Weather SAS
NNEW WP1
NextGen 4-D Wx Cube
WMSCR
ITWSTR
NG Far Term WP
NextGen Wx Processor (WP3)
NextGen Wx Processor (WP2)
NextGen Wx Processor WP1
0-2 Hour Convective Forecast
WARP NextGen Fcns (RAMP)
2-6 Hour Convective Forecast
NextGen Reduced Weather Impact (RWI) Solution Set
0-2 hr Conv FCST
Ops & WX R&D funding
WARP RAMP
WT Mitigation for Single Runway
WT Mitigation for Arrivals (CSPR)


Weather Roadmap (3 of 4)
CY
2009
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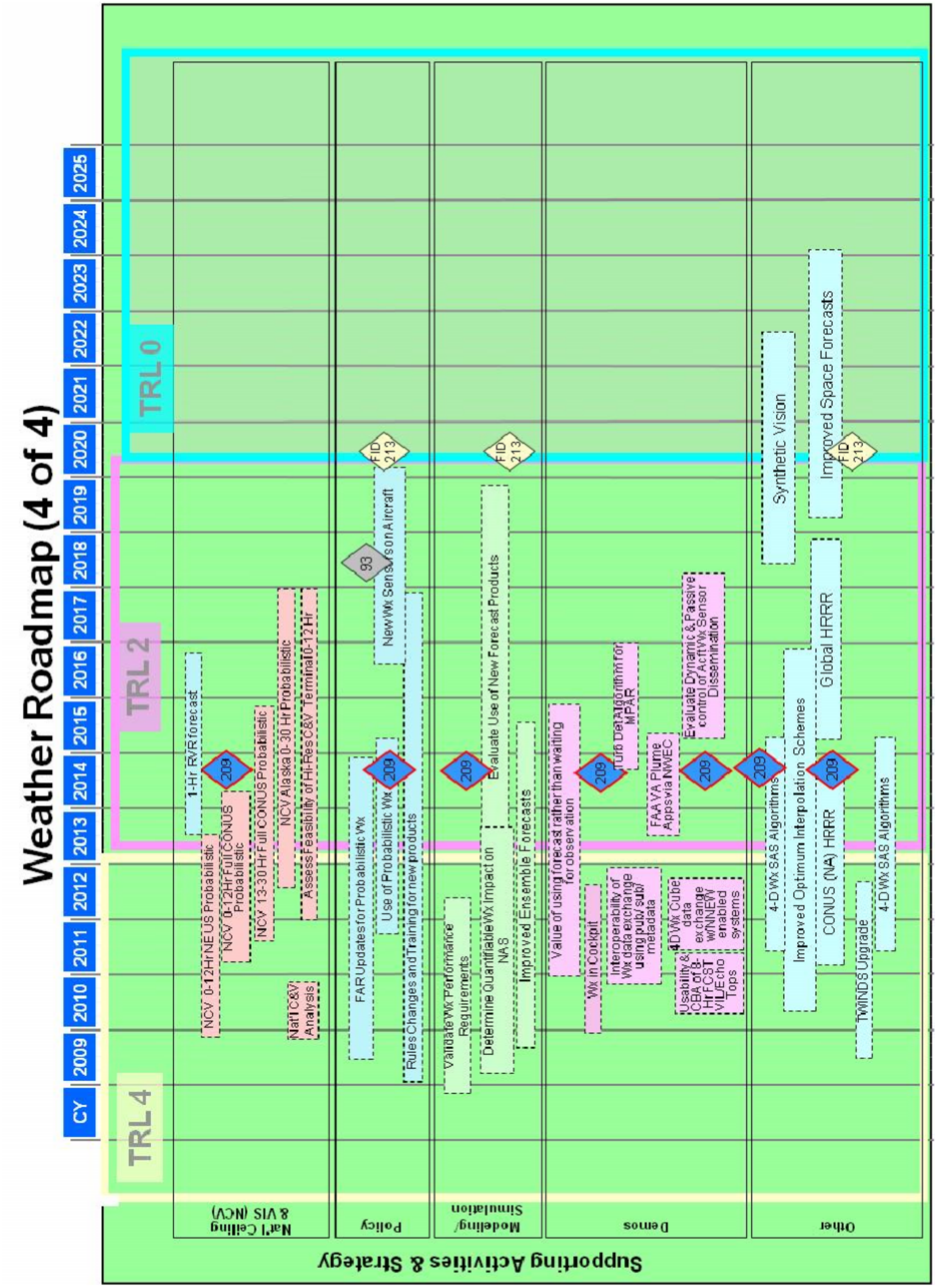
2025
Supporting Activities & Strategy
Convection
Improved Icing
Improved Turbulence
Volcanic Ash
TRL 4
TRL 2
TRL 0
MIAWS Prototype
Conv FCST 2-Hr
4-D Wx Cube Demo/Prototype
Conv FCST 6 Hour
Path Based Wind shear
Wx Radar Data Fusion
Conv FCST 8 Hour
Oceanic Conv Forecasting
Conv FCST 10 Hour
6-Hr Terminal Scale Winter Forecasts
Conv FCST Global
FIP SLD (severity)
Improved Icing/Hail Algorithms for NEXRAD
FIP AK (severity)
CIP AK (severity)
Humidity Obs from ACFT
Global CIP
Global FIP
Aircraft Icing Sensor
Icing Forecast by Aircraft Type
GTG2 (FL 100+)
GTG (all FL)
GTG4 (CIT)
GTG3 (MWT)
GTGN-1
GTGN-2
GTG Global
4 km Turbulence Global
Turb Obs (edr) from DAL/UAL ACFT
Demo Wind Shear Det Algorithm for MPAR
Demo Turb Det Algorithm for MPAR
Dev Satellite-based Volcanic Eruption Detect Algorithm
Add satellite sensor data, Refine/Add Detect Algorithms
Adapt Navy Aerosol Model for FAA/Global VA Plume Applications
Refine Spiral 1 Aerosol Model for source, aerosol physics & particle size
Develop ensemble approach w/NOAA ARL in support of VAAC
Develop ash cloud density modeling capabilities
Develop improved source parameters
Obtain product dissemination approval
Develop SO_2 Satellite Detection Capability
Develop Volcanic Ash Product
Oceanic FL Winds & Volcanic Ash Transport
Volcanic Ash Transport Model
Aircraft Volcanic Ash Sensor
48
209
FID 89
FID 483
FID 143
FID 213
ARD 144


Weather Roadmap (4 of 4)
CY
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2025
TRL 4
TRL 2
TRL 0
Supporting Activities & Strategy
Nat'l Ceiling & VIS (NCV)
Policy
Modeling/ Simulation
Demos
Other
NCV 0-12Hr NE US Probabilistic
NCV 0-12Hr Full CONUS Probabilistic
NCV 13-30 Hr Full CONUS Probabilistic
NCV Alaska 0-30 Hr Probabilistic
Assess Feasibility of Hi-Res C&V Terminal 0-12 Hr
Nat'l C&V Analysis
1-Hr RVR forecast
209
FAR Updates for Probabilistic Wx
Use of Probabilistic Wx
Rules Changes and Training for new products
New Wx Sensors on Aircraft
93
FID 213
Validate Wx Performance Requirements
Determine Quantifiable Wx Impact on NAS
Evaluate Use of New Forecast Products
Improved Ensemble Forecasts
Value of using forecast rather than waiting for observation
Wx in Cockpit
Interoperability of Wx data exchange using pub/ sub/ metadata
Turb Det Algorithm for MPAR
FAA VA Plume Apps via NWEC
Usability & CBA of 8-Hr FCST VIL/Echo Tops
4D Wx Cube data exchange w/NNEW enabled systems
Evaluate Dynamic & Passive control of Act Wx Sensor Dissemination
4-D Wx SAS Algorithms
Improved Optimum Interpolation Schemes
CONUS (NA) HRRR
Global HRRR
TWINDS Upgrade
Synthetic Vision
Improved Space Forecasts

Weather Roadmap: Assumptions (1 of 2)

Identifier	Description
WX-01	Ongoing NextGen (NG) Weather functional and performance requirements development may result in new/emerging requirements that create perturbations in NextGen Weather Architecture
WX-02	Weather Sensor Sustainment Issues: 1) Terminal Portfolio approach a) Wind Shear systems (LLWAS, WSP, TDWR & LIDAR) consolidated into WSDS (Wind Shear Detection Services) to sustain capabilities with DP's for IARD, IID, FID & ISD b) Perform ATO-T Wx 'Right Sizing' study for NextGen Sfc Observing Capability; then consolidate Automated Sfc Observing systems (ASOS, AWOS, AWSS) plus F-420, DASI, WME & CHI into a single platform if NG Sfc Observing requirements permit 2) NextGen Surveillance/Weather Radar continues to support Weather requirements (Terminal & En route) 3) Continue obtaining Surface Observations from non-Fed AWOS systems 4) Both NextGen Surveillance/Weather Radar & Sfc Observing capabilities will consider multi-agency requirements
WX-03	1) Having replaced aging technology, ADAS-Rehost serves as a consolidating access point for Wx observations at NNCCs (National Network Control Center) rather than ARTCCs 2) WMSCR ADAS/ALDARS functionality to be subsumed by NNEW WP 2 (information extraction functionality of NNEW WP2 enables publishing of lightning reports to NG Sfc Observing capability)
WX-04	Wind Shear/Microburst functionality continues to be ground based unless aircraft avionics technology matures to the point where the capability can be transferred to the aircraft
WX-05	The following aircraft decisions may have an impact on weather: 93, 174. For full descriptions see decision spreadsheet 1) Regulatory action likely per DP 93 to define Wx Sensor equipage for fully-capable aircraft
WX-06	Migrate Wx to common Network Enabled Operations (NEO) 1) Fund FAA portion of multi-agency 4-D Weather Cube development and management 2) Fund FAA portion of the development of associated modeling capability* that produces SAS data/information, implementation and operation of multi-agency 4-D Weather Single Authoritative Source (SAS) for NextGen ATM *NOTE: 1) NWS modeling capability not part of the 4-D Wx SAS but required to create data 2) In accordance with ICAO ConOps for ATM, ATM includes Service Providers & Users, e.g., pilots & dispatchers
WX-07	Develop Wx Performance Requirements & pursue aggressive AMS schedule to field NextGen Wx Processor by 2015

Weather Roadmap: Assumptions (2 of 2)

Identifier	Description
WX-08	Convergence of Wx Processing Capability into NextGen Wx Processor 1) NextGen Weather Processor WP 1 a) CIWS continues as prototype until integrated into NWP WP1 as part of 0-6 hour convective forecast capability b) WARP RAMP (radar acquisition & mosaic processor) must be sustained into NextGen era until transferred to NextGen system and RBT functionality to general IDS with NNEW-provided data c) ITWS data/product exchanges to achieve operational consistency among Wx system displays 2) NextGen Wx WP2: a) Selected Wx R&D algorithms matured since WP1 baseline was frozen b) Implement improved Convective algorithms from Aviation Wx R&D c) Majority of ITWS functionality transferred to NWP WP2, except functions allocated to NextGen Far Term Work Package to meet latency requirements of Wind Shear/Microburst Detection & Prediction advisories, or ITWS Tech Refresh 3) NextGen Wx WP3: a) Selected Wx R&D algorithms matured since WP2 baseline was frozen 4) NextGen Wx Processor WP3 most likely not an FAA 'box'
WX-09	To provide improved observations & enhanced forecasts, significant R&D and infrastructure changes are required 1) R&D must be prioritized in order to meet NextGen Vision 2) To reach NextGen by 2025 R&D funding (Near/Mid-term) must be increased 3) The output of a number of Algorithms developed via R&D will be available via the 4-D Wx SAS 4) Sensor measurement, accuracy, & frequency must be increased in accordance with Mid-/Far-term Performance Rqm'ts
WX-10	Weather information becomes available at user-specified resolution but weather impact is determined by user DST
WX-11	Wx Comms functionality to be provided by NNEW
WX-12	That NG Sfc Observing Capability & NG Surv/Wx Radar Capability [systems] will be implemented as multi-agency systems
WX-13	CWSU support system will not be addressed in this Roadmap as it is not envisioned as an FAA system
WX-14	WARP Remote Brfg Terminal requirements to be included in National IDS contract
WX-15	CIWS prototype continues receiving Avn Wx R&D funding to develop longer-range Convective forecasts & improved Winter Weather products/forecasts that will be available to operational users
WX-16	Weather will Translate state of Atmosphere into constraints for airspace for Decision Makers & their DSTs

Weather Roadmap: Decision Points (1 of 3)

DP#	Target Date	High Priority	Domain	Name
31	2012 Q1	N	Automation	Final Investment Decision for 'auto PIREP' in Post ERAM R3 Work Package **No sponsor; RWI NI&I ??**
37	2010 Q4	N		Wind Shear Detection Services (WSDS) Work Pkg 1 to SLEP/Tech Refresh Legacy Wind Shear systems, TDWR, WSP & LLWAS; Tailored IARD requested
38 & 88	2012 Q3	N	**88 Combined w/this one**	Executive Level Decision to transition WMSCR Comms functionality to web access via NNEW WP2 & incorporate ADAS/ALDARS functionality to NNEW WP2
40	2011	N	**DELETE ROW**	Investment Decision (IID) to acquire & deploy initial phase of Wake Turbulence capability for Mitigation for Departures (WTMD) from Closely Spaced Parallel Runways (CSPR)
48	2010 Q3	N	**???**	Strategy to Fund FAA Portion of NextGen 4-D Weather Cube **(in RPD but Scheduled w/EC ???)**
49	2010 Q3	N	**???**	Strategy to Obtain and Disseminate Total Lightning Data **(Strategy Mtg Scheduled w/EC ???)**
61	2015	N		Investment Decision to add WT for Mitigation for Arrivals (WTMA) from Closely Spaced Parallel Runways (CSPR)
77	2016 Q1	N	Surveillance	Investment Decision (IID) to implement a NextGen Surveillance and Weather Radar Capability for ATC
79	2010 Q4	Y		Investment Decision (IARD) for NextGen Wx Processor WP1 and NNEW WP1 to enter IA
85	2013	N		Investment Decision (IARD) to Consolidate & Replace Automated Surface Observing Systems
86	2012 Q1	Y		Investment Decision (IID) for NextGen Wx Processor WP1 (includes CIWS functionality, NG WARP functionality & NNEW WP1 functionality (includes WARP WINS & FBWTG))
88	2018	N	**Combined w/38**	Executive Level Decision to move ADAS/ALDARS functionality to NNEW WP2
89	2012 Q4	Y		Investment Decision (FID) for NextGen Wx Processor WP1 & NNEW WP1
93	2018	N	Aircraft	Rulemaking decision for equipage of Weather Sensors and Wake Turbulence implementation
104	2017	N	Surveillance	Investment Decision (FID) to implement a NextGen Surveillance and Weather Radar Capability for ATC
130	2009 Q3	N	Enterprise Services	Selection of SWIM Segment 2 candidates (Complete) **???**
143	2022	N		Investment Decision (FID) to Provide 10-Hour Convective Forecast Capability and In-Flight Icing Observation from Airborne Aircraft To NextGen Weather Processor WP3
144	2011 Q4	N		Investment Decision (IARD) to Tech Refresh ITWS systems (includes improved data quality, upgraded TWINDS & path-based wind shear), or transfer all functionality (TWINDS & path-based wind shear) to NWP WP2 or Tech Refresh ITWS
147	2018	N		Executive Level Decision to transfer ITWS' functionality to NWS WP3 (if not done in DP 144) and safety functionality (Microburst Predict) to NextGen Far Term WP (NG FT WP)
Wx A	2011 Q3	N		Investment Decision (CRDR) for WSDS Work Pkg 2 using rightsizing study to examine new technology, NEXRAD improvements & LIDAR to extend WSDS coverage expansion to un-/under-protected sites
Wx B	2012 Q2	N		Investment Decision (IARD) for WSDS Work Pkg 2 using rightsizing study to examine new technology, NEXRAD improvements & LIDAR to extend WSDS coverage expansion to un-/under-protected sites

Weather Roadmap: Decision Points (2 of 3)

DP#	Target Date	High Priority	Domain	Name
209	2014	Y		Executive Level Decision to fund FAA portion of NextGen 4-D Weather Single Authoritative Source (4-D Wx SAS); includes funding for S/W development to create SAS information
210	2008 Q4	N		Investment Decision (FID) to fund WARP contract maintenance until subsumed into NextGen Wx Processor Work Package 1 (NWP WP1) (Complete)
212	2020	N		Investment Decision (IARD) to add WT Mitigation for Single Runway (WTSR) decision support capability
213	2020	N		Executive Level Decision to fund FAA portion 4-D Wx SAS Tech Refresh
341	2015	N		Investment Decision (FID) to transition WMSCR Comms functionality to web access via SWIM Seg 3 & ALDARS Comms to NNEW WP2
407	2013 Q4	N	Surveillance	Investment Decision (IARD) for NextGen Surveillance and Weather Radar Capability
443	2011 Q4	N		Investment Decision (IID) to Tech Refresh/SLEP wind shear detection services Legacy WS systems to sustain capability
444	2012 Q4	N		Investment Decision (FID) to Tech Refresh/SLEP wind shear detection services Legacy systems to sustain capability
445	2015	N		Investment Decision (IID) to consolidate and replace automated surface observing capability with multi-agency NextGen Surface Observing capability
446	2016	N		Investment Decision (FID) to consolidate and replace automated surface observing capability
447	2022	N		Investment Decision (ISD) to replace all automated surface observing systems with NextGen Surface Observing capability
448	2013	N		Investment Decision (IARD) to fund FAA portion of NNEW WP2 & transition WMSCR/ALDARS Comms to NNEW WP
449	2014	Y		Investment Decision (IID) to fund FAA portion of NNEW WP2 & transition WMSCR/ALDARS Comms to NNEW WP2
450	2018	Y		Investment Decision (IARD) to fund FAA portion of 4-D Weather SAS Tech Refresh
451	2019	Y		Investment Decision (IID) to fund FAA portion of 4-D Weather SAS Tech Refresh
635	2020	Y		Investment Decision (FID) to fund FAA portion of 4-D Weather SAS Tech Refresh; includes funding for S/W development to create SAS information
452	2020	Y		Investment Decision (IARD) to provide 10-hour Convective Forecast capability to NWP WP3 and in-flight Icing Observation from airborne aircraft to NWP WP3
453	2021	Y		Investment Decision (IID) to provide 10-hour Convective Forecast capability to NWP WP3 and provide in-flight Icing Observation from airborne aircraft to NWP WP3
454	2024	Y		Investment Decision (ISD) to document final configuration of the NextGen Wx Processor Work Pkg 3 (NWP WP3)
455	2012 Q2	Y	DELETE ROW	Investment Decision (FID) to Acquire and Deploy Wake Turbulence for Mitigation for Departures (WTMD)
456	2014	Y	DELETE ROW	Investment Decision (ISD) to Acquire and Deploy Wake Turbulence for Mitigation for Departures (WTMD)

Weather Roadmap: Decision Points (3 of 3)

DP #	Target Date	High Priority	Domain	Name
457	2016	Y		Investment Decision (IID) to Add Wake Turbulence for Mitigation for Arrivals (WTMA) from Closely Spaced Parallel Runways (CSPR)
458	2017	Y		Investment Decision (FID) to Add Wake Turbulence for Mitigation for Arrivals (WTMA) from Closely Spaced Parallel Runways (CSPR)
459	2019	Y		In Service Decision (ISD) to Add Wake Turbulence for Mitigation for Arrivals (WTMA) from Closely Spaced Parallel Runways (CSPR)
460	2020	Y		Investment Decision (IID) to Add Wake Turbulence for Mitigation for Single Runway (WTSR)
461	2021	Y		Investment Decision (FID) to Add Wake Turbulence for Mitigation for Single Runway (WTSR)
462	2024	Y		In Service Decision (ISD) to Add Wake Turbulence for Mitigation for Single Runway (WTSR)
481	2013	N		Executive Level Decision to move access to Lightning data to NNEW
482	2012	N		Investment Decision (IID) to transfer most ITWS functionality to NWP WP2 or Tech Refresh ITWS
483	2014	N		Investment Decision (FID) to transfer most ITWS functionality to NWP WP2 or Tech Refresh ITWS
Wx C	2013 Q2	N		Investment Decision (IID) for WSDS Work Pkg 2 using rightsizing study to examine new technology, NEXRAD improvements & LIDAR to extend WSDS coverage expansion to un-/under-protected sites
Wx D	2014 Q2	N		Investment Decision (FID) for WSDS Work Pkg 2 using rightsizing study to examine new technology, NEXRAD improvements & LIDAR to extend WSDS coverage expansion to un-/under-protected sites
Wx E	2018 Q2	N		Investment Decision (ISD) for WSDS Work Pkg 2 using rightsizing study to examine new technology, NEXRAD improvements & LIDAR to extend WSDS coverage expansion to un-/under-protected sites
Wx F	2011 Q3	N		Investment Decision (CRD) for NextGen Surface Observing Capability
Wx G	2010 Q4	N		Investment Decision (IARD) for ASWON Tech Refresh of ASOS/AWOS/AWSS processors & S/W
Wx H	2011 Q3	N		Investment Decision (IID) for ASWON Tech Refresh of ASOS/AWOS/AWSS processors & S/W
Wx I	2012 Q3	N		Investment Decision (FID) for ASWON Tech Refresh of ASOS/AWOS/AWSS processors & S/W

F. ACRONYMS

ACRONYM	**DEFINITION**
2D	Two Dimension
3D	Three Dimension
4-D	Four Dimension
4-D Wx Data Cube	Four Dimension Weather Data Cube
4-D Wx SAS	Four Dimension Weather Single Authoritative Source
4-DT	Four Dimension Trajectory
A/DMT	Arrival / Departure Management Tool
AACR	Automated Airspace Congestion Resolution
AAR	Airport Arrival Rate
ACES	Airspace Concept Evaluation System
ACM	Adjacent Center Metering
ACP	Airspace Congestion Predictor
ADDS	Aviation Digital Data Service
ADR	Airport Departure Rate
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
AFP	Airspace Flow Program
AGL	Above Ground Level
AIM	Aeronautical Information Management
AIRE	Atlantic Interoperability Initiative to Reduce Emissions
AIRMET	Airman's Meteorological Information
AIV	Atmospheric Impact Variable
AIXM	Aeronautical Information Exchange Model
AJN	FAA Operations Organization
ALNOT	Alert Notice
ANS	Aviation Network Service
ANSP	Air Navigation Service Provider
AOC	Air Operations Center
API	Application Programming Interface

APREQ	Approval Request
ARR	Arrival
ARTCC	Air Route Traffic Control Center
ASIAS	Aviation Safety Information Analysis and Sharing
ASOS	Automated Surface Observing System
ASPIRE	Asia and South Pacific Initiative to Reduce Emissions
ASPM	Aviation System Performance Metrics
ASR-8/9/11	Airport Surveillance Radar Models 8, 9, and 11
ASR-WSP	Airport Surveillance Radar Weather System Processor
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATCT	Air Traffic Control Tower
ATIS	Automated Terminal Information System
ATL	Hartsfield-Jackson Atlanta International Airport
ATM	Air Traffic Management
ATM-WIP	Air Traffic Management – Weather Integration Process
ATO	Air Traffic Organization
ATS	Air Transportation System
AVS	Aviation Safety
AWG	Aviation Weather Group
AWOS	Automated Weather Observing System
AWRP	Aviation Weather Research Program
AWSS	Automated Weather Sensor System
BA	Big Airspace
C&V	Ceiling and Visibility
CAASD	Center for Advanced Aviation System Development
CAT	Clear Air Turbulence
CAT I	Facility providing operation down to 200 feet decision height and runway visual range not less than 2600 feet.
CAT II	Facility providing operation down to 100 feet decision height and runway visual range not less than 1200 feet.
CAT III	Facility providing operation possibly down to no decision height and no runway visual range. Can possibly use auto pilot for landing.
CATM / C-ATM	Collaborative Air Traffic Management

CATM-T	Collaborative Air Traffic Management Technologies
CAVS	Cockpit Display of Traffic Information Assisted Visual Separation
CbTA	Control by Time of Arrival
CCFP	Collaborative Convective Forecast Product
CD	Concept Development
CDA	Continuous Descent Arrival
CDF / cdf	Cumulative Distribution Function
CDM	Collaborative Decision Making
CDQM	Collaborative Decision Queue Management
CDR	Coded Departure Route
CDTI	Cockpit Display of Traffic Information
CE	Concept Exploration
CIP	Current Icing Product
CIT	Convective Induced Turbulence
CIWS	Corridor Integrated Weather System
CLEEN	Continuous Low Energy, Emissions and Noise
CM	Capacity Management
CO	Carbon Monoxide
CO2	Carbon Dioxide
COI	Communities of Interest
ConOps	Concept of Operations
CONUS	Continental United States
CoSPA	Consolidated Storm Prediction for Aviation
CREWS	CTAS Remote Weather Service
CSC	Computer Sciences Corporation
CSPR	Closely Spaced Parallel Runways
CTA	Controlled Time of Arrival
CTAS	Center-TRACON Automation System
C-TOP	Collaborative Trajectory Options Program (formerly known as SEVEN)
CWAM	Convective Weather Avoidance Model
CWSU	Center Weather Support Unit
DARP	Dynamic Airborne Reroute Procedures

DASI	Digital Altimeter Setting Indicator
DD	Departure Director
DEP	Departure
DFM	Departure Flow Management
DFW	Dallas Fort Worth International Airport
DHS	Department of Homeland Security
DME	Distance Measuring Equipment
DOC	Department of Commerce
DOD	Department of Defense
DOJ	Department of Justice
DOT	Department of Transportation
DSR	Display System Replacement
DSP	Defense Service Provider
DST	Decision Support Tool
EA	Enterprise Architecture
EDCT	Expected Departure Clearance Time
EDR	Eddy Dissipation Rate
EFVS	Enhanced Flight Vision System
EMS	Environmental Management System
EN	Enabler
ERAM	En Route Automation Modernization
E-RBD	Equity-based Ration-by-Distance
ETA	Estimated Time of Arrival
ETE	Estimated Time Enroute
ETMS	Enhanced Traffic Management system
EVS	Enhanced Vision Systems
E-WITI	En-route Weather Impacted Traffic Index
FAA	Federal Aviation Administration
Facilities	Transform Facilities Solution Set
FANS	Future Air Navigation System
FAR	Federal Aviation Regulation
Far-Term	2018 – 2025 (Full NextGen)

FAWB	Federal Aviation Weather Board
FBI	Federal Bureau of Investigation
FCA	Flow Constrained Area
FCFS	First-Come First-Served
FCM	Flow Contingency Management
FCT	Future Concepts Team
FDIO	Flight Data Input/Output
FDM	Flight Data Manager
FDR	Flight Data Report
FEA	Flow Evaluation Area
FET	Flow Evaluation Team
FIP	Forecast Icing Product
FIS-B	Flight Information Service-Broadcast
FL	Flight Level
FlexTerm	Increase Flexibility in the Terminal Environment Solution Set
FMS	Flight Management System
FOC	Flight Operations Center
FSD	Full System Development
FSDM	Flight and State Data Management
FSM	Flight Schedule Monitor
GA	General Aviation
G-AIRMET	Graphical Airman’s Meteorological Information
GBAS	Ground-Based Augmentation System
GBT	Ground-Based Transceivers
GC	Ground Controller
GDP	Ground Delay Program
GNSS	Global Navigation Satellite System
GPS	Global Positioning Satellite
GPSM	GDP Parameter Selection Model
GRASP	Generalized Random Adaptive Search Procedure
GS	Ground Stop
GSE	Ground Support Equipment

GTG	Graphical Turbulence Guidance
GUI	Graphical User Interface
HCS	Host Computer System
HEMS	Helicopter Emergency Management System
HF	High Frequency
HiDensity	Increase Arrivals/Departures at High Density Airports Solution Set
HITL	Human In The Loop
HPA	High Performance Airspace
HRJ	Hydrotreated Renewable Jet
HRRR	High Resolution Rapid Refresh
HRRRE	High Resolution Rapid Refresh Model
hrs	Hours
HUD	Head-Up Display
I&I	Implementation and Integration
IAH	George Bush Intercontinental Airport
IASDF	Improved Management of Arrival/Surface/Departure Flow Operations
ICAO	International Civil Aviation Organization
ICR	Integrated Collaborative Routing
IDAC	Integrated Departure/Arrival Capability
IDRP	Integrated Departure Route Planning
IDFL	Interactive Dynamic Flight List
IES	Integrated Enterprise Solution
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IOC	Interim Operational Capability
IPE	Integrated Program Execution
IPM	Integrated Program Modeling
IR	Infrastructure Roadmap
ITBFM	Integrated Time-Based Flow Management
ITWS	Integrated Terminal Weather System
IWP	Integrated Work Plan

JFK	John F. Kennedy Airport
JMBL	Joint Meteorological and Oceanographic Brokering Language
JMDB	Joint Meteorological and Oceanographic Data Base
JPDO	Joint Planning and Development Office
JPDO WG	Joint Planning and Development Office Working Group
km	Kilometer
LAAS	Local Area Augmentation System
LAHSO	Land And Hold Short Operations
LAX	Los Angeles International Airport
LC	Local Controller
LIDAR	Light Detection and Ranging
LLWAS	Low Level Windshear Alerting System
LOA	Letter of Agreement
LP	Localizer Performance
LPV	Localizer Performance with Vertical Guidance
LR	Lagrangian Relaxation
LWE	Liquid Water Equivalent
M2M	Machine-to-Machine
MADE	Military Airspace Data Entry
MAP	Monitor Alert Parameter
mb	Millibar
MDCRS	Meteorological Data Collection and Reporting System
MEA	Minimum En Route Altitude
METAR	Aviation Routine Weather Report (an hourly surface weather observation)
METOC	Meteorological and Oceanographic
Mid-Term	2010 – 2018 (Transition to NextGen)
MIT	Miles in Trail
MIT/LL	Massachusetts Institute of Technology Lincoln Laboratories
MITRE	The MITRE Corporation
MM	Maxflow/Mincut
MoG	Moderate or Greater
MPA	Mixed Performance Airspace

NAS	National Airspace System
NAS EA	National Airspace System Enterprise Architecture
NASA	National Aeronautics and Space Administration
NASEIM	NAS-Wide Environmental Modeling
NASR	National Airspace System Resource
NAVAID	Navigational Aid
NCEP	National Center for Environment Prediction
NCWF-6	National Convective Weather Forecast - 6
NCWP-6	National Convective Weather Product - 6
NDFD	National Digital Forecast Database
Near-Term	Current to 2010
NetFM	Network Flow Model
NEVS	Network Enabled Verification System
NextGen	Next Generation Air Transportation System
NEXRAD	Next Generation Weather Radar
NIP	NextGen Implementation Plan
nm	Nautical Mile
NNEW	Next Generation Air Transportation System Network Enabled Weather
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NOx	Nitrogen Oxides
NRA	NASA Research Announcement
NTML	National Traffic Management Log
NWP	Numerical Weather Prediction
NWS	National Weather Service
NWX	National Weather Index
NYC	New York Center Airspace
OAG	Official Airline Guide
OAT	Outside Air Temperature
ODNI	On-Demand NAS Information
OEP	Operational Evolution Partnership
OGC	Open Geospatial Consortium

OI	Operational Improvements
OPD	Optimized Profile Descent
ORD	Chicago O'Hare Airport
OTN4-D	Oceanic Trajectory Management Four Dimensional
OTV	Obstructions to Visibility
PAAR	Planned Arrival
PAR	Periodic Auto-Regressive
PCA	Polar Cap Absorption
PCP	Probability Cut-off Parameter
PD	Prototype Development
PDC	Proposed Departure Clearance
PDF / pdf	Probability Density Function
PDT	Proposed Departure Time
PGUI	TMA Plan View Graphical User Interface
PIC	Aircraft
PIREP	Pilot Report
Plan	JPDO-ATM Weather Integration Plan
PMF	Probability Mass Function
POET-R	Research Version of the Post Operations Evaluation Tool
PRM-A	Precision Runway Monitor – Alternate
QMS	Quality Management System
R&D	Research and Development
RACW	Route Availability in Convective Weather
RAPT	Route Availability Planning Tool
RB	Route Blockage
RBS	Ration-by-Schedule
REDAC	Research Engineering and Development Advisory Committee
REPEAT	RAPT Evaluation and Post Analysis Tool
RNAV	Area Navigation
RNP	Required Navigation Performance
RPD	Resource Planning Data
RR	Rapid Refresh

RRE	Rapid Refresh Ensemble
RRIA	Reroute Impact Assessment
RTA	Required Time of Arrival
RUC	Rapid Update Cycle
RVR	Runway Visual Range
RWI	Reduced Weather Impact
RWSL	Runway Status Lights
SAA	Special Activity Airspace
SAAAR	Special Aircraft and Aircrew Authorization Required
SAMS	Special Use Airspace Management System
SAR	Search and Rescue
SAS	Single Authoritative Source
SAWS	Stand Alone Weather Sensor
SBAS	Satellite-Based Augmentation System
SBS	Surveillance Broadcast Services
S-CAOSS	Super Computer Aided Operational Support System
SCG	Stochastic Congestion Grid
SDF	Louisville International-Standiford Airport
SDO	Super Density Operations
SDSS	Surface Decision Support System
SEP	Solar Energetic Particles
SESAR	Single European Sky Air Traffic Management Research
SEVEN	System Enhancement for Versatile Electronic Negotiation (now known as C-TOP)
sfc	Surface
SFO	San Francisco International Airport
SID	Sudden Ionospheric Disturbance / Standard Instrument Departure
SIGMET	Significant Meteorological Information
SIT	System-Integrated TMI
SITS	Security Integrated Toolset
SM	Statute Mile
SME	Subject Matter Expert
SMS	Surface Management System

SOA/IT	Service Oriented Architecture/Information Technology
SoG	Severe or Greater
SOP	Standard Operating Procedure
SOx	Sulfur Oxides
SPARC	Strategic Planning Advisory Review Cadre
SSA	Shared Situational Awareness
SSE	Safety, Security, and Environmental Performance Solution Set
SSFS	SFO Stratus Forecast System
SSMT	System Safety Management Transformation
SSOA	Solution Set-Oriented Analysis
SSP	Security Service Provider
STA	Scheduled Time of Arrival
STAR	Standard Terminal Arrival
STBO	Surface Trajectory Based Operations
STL	St Louis International Airport
SUA	Special Use Airspace
SVS	Synthetic Vision System
SWAP	Severe Weather Avoidance Plan
SWIM	System-Wide Information Management
T Routes	Trajectory Routes
TAF	Terminal Area Forecast
TBFM	Time-Based Flow Management
TBM	Time Based Metering
TBD	To Be Determined
TBO	Trajectory Based Operations
TDWR	Terminal Doppler Weather Radar
TFDM	Trajectory Flight Data Management
TFM	Traffic Flow Management
TFMS	Traffic Flow Management System
TGUI	TMA Timeline Graphical User Interface
TM	Traffic Manager
TMA	Traffic Management Advisor

TMC	Traffic Management Coordinator
TMI	Traffic Management Initiative
TMU	Traffic Management Unit
TOS	Trajectory Options Set
TRACON	Terminal Radar Approach Control
TRL	Technology Readiness Level
TSA	Transportation Security Administration
TSD	Traffic Situation Display
T-WITI	Terminal Weather Impacted Traffic Index
UAS	Unmanned Aircraft Systems
UAT	Universal Access Transceiver
URET	User Request Evaluation Tool
US	United States
UTC	Coordinated Universal Time
V&V	Validation and Verification
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VOLPE	Volpe Center / Volpe National Transportation Systems Center
WAAF	Weather Avoidance Altitude Field
WAAS	Wide-Area Augmentation System
WAF	Weather Avoidance Field
WAIWG	Weather Air Traffic Management Integration Working Group
WARP	Weather and Radar Processor
WATRS	Western Atlantic Track Route System
WIST-1	Weather Integration Sub Team Number 1
WITI	Weather Impacted Traffic Index
WITI-B	Weather Impacted Traffic Index for Sever Weather
WJHTC	William J. Hughes Technical Center
WMO	World Meteorological Organization
WP2	Work Package 2

WRF	Weather Research and Forecasting Model
WTIC	Weather Technology in the Cockpit
WTMD	Wake Turbulence Mitigation for Departures
WV	Wake Vortex
Wx	Weather
Z	Zulu Time – Equivalent to UTC
XML	Extensible Markup Language
ZTL	Atlanta Air Route Traffic Control Center